GHANA CIVIL AVIATION
(AIR NAVIGATION SERVICES)
DIRECTIVES

PART 23: SUBPART 4 –

AERONAUTICAL TELECOMMUNICATIONS - SURVEILLANCE RADAR AND COLLISION AVOIDANCE SYSTEMS

23.4 AERONAUTICAL TELECOMMUNICATIONS - SURVEILLANCE RADAR AND COLLISION AVOIDANCE SYSTEMS

INTRODUCTION

This **Subpart 4 of Part 23** is in accordance with Amendment 92 to Annex 10 Volume IV – Aeronautical Telecommunications – Surveillance Radar and Collision Avoidance Systems. It contains requirements and guidance material for secondary surveillance radar (SSR) and airborne collision avoidance systems (ACAS), including requirement for SSR Mode A, Mode C and Mode S, and the technical characteristics of ACAS.

23.4.1 GENERAL

23.4.1.1 APPLICABILITY

(1) This Part shall apply to:

(a) Air Navigation Service Providers;

(b) Air Traffic Service Providers;

(c) Aeronautical Telecommunication Service Providers;

(d) Aerodrome Operators in Ghana;

(e) Ghana registered aircraft;

(f) Aircraft registered in another Contracting State that are operated by a person licensed by Ghana; and

(g) Aircraft of other Contracting States operating within the Accra Flight Information Region.

(2) This Part prescribes the requirements for:

(a) secondary surveillance radar (SSR) systems, including Mode S;

(b) airborne collision avoidance systems (ACAS);

(c) Mode S extended squitter, including automatic dependent surveillance – broadcast (ADS-B) and traffic information service – broadcast (TIS-B);

(d) multilateration (MLAT) systems; and

(e) airborne surveillance applications.

23.4.1.2 DEFINITIONS

Airborne collision avoidance system (ACAS) means an aircraft system based on secondary surveillance radar (SSR) transponder signals, which operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft that are equipped with SSR transponders.

Note. — SSR transponders referred to above are those operating in Mode C or Mode S. ACAS may also use automatic dependent surveillance — broadcast (ADS-B) signals received from other aircraft to improve its performance.

ACAS I means an ACAS which provides information as an aid to "see and avoid" action but does not include the capability for generating resolution advisories (RAs).

ACAS II means an ACAS which provides vertical resolution advisories (RAs) in addition to traffic advisories (TAs).

ACAS III means an ACAS which provides vertical and horizontal resolution advisories (RAs) in addition to traffic advisories (TAs).

ACAS broadcast means a long Mode S air-air surveillance interrogation (UF =16) with the broadcast address.

Active RAC means an RAC is active if it currently constrains the selection of the RA. RACs that have been received within the last six seconds and have not been explicitly cancelled are active.

Aircraft address means a unique combination of twenty-four bits available for assignment to an aircraft for the purpose of air-ground communications, navigation and surveillance.

Note. — SSR Mode S transponders transmit extended squitters to support the broadcast of aircraft-derived position for surveillance purposes. The broadcast of this type of information is a form of automatic dependent surveillance (ADS) known as ADS-broadcast (ADS-B).

Air Traffic Services (ATS) Provider

Altitude crossing RA means a resolution advisory is altitude crossing if own ACAS aircraft is currently at least 30 m (100 ft) below or above the threat aircraft for upward or downward sense advisories, respectively.

Automatic dependent surveillance-broadcast (ADS-B) OUT means a function on an aircraft or vehicle that periodically broadcasts its state vector (position and velocity) and other information derived from on-board systems in a format suitable for ADS-B IN capable receivers.

Automatic dependent surveillance-broadcast (ADS-B) IN means a function that receives surveillance data from ADS-B OUT data sources.

Climb RA means a positive RA recommending a climb but not an increased climb.

Closest approach means the occurrence of minimum range between own ACAS aircraft and the intruder. Thus, range at closest approach is the smallest range between the two aircraft and time of closest approach is the time at which this occurs.

Collision avoidance logic means the sub-system or part of ACAS that analyses data relating to an intruder and own aircraft, decides whether or not advisories are appropriate and, if so, generates the advisories. It includes the following functions: range and altitude tracking, threat detection and RA generation. It excludes surveillance.

Coordination means the processes by which two ACAS-equipped aircraft select compatible resolution advisories (RAs) by the exchange of resolution advisory complements (RACs).

Coordination interrogation means a Mode S interrogation (uplink transmission) radiated by ACAS II or III and containing a resolution message.

Coordination reply means a Mode S reply (downlink transmission) acknowledging the receipt of a coordination interrogation by the

Mode S transponder that is part of an ACAS II or III installation.

Corrective RA means a resolution advisory that advises the pilot to deviate from the current flight path.

Cycle means the term "cycle" used in this section refers to one complete pass through the sequence of functions executed by ACAS II or ACAS III, nominally once a second.

Descend RA means a positive RA recommending a descent but not an increased descent.

Established track means a track generated by ACAS air-air surveillance that is treated as the track of an actual aircraft.

Human Factors principles mean principles which apply to design, certification, training, operations and maintenance and which seek safe interface between the human and other system components by proper consideration to human performance.

Increased rate RA means a resolution advisory with a strength that recommends increasing the altitude rate to a value exceeding that recommended by a previous climb or descend RA.

Intruder means an aircraft for which ACAS has an established track.

Lost C2 Link state means the state of the RPAS in which the C2 Link performance has degraded, as a result of a C2 Link interruption that is longer than the lost C2 Link decision time, to a point where it is not sufficient to allow the remote pilot to actively manage the flight in a safe and timely manner.

Matching Interrogator Identifier (II) code means II code whose binary format in the interrogator code (IC) field is the same as the binary format in the IC field of the surveillance identifier (SI) code.

Matching Surveillance Identifier (SI) code means SI code whose binary format in the IC field is the same as the binary format in the IC field of the

interrogator identifier (II) code.

Own aircraft means the aircraft fitted with the ACAS that is the subject of the discourse, which ACAS is to protect against possible collisions, and which may enter a maneuver in response to an ACAS indication.

Positive RA means a resolution advisory that advises the pilot either to climb or to descend (applies to ACAS II).

Potential threat means an intruder deserving special attention either because of its close proximity to own aircraft or because successive range and altitude measurements indicate that it could be on a collision or near-collision course with own aircraft. The warning time provided against a potential threat is sufficiently small that a traffic advisory (TA) is justified but not so small that a resolution advisory (RA) would be justified.

Preventive RA means a resolution advisory that advises the pilot to avoid certain deviations from the current flight path but does not require any change in the current flight path.

RA sense means the sense of an ACAS II RA is “upward” if it requires climb or limitation of descent rate and “downward” if it requires descent or limitation of climb rate. It can be both upward and downward simultaneously if it requires limitation of the vertical rate to a specified range.

Radio Regulations means the Radio Regulations published by the International Telecommunication Union (ITU).

Note. - Radio Regulations are amended from time to time by the decisions embodied in the Final Acts of World Radiocommunication Conferences held normally every two to three years. Further information on the ITU processes as they relate to aeronautical radio system frequency use is contained in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (Doc 9718).

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Resolution advisory (RA) means an indication given to the flight crew recommending:

(1) a maneuver intended to provide separation from all threats; or
(2) a maneuver restriction intended to maintain existing separation.

Resolution advisory complement (RAC) means information provided by one ACAS to another via a Mode S interrogation in order to ensure complementary maneuver by restricting the choice of maneuver available to the ACAS receiving the RAC.

Resolution advisory complements record (RAC record) means a composite of all currently active vertical RACs (VRCs) and horizontal RACs (HRCs) that have been received by ACAS. This information is provided by one ACAS to another ACAS or to a Mode S ground station via a Mode S reply.

Resolution advisory strength means the magnitude of the maneuver indicated by the RA. An RA may take on several successive strengths before being cancelled. Once a new RA strength is issued, the previous one automatically becomes void.

Resolution message means the messages containing the resolution advisory complement (RAC).

Reversed sense RA means a resolution advisory that has had its sense reversed.

Runway Transition Zone means a zone of a rectangular box exactly enclosing a runway in the horizontal direction and extending to 100 feet altitude above ground level.

Secondary surveillance radar (SSR) means a surveillance radar system which uses transmitters/receivers (interrogators) and transponders.

Note. — The requirements for interrogators and transponders are specified in 23.4.3.

Sensitivity level (S) means an integer defining a set of parameters used by the traffic advisory (TA) and collision avoidance algorithms to control the warning time provided by the potential threat and threat detection logic, as well as the values of parameters relevant to

the RA selection logic.

Note. — For TA and RA selection, sensitivity level is not used in ACAS X compliant systems.

Surveillance radar means radar equipment used to determine the position of an aircraft in range and azimuth.

Threat means an intruder deserving special attention either because of its close proximity to own aircraft or because successive range and altitude measurements indicate that it could be on a collision or near-collision course with own aircraft. The warning time provided against a threat is sufficiently small that an RA is justified.

Track means the sequence of at least three measurements representing positions that could reasonably have been occupied by an aircraft.

Traffic information service – broadcast (TIS-B) IN means a surveillance function that receives and processes surveillance data from TIS-B OUT data sources.

Traffic information service – broadcast (TIS-B) OUT means a function on the ground that periodically broadcasts the surveillance information made available by ground sensors in a format suitable for TIS-B IN capable receivers.

Note. — This technique can be achieved through different data links. The requirements for Mode S extended squitters are specified in. 23.4.5 The requirements for VHF digital link (VDL) Mode 4 and universal access transceiver (UAT) are specified in 23.3 Part I.

Traffic advisory (TA) means an indication given to the flight crew that a certain intruder is a potential threat.

Transponder occupancy means a state of unavailability of the transponder from the time it detects an incoming signal that appears to cause some action or from the time of a self-initiated transmission, to the time that it is capable of replying to another

interrogation.

Note.— Signals from various systems that contribute to transponder occupancy are described in the Aeronautical Surveillance Manual (Doc 9924), Appendix M.

Vertical speed limit (VSL) RA means a resolution advisory advising the pilot to avoid a given range of altitude rates. A VSL RA can be either corrective or preventive.

Warning time means the time interval between potential threat or threat detection and closest approach when neither aircraft accelerates.

23.4.2 GENERAL

23.4.2.1 SECONDARY SURVEILLANCE RADAR (SSR)

23.4.2.1.1 GENERAL REQUIREMENT

When SSR is installed and maintained in operation as an aid to air traffic services, it shall conform with the provisions of 23.4.3.1 unless otherwise specified in this 23.4.2.1.

Note. — As referred to in this Part, Mode A/C transponders are those which conform to the characteristics prescribed in 23.4.3.1.1. Mode S transponders are those which conform to the characteristics prescribed in 23.4.3.1.1. and 23.4.3.1.2. The functional capabilities of Mode A/C transponders are an integral part of Mode S transponders.

23.4.2.1.2 INTERROGATION MODES (GROUND-TO-AIR)

(1) Interrogation for air traffic services shall be performed on the modes described in 23.4.3.1.1.4(3) or 23.4.3.1.2. The uses of each mode shall be as follows:

(a) Mode A – to elicit transponder replies for identity and surveillance.

(b) Mode C – to elicit transponder replies for automatic pressure-altitude transmission and surveillance.

(c) Intermode –

(i) Mode A/C/S all-call: to elicit replies for surveillance of Mode A/C transponders and for the acquisition of Mode S transponders.

(ii) Mode A/C-only all-call: to elicit replies for surveillance of Mode A/C transponders. Mode S transponders do not reply.

(d) Mode S –

(i) Mode S-only all-call: to elicit replies for acquisition of Mode S transponders.

(ii) Broadcast: to transmit information to all Mode S

transponders. No replies are elicited.

(iii) Selective: for surveillance of, and communication with, individual Mode S transponders. For each interrogation, a reply is elicited only from the transponder uniquely addressed by the interrogation.

Note 1. Mode A/C transponders are suppressed by Mode S interrogations and do not reply.

Note 2.— There are 25 possible interrogation (uplink) formats and 25 possible Mode S reply (downlink) formats.

For format assignment see 23.4.3.1.2.3.2, Figures 3-7 and 3-8.

(2) An ANSP shall coordinate with appropriate national and international authorities those implementation aspects of the SSR system which will permit its optimum use. 9

Note. — In order to permit the efficient operation of ground equipment designed to eliminate interference from unwanted *aircraft transponder replies to adjacent interrogators (defruiting equipment), ANSPs may need to develop coordinated plans for the assignment of pulse recurrence frequencies (PRF) to SSR interrogators.*

(3) ~~shall coordinate with National Communication Authority and international authorities to implement the aspects of the SSR system which will permit its optimum use.~~The assignment of interrogator identifier (II) codes, where necessary in areas of overlapping coverage, across international boundaries of flight information regions, shall be the subject of regional air navigation agreements.

(4) The assignment of surveillance identifier (SI) codes, where necessary in areas of overlapping coverage, shall be the subject of regional air navigation agreements.

Note. - The SI lockout facility cannot be used unless all Mode S transponder within coverage range are equipped for this purpose.

(5) Mode A and Mode C interrogations shall be provided.

Note 1. Requirements for the Mode A and C interrogator are specified in 23.4.3.1.

Note 2. —This requirement may be satisfied by intermode interrogations which elicit Mode A and Mode C replies from Mode A/C transponders

(6) Interrogators commissioned on or after 1 January 2030 shall also comply with the Mode A and C interrogator requirements specified in 23.4.3.1.1.5(2)(b) and 23.4.3.1.1.8(3)(b).

Note. — This requirement may be satisfied by intermode interrogations which elicit Mode A and Mode C replies from Mode A/C transponders.

(7) In areas where improved aircraft identification is necessary to enhance the effectiveness of the ATC system, SSR ground facilities having Mode S features shall include aircraft identification capability.

Note. Aircraft identification reporting through the Mode S data link provides unambiguous identification of aircraft suitably equipped.

23.4.2.1.3 SIDE-LOBE SUPPRESSION CONTROL INTERROGATION

(1) Side-lobe suppression shall be provided in accordance with the provisions of 23.4.3.1.1.4 and 23.4.3.1.1.5 on all Mode A, Mode C interrogations.

(2) Side-lobe suppression shall be provided in accordance with the provisions of 23.4.3.1.2.1(v) on all Mode A/C-only all-call interrogations.

(3) Side-lobe suppression shall be provided in accordance with the provisions of 23.4.3.1.2.4.2.1(2)(a) on all Mode S-only all-call interrogations.

23.4.2.1.4 TRANSPONDER REPLY MODES (AIR-TO-GROUND)

(1) Transponders shall respond to Mode A interrogations in accordance with the provisions of 23.4.3.1.1.7(12)(a) and to Mode C interrogations in accordance with the provisions of 23.4.3.1.1.7(12)(b).

Note. - If pressure-altitude information is not available, transponders reply to Mode C interrogations with framing pulses only.

(2) The pressure altitude reports contained in Mode S replies shall be derived as specified in 23.4.3.1.1.7(12) (b).

Note. 23.4.3.1.1.7(12) (b). *is intended to relate to Mode C replies and specifies,* inter alia, *that Mode C pressure-altitude reports be referenced to a standard pressure setting of 1013.25 hectopascals. The intention of 23.4.2.1.4(2) is to ensure that all transponders, not just Mode C transponders, report uncorrected pressure-altitude.*

(3) Where the need for Mode C automatic pressure-altitude transmission

capability within a specified airspace has been determined, transponders, when used within the airspace concerned, shall respond to Mode C interrogations with pressure-altitude encoding in the information pulses.

(4) All transponders, regardless of the airspace in which they will be used, shall respond to Mode C interrogations with pressure-altitude information.

Note. — Operation of the airborne collision avoidance system (ACAS) depends upon intruder aircraft reporting pressure-altitude in Mode C replies.

(5) For aircraft with 7.62 m (25 ft) or better pressure altitude sources, the pressure-altitude information provided by Mode S transponders in response to selective interrogations (i.e. in the AC field, 23.4.3.1.2.6.5(4) ~~should~~ shall be reported in 7.62 m (25 ft) increments.

Note. — Performance of the ACAS is significantly enhanced when an intruder aircraft is reporting pressure-altitude in 7.62 m (25 ft) increments.

(6) All Mode A/C transponders installed shall report pressure-altitude encoded in the information pulses in Mode C replies.

(7) All Mode S transponders installed shall report pressure-altitude encoded in the information pulses in Mode C replies and in the AC field of Mode S replies.

(8) When a Mode S transponder is not receiving more pressure-altitude information from a source with a quantization of 7.62 m (25 ft) or better increments, the reported value of the altitude shall be the value obtained by expressing the measured value of the uncorrected pressure altitude of the aircraft in 30.48 m (100 ft) increments and the Q bit (see 23.4.3.1.2.6.5(4)(b)) shall be set to 0.

Note. — This requirement relates to the installation and use of the Mode S transponder. The purpose is to ensure that altitude data obtained from a 30.48 m (100 ft) increment source are not reported using the formats intended for 7.62 .02255m (25 ft) data.

(9) Transponders used within airspace where the need for Mode S airborne capability has been determined shall also respond to intermode and Mode S interrogations in accordance with the applicable provisions of 23.4.3.1.2.

(10) Requirements for mandatory carriage of SSR Mode S transponders shall be on the basis of regional air navigation agreements which shall specify the airspace and the airborne implementation timescales.

(11) The agreements indicated in 23.4.2.1.4(10) shall provide at least five years' notice.

23.4.2.1.5 MODE A REPLY CODES (INFORMATION PULSES)

(1) All transponders shall be capable of generating 4 096 reply codes conforming to the characteristics given in 23.4.3.1.1.6(2) .

(2) ATS Provider shall establish the procedures for the allotment of SSR codes in conformity with Regional Air Navigation agreements, taking into account other users of the system.

Note. — Principles for the allocation of ASSR codes are given in Doc 4444, Chapter 8.

(3) The following Mode A codes shall be reserved for special purposes:

(a) Code 7700 to provide recognition of an aircraft in an emergency.

(b) Code 7600 to provide recognition of an aircraft with Radio communication failure.

(c) Code 7500 to provide recognition of an aircraft which is being subjected to unlawful interference.

(d) Code 7400 to provide recognition of a remotely piloted aircraft system (RPAS) in a lost C2 Link state.

Note. — Details on a lost C2 Link state can be found in Part 23.8 – Communication Systems and Procedures relating to Remotely Piloted Aircraft Systems C2 Link.

(4) Appropriate provision shall be made in ground decoding equipment to ensure immediate recognition of Mode A codes 7400, 7500, 7600 and 7700.

(5) Mode A code 0000 shall be reserved for allocation subject to regional agreement, as a general purpose code.

(6) Mode A code 2000 shall be reserved to provide recognition of an aircraft which has not received any instructions from air traffic control units to operate the transponder.

23.4.2.1.6 MODE S AIRBORNE EQUIPMENT CAPABILITY

(1) Transponder levels. All Mode S transponders shall conform to one of the following five levels:

Note. — The transponder used for a Mode S site monitor may differ from the requirements defined for a normal Mode S transponder. For example, it may be necessary to reply to all-call interrogations when the effective air/ground state is "on-the-ground". For more details see the Aeronautical Surveillance Manual (Doc 9924) Appendix D.

(a) **Level 1 transponders**—

(i) Level 1 transponders shall have the capabilities prescribed for:

(A) Mode A identity and Mode C pressure-altitude reporting (23.4.3.1.1);

(B) intermode and Mode S all-call transactions (23.4.3.1.2.5);

(C) addressed surveillance altitude and identity transaction (23.4.3.1.2.6.1,23.4.3.1.2.6.3, 23.4.3.1.2.6.5 and 23. 4.3.1.2.6.7);

(D) lockout protocols (23.4.3.1.2.6.9);

(E) basic data protocols except both data link capability reporting (23.4.3.1.2.6.10(2)(b) and basic data flash protocol (23.4.3.1.2.6.10(3);

(F) air-air service and squitter transactions (23.4.3.1.2.8); and

(G) system characteristics of the SSR Mode S transponder (23.4.3.1.2.10) as applicable to the transponder level.

Note 1.— Level 1 transponders permits SSR surveillance based on pressure-altitude reporting and the Mode A identity code. In an SSR Mode S environment, technical performance relative to a Mode A/C transponder is improved due to Mode S selective aircraft interrogation.

Note 2.— Level 1 transponders are not sufficient to support ADS-B, elementary surveillance and enhanced surveillance. Also, RTCA DO-181F and EUROCAE ED-73F transponder MOPS no longer support Level 1

(b) **Level 2 transponders —**

(i) Level 2 transponders shall have the capabilities of 23.4.2.1.6(1)(a) and also those prescribed for:

(A) standard length communications (Comm-B) (23.4.3.1.2.6.6, 23.4.3.1.2.6.8, 23.4.3.1.2.6.11(2) and 23.4.3.1.2.6.11.4);

(B) data link capability reporting (23.4.3.1.2.6.10(2)(b));

(C) aircraft identification reporting (23.4.3.1.2.9); and

(D) SI code capability and o (23.4.3.1.2.3.2(1)(d), 23.4.3.1.2.5(2)(a), 23.4.3.1.2.6.1(3), 23.4.3.1.2.6.1(4)(a), 23.4.3.1.2.6.9(1)(a) and 23.4.3.1.2.6.9(2)).

Note. — The aircraft identification reporting capability requires an interface and appropriate input device.

(ii) **Level 2 transponders with Comm-A capability.** Level 2 transponders with Comm-A capability shall have the capabilities of 23.4.2.1.6(1)(b)(i) and those prescribed for Comm-A standard length communication described in 23.4.3.1.2.6.2, 23.4.3.1.2.6.4 and 23.4.3.1.2.6.11(1)

(iii) **Level 2 transponders with Air-initiated Comm-B capability.** Level 2 transponders with Air-initiated Comm-B capability shall have the capabilities of 23.4.2.1.6(1)(b)(i) and those prescribed for Air-initiated Comm-B standard length communication described in 23.4.3.1.2.6.11.3

Note. — Air-initiated Comm-B capability is an optional capability that is not reported to the ground. However, it will be detectable by the existence of applications supporting communication through Air-initiated Comm-B.

(iv) **Level 2 transponders with basic data flash capability.** Level 2 transponders with basic data flash

capability shall have the capabilities of 23.4.2.1.6(1)(b)(i) and also those prescribed for basic data flash described in 23.4.3.1.2.6.10(3).

(c) Level 3 transponders —

Level 3 transponders shall have the capabilities of 23.4.2.1.6(1)(b) and also those prescribed for ground-to-air extended length message (ELM) communications (23.4.3.1.2.7(1) to 23.4.3.1.2.7(5)).

Note. — Level 3 permits extended length data link communications from ground to air and thus may provide retrieval from ground-based data banks and receipt of other air traffic services which are not available with Level 2 transponders.

(d) Level 4 transponders —

Level 4 transponders shall have the capabilities of 24.4.2.1.6(1)(c) and also those prescribed for air-to-ground extended length message (ELM) communications (23.4.3.1.2.7.7 and 23.4.3.1.2.7.8).

Note. — Level 4 permits extended length data link communications from air to ground and thus may provide access from the ground to airborne data sources and the transmission of other data required by air traffic services which are not available with Level 2 transponders.

(e) **Level 5 transponders —**

Level 5 transponders shall have the capabilities of 23.4.2.1.6(1)(d) and also those prescribed for enhanced Comm-B and extended length message (ELM) communications (23.4.3.1.2.6.11.3(4), 23.4.3.1.2.7(6) and 23.4.3.1.2.7.9).

Note. — Level 5 permits Comm-B and extended length data link communications with multiple interrogators without requiring the use of multisite reservations. This level of transponder has a higher minimum data link capacity than the other transponder levels.

(f) **Extended squitter —** Extended squitter transponders shall have the capabilities of 23.2.1.6(1)(b), 23.4.2.1.6(1)(c), 23.4.2.1.6(1)(d) or 23.4.2.1.6(1)(e) the capabilities prescribed for extended squitter operation (23.4.3.1.2.8.6) and the capabilities prescribed for ACAS cross-link operation (23.4.3.1.2.8(3) and 23.4.3.1.2.8(4)). Transponders with this capability shall be designated with a suffix “e”.

Note. — For example, a Level 2 transponder with extended squitter

capability would be designated "level 4e".

(g) Extended squitter non-transponder devices. Devices that are capable of broadcasting extended squitters that are not part of a Mode S transponder shall conform to all of the 1 090 MHz RF signals in space requirements specified for a Mode S transponder, except for transmit power levels for the identified equipment class as specified in 23.4.5.1(1).

(2) Mode S transponder minimum capability

(a) All Mode S transponders used by international civil air traffic shall conform, at least, to the requirements of Level 2 transponders prescribed in 23.4.2.1.6(1)(b)(i).

(b) ANSPs shall ensure that Level 1 transponders are not used in areas where SI codes are used.

Level 1 transponders do not report SI code capability. They remain unlocked in areas where SI codes are used; therefore, they affect the usage of 1 090 MHz frequency and contribute to 1 090 MHz RF pollution.~~Note 1.— Level 1 may be admitted for use within an individual State or within the terms of a regional air navigation agreement. The Mode S Level 1 transponder comprises the minimum set of features for compatible operation of Mode S transponders with SSR Mode S interrogators. It is defined to prevent a proliferation of transponder types below Level 2 which would be incompatible with SSR Mode S interrogators.~~

(c) All Mode S transponders shall maintain the alert condition if the Mode A identity code is changed to one of the Mode A codes of set 1 defined in 23.4.3.1.2.6.10(1)(a)(i)(A).

(3) Mode S transponders installed on aircraft with gross mass in excess of 5 700 kg or a maximum cruising true airspeed capability in excess of 463 km/h (250 kt) shall operate with antenna diversity as prescribed in 23.4.3.1.1.7(18) and 23.4.3.1.2.10(4) if:

(a) the aircraft individual certificate of airworthiness is first issued on or after 1 January 1990; or

(b) Mode S transponder carriage is required on the basis of regional

air navigation agreement in accordance with 23.4.2.1.4(10) and 23.4.2.1.4(11).

Note. — Aircraft with maximum cruising true airspeed exceeding 324 km/h (175 kt) are required to operate with a peak power of not less than 21.0 dBW as specified in 23.4.3.1.2.10(2)(c).

TRANSPONDER CAPABILITY REQUIRED AT SPECIFIC DATES ~~REPORTING IN MODE S SQUITTERS~~

(4)

(a) All Mode S transponders certified on or after 1 January 1999 shall recover sensitivity to within 3 dB of minimum triggering level (MTL) no later than 45 microseconds after receipt of the sync phase reversal following a Mode S interrogation that is not accepted (23.4.3.1.2.4.1.2) or that is accepted but requires no reply.

Note. — The capabilities defined in this section allow a smooth implementation of new features and improvements of SSR Mode S transponders. The requirements on transponders are ensured through the certification process. Requirements on installation are ensured by the State in charge of the aircraft installation approval. Mode S transponder minimum capabilities are listed in 23.4.2.1.6(2).

(b) Transponder designs first certified on or after 1 January 2011 shall have the spurious Mode A/C reply protection capability as specified in 23.4.3.1.1.7(8)(e)(ii).

(c) Mode S Level 2 transponders certified on or after 1 January 2020 shall have data parity with overlay control as specified in 23.4.3.1.2.6.11(2)(e).

(d) All Mode S transponders certified on or after 1 January 2020 shall not reply to Mode A/C/S all-call interrogations defined in 23.4.3.1.2.1(e)(i).

Note 1. — If those transponders receive a Mode A/C/S all-call interrogation, it will be recognized as a Mode A/C-only all-call interrogation.

Note 2.— The replies to Mode A/C/S all-call interrogations are no longer supported by equipment certified on or after 1 January 2020 in order to reduce the RF pollution generated by the replies triggered by the false detection of Mode A/C/S all-call interrogations within other types of interrogation.

(e) Mode S transponders certified on or after 1 January 2030 shall not accept the type control subfield (TCS), rate control subfield (RCS), or surface antenna subfield (SAS) commands received when DI = 2.

Note. — TCS, RCS and SAS were previously defined in 23.4.3.1.2.6.1(4)(a), DI = 2.

(f) Mode S transponders certified on or after 1 January 2030 shall maintain the alert condition if the Mode A identity code is changed to one of the codes of set 2 defined in 23.4.3.1.2.6.10(1)(i)(B).

Note. — Set 2 allows the reporting of a Mode A code of 7400 to indicate a lost C2 Link state for remotely piloted aircraft systems (RPAS).

(g) Mode S transponders certified on or after 1 January 2030 shall not set to zero in bit 33 of the data link capability report when aircraft identification cannot be updated within 8 seconds (see 23.4.3.1.2.6.10(2)(b)(iii)).

Note. — Transponders certified before 1 January 2030 may be set to zero in bit 33 of the data link capability report when losing the aircraft identification input.

(h) Mode S transponders certified on or after 1 January 2030 shall not set to zero for the aircraft identification upon the loss of the interface providing aircraft identification (see 23.4.3.1.2.9(1)(d)).

(i) Transponders certified on or after 1 January 2030 shall have their RF output power as specified in 23.4.3.1.1.7(17)(b) and 23.4.3.1.2.10(2)(e)(ii).

(j) Transmitters used to replace defective obsolete transmitters in transponders shall meet the requirement defined in 23.4.3.1.1.7(17)(b)(i) and 23.4.3.1.2.10(2)(e)(ii)(A).

(k) Transponders certified on or after 1 January 2030 shall have an improved dead time as specified in 23.4.3.1.1.7(3)(b) and 23.4.3.1.2.10(3)(c)(ii).

(l) Mode S transponders certified on or after 1 January 2030 shall have a Mode S reply rate limiting of type 1 as specified in 23.4.3.1.2.10(3)(g)(i)(B).

23.4.2.1.7 SSR MODE S ADDRESS (AIRCRAFT ADDRESS)

The SSR Mode S address shall be one of 16 777 214 twenty-four-bit aircraft addresses allocated by ICAO to the State of Registry or common mark registering authority and assigned as prescribed in 23.4.3.1.2.4.1.2(3)(e)(iv) and the IS: 23.3.7 to Part 23 Subpart 3.

23.4.2.1.8 TRANSPONDER OCCUPANCY

23.4.2.1.9 1 090 MHz RECEIVER

(1) Decoding of 1 090 MHz messages

(a) 1 090 MHz receivers produced on or after 1 January 2030 shall be capable of decoding messages transmitted by transponders compliant with the active state transponder output power specified in 23.4.3.1.1.7.17(2) and 23.4.3.1.2.10(2)(e)(ii).

(b) 1 090 MHz receivers produced before 1 January 2030 shall be capable of decoding messages transmitted by transponders compliant with the active state transponder output power specified in 23.4.3.1.1.7.17(2) and 23.4.3.1.2.10(2)(e)(ii).

Note. — See Appendix M of the Aeronautical Surveillance Manual (Doc 9924) for guidance on consistent modelling of transponder occupancy.

(2) Mode S interrogator capability

(a) Mode S interrogators shall comply with the requirements defined in 23.4.3.1.1 and 23.4.3.1.2.

(b) Mode S interrogators shall not use Mode A/C/S all-call interrogations.

Note. — The use of Mode A/C/S all-call interrogations does not allow the use of stochastic lockout override and therefore might not ensure a sufficient probability of acquisition in areas of high density of flights or when other interrogators lockout transponder on II = 0 for supplementary acquisition.

(c) II/SI code operation

(i) Mode S ground station using an SI code shall:

(A) acquire Mode S II-only transponders on the matching II code;

(B) selectively interrogate Mode S II-only transponders on the matching II code; and

(C) not lockout Mode S II-only transponders when ground stations with overlapping coverage are assigned matching II or SI codes.

Note 1.— A table of matching II/SI codes can be found in Doc 9924, Appendix H.

Note 2. — Mode S II/SI capable transponders support both II and SI codes. Only locking out Mode S II/SI capable transponders means the legacy Mode S II-only transponders are not in a lockout condition and can be acquired by other Mode S ground stations using the matching II code. The suppression of lockout for Mode S II-only transponder is only used when there is overlapping coverage with a ground station using a matching II or SI code, as it is important to use lockout to reduce RF transmissions.

(ii) Mode S II/SI capable interrogator using an II code shall be configurable to only lockout Mode S II/SI capable transponders.

Note 1. — This mode of operation is used when matching SI codes are used by overlapping interrogators.

Note 2. — A matching SI code is an SI code whose binary format in the IC field is the same as the binary format in the IC field of the II code. Each Mode S II code has four "matching" SI codes. A table of matching II/SI codes can be found in Doc 9924, Appendix H.

Note 3. — This provision is to make possible the assignment of matching II codes to Mode S interrogators in areas in which not all transponders

are SI code capable and where a matching SI code is assigned.

Note 4. — This recommendation is not necessary if a monitoring programme has demonstrated that all transponders are SI code capable or if SI codes do not need to be used in the ICAO Region. More information on the use of this capability to make possible the assignment of SI codes can be found in Doc 9924, Appendix J.

23.4.2.2 HUMAN FACTORS CONSIDERATIONS

Human Factors principles shall be observed in the design and certification of surveillance radar and collision avoidance systems.

Note. — Guidance material on Human Factors principles can be found in Doc 9683, Human Factors Training Manual and Circular 249 (Human Factors Digest No. 11 — Human Factors in CNS/ATM Systems).

23.4.2.2.1 OPERATION OF CONTROLS

(1) Transponder controls which are not intended to be operated in flight shall not be directly accessible to the flight crew.

(2) The operation of transponder controls, intended for use during flight, ~~should~~ shall be evaluated to ensure they are logical and tolerant to human error. In particular, where transponder functions are integrated with other system controls, the manufacturer ~~should~~ shall ensure that unintentional transponder mode switching (i.e. an operational state to 'STANDBY' or 'OFF') is minimized.

Note. — This may take the form of a confirmation of mode switching, required by the flight crew. Typically, 'Line Select' Keys, 'Touch Screen' or 'Cursor Controlled/Tracker-ball' methods used to change transponder modes should be carefully designed to minimize flight crew error.

(3) The flight crew shall have access at all times to the information of the operational state of the transponder.

Note. — Information on the monitoring of the operational state of the transponder is provided in RTCA DO-181 F, Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/ Mode Select (ATCRBS/Mode S) Airborne Equipment, and in EUROCAE ED-73F, Minimum Operational Performance Standards (MOPS) for Secondary Surveillance Radar Mode S Transponders.

23.4.2.3 INTERFERENCE TOLERANCE CRITERION

Aeronautical surveillance and collision avoidance system receivers defined in this Subpart utilizing the 1 030 and/or 1 090 MHz channels shall be able to meet their performance requirements under an average interference power to average noise power level ratio of no more than minus 10 dB.

Note 1. — Interference levels above this level may be harmful to the intended operation of the systems in this subpart. This would apply to the combination of all non-pulsed interference sources present. Pulsed interference sources or sources with less than 100 per cent operational duty cycle need to be evaluated on a case-by-case basis. Compatibility between standardized systems in this Part may be evaluated on a case-by-case basis, and interference mitigations may be used which are only available to standardized systems in this Part.

Note 2.— The interference can be treated as additive noise such that interference 10 dB below a receiver's baseline noise floor generates 0.4 dB of additive noise.

Note 3.— Additional information on application of this interference tolerance criterion and means of compliance can be found in Doc 9924.

23.4.3 SURVEILLANCE SYSTEMS

23.4.3.1 SECONDARY SURVEILLANCE RADAR (SSR) SYSTEM CHARACTERISTICS

(1) This ~~Note~~ Section prescribes the technical characteristics of SSR ~~systems having only~~ Mode A and Mode C capabilities ~~. Section~~ 23.4.3.1.2and prescribes the characteristics of ~~systems with~~ Mode S capabilities.

(2) Table 3-11 provides a summary of the interrogation signal details. Section 23.4.5 prescribes additional requirements on Mode S extended squitters.

Note 1. — Systems using Mode S capabilities are generally used for air traffic control surveillance systems. In addition, certain ATC applications may use Mode S emitters, e.g. for vehicle surface surveillance or for fixed target detection on surveillance systems. Under such specific conditions, the term "aircraft" can be understood as "aircraft or vehicle (A/V)". While those applications may use a limited set of data, any deviation from standard physical characteristics must be considered very carefully by the appropriate authorities. They must take into account not only their own surveillance (SSR) environment but also possible effects on other systems like ACAS.

Note 2.— Non-Standard-International alternative units are used as permitted by GCAD Part 22.3.3.2.

23.4.3.2.1 ~~SYSTEMS HAVING ONLY~~ MODE A AND MODE C CAPABILITIES

Note 1. — In this section, SSR modes are designated by letters A and C. Suffixed letters, e.g. A2, C4, are used to designate the individual pulses used in the air-to-ground pulse trains. This common use of letters is not to be construed as implying any particular association of modes and codes.

Note 2.— Provisions for the recording and retention of radar data are contained in Part 24, Section 24.7.

23.4.3.1.1.1 INTERROGATION AND CONTROL (INTERROGATION SIDE-LOBE SUPPRESSION) RADIO FREQUENCIES (GROUND-TO-AIR)

(1) The carrier frequency of the interrogation and control transmissions shall be 1030 MHz.

(2) The frequency tolerance shall be plus or minus 0.2 MHz.

(3) The carrier frequencies of the control transmission and of each of the interrogation pulse transmissions shall not differ from each other by more than 0.2 MHz.

23.4.3.1.1.2 REPLY CARRIER FREQUENCY (AIR-TOGROUND)

(1) The carrier frequency of the reply transmission shall be 1090 MHz.

(2) The frequency tolerance shall be plus or minus 1 MHz.

23.4.3.1.1.3 POLARIZATION

Polarization of the interrogation, control and reply transmissions shall be predominantly vertical.

23.4.3.1.1.4 INTERROGATION MODES (SIGNALS-IN-SPACE)

(1) The interrogation shall consist of two transmitted pulses designated P1 and P3. A control pulse P2 shall be transmitted following the first interrogation

pulse P1.

Note. — The paragraphs herein describe the signals-in-space at the antenna(s) of the interrogator. Table 3-11 provides a summary of the interrogation signal details.

(2) Interrogation Modes A and C shall be as defined in 23.4.3.1.1.4(3).

(3) The interval between P1 and P3 shall determine the mode of interrogation and shall be as follows:

(a) Mode A 8 ±0.18 microseconds

(b) Mode C 21 ±0.18 microseconds

(4) The interval between P1 and P2 shall be 2.0 plus or minus 0.1 microsecond.

(5) The duration of pulses P1, P2 and P3 shall be 0.8 plus or minus 0.09 microsecond.

(6) The rise time of pulses P1, P2 and P3 shall be between 0.05 and 0.1 microsecond.

Note 1.— The definitions are contained in Figure 3-1 "Definitions of secondary surveillance radar waveform shapes, intervals and the reference point for sensitivity and power".

Note 2. — The intent of the lower limit of rise time (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which, theoretically, would be produced by a trapezoidal wave having the stated rise time.

(7) The decay time of pulses P1, P2 and P3 shall be between 0.05 and 0.2 microsecond.

Note. — The intent of the lower limit of decay time (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which, theoretically, would be produced by a trapezoidal wave having the stated decay time.

23.4.3.1.1.5 INTERROGATOR AND CONTROL TRANSMISSION CHARACTERISTICS (INTERROGATION SIDELOBE SUPPRESSION - SIGNALS-IN-SPACE)

(1) The radiated amplitude of P2 shall be:

(a) equal to or greater than the radiated amplitude of P1 from the side- lobe transmissions of the antenna radiating P1; and

(b) at a level lower than 9 dB below the radiated amplitude of P1, within the desired arc of interrogation.

(2) Within the desired beam width of the directional interrogation (main lobe), the radiated amplitude of P3 shall comply with 23.4.3.1.1.5(2)(a) or 23.4.3.1.1.5(2)(b).

(a) For interrogator commissioned before 1 January 2030, the radiated amplitude of P3 shall be within 1 dB of the radiated amplitude of P1.

(b) For interrogator commissioned on or after 1 January 2030, the radiated amplitude of P3 shall be within 0.5 dB of the radiated amplitude of P1.

(3) One or two control pulses (P2 alone, or P1 and P2) shall be transmitted using a separate antenna pattern to suppress responses from aircraft in the side lobes of the interrogator antenna.

Note. — When using control pulses P1 and P2, separate RF paths are used for the interrogation P1 pulse and the control P1 pulse. The pulse characteristics and timing for both P1 pulses are given in 23.4.3.1.1.4 Further details on the use of control pulses can be found in Doc 9924.

23.4.3.1.1.6 REPLY TRANSMISSION CHARACTERISTICS (SIGNALS-IN-SPACE)

Note. —The paragraphs herein describe the signals-in-space at the antenna(s) of the transponder.

(1) Framing pulses. The reply function shall employ a signal comprising two framing pulses spaced 20.3 microseconds as the most elementary code.

(2) Information pulses.

(a) Information pulses shall be spaced in increments of 1.45 microseconds from the first framing pulse. The designation and position of these information pulses shall be as follows:

Pulses	Position (microseconds)
C1	1.45
A1	2.90
C2	4.35
A2	5.80
C4	7.25
A4	8.70
X	10.15
B1	11.60
D1	13.05
B2	14.50
D2	15.95
B4	17.40
D4	18.85

Note. — The Standard relating to the use of these pulses is given in 23.4.2.1.5(1). Information on the "X" pulse is contained in the Aeronautical Surveillance Manual (Doc 9924).

(b) The position of the X pulse shall not be used in replies to Mode A or Mode C interrogations if the safe operation of surveillance systems cannot be maintained.~~However, the position of the "X" pulse is not used in replies to Mode A or Mode C interrogations and is specified only as a technical standard to safeguard possible future expansion of the system. It has nevertheless been decided that such expansion should be achieved using Mode S.~~

(c) The Utilization of the X pulse for special applications shall be carried out in conformance with a procedure established by the Republic of Ghana to ensure compatibility of all systems.~~presence of a pulse in the X pulse position is used in some States to invalidate replies.~~

(3) Special position identification pulse (SPI). In addition to the information pulses provided, a special position identification pulse shall be transmitted but only as a result of manual (pilot) selection. When transmitted, it shall be spaced at an interval of 4.35 microseconds following the last framing pulse of Mode A replies only.

(4) Reply pulse shape. All reply pulses shall have a pulse duration of 0.45 plus or minus 0.1 microsecond, a pulse rise time between 0.05 and 0.1 microsecond and a pulse decay time between 0.05 and 0.2 microsecond. The pulse amplitude variation of one pulse with respect to any other pulse in

a reply train shall not exceed 1 dB.

Note. — The intent of the lower limit of rise and decay times (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is not greater than that which, theoretically, would be produced by a trapezoidal wave having the stated rise and decay times.

(5) Reply pulse position tolerances. The pulse spacing tolerance for each pulse (including the last framing pulse) with respect to the first framing pulse of the reply group shall be plus or minus 0.10 microsecond. The pulse interval tolerance of the special position identification pulse with respect to the last framing pulse of the reply group shall be plus or minus 0.10 microsecond. The pulse spacing tolerance of any pulse in the reply group with respect to any other pulse (except the first framing pulse) shall not exceed plus or minus 0.15 microsecond.

(6) Code nomenclature.

The code designation shall consist of digits between 0 and 7 inclusive and shall consist of the sum of the subscripts of the pulse numbers given in 23.4.3.1.1.6(2) above, employed as follows:

Digit	Pulse Group
First (most significant)	A
Second	B
Third	C
Fourth	D

23.4.3.1.1.7 TECHNICAL CHARACTERISTICS OF TRANSPONDERS MODE A AND MODE C CAPABILITIES

(1) **REPLY.** The transponder shall reply (not less than 90 per cent triggering) when all of the following conditions have been met:

(a) the received amplitude of P3 is within plus or minus 1 dB of the received amplitude of P1;

(b) either no pulse is received in the interval 1.3 microseconds to 2.7 microseconds after P1, or P1 exceeds by more than 9 dB any pulse received in this interval;

(c) the received amplitude of a proper interrogation is more than 10 dB above the received amplitude of random pulses where the

latter are not recognized by the transponder as P1, P2 or P3.

(d) the interval between P1 and P3 is 8 plus or minus 0.2 microsecond (Mode A), or 21 plus or minus 0.2 microsecond (Mode C); and

(e) the duration of P1 and P3 is 0.8 plus or minus 0.1 microsecond.

(2) The transponder shall not reply under the following conditions:

(a) to interrogations when the interval between pulses P1 and P3 differs from those specified in 23.4.3.1.1.4(3) by more than plus or minus 1.0 microsecond;

(b) upon receipt of any single pulse which has no amplitude variations approximating a normal interrogation condition.

(3) Dead time.

(a) For all transponders, the time interval beginning at the end of a reply transmission and ending when the receiver has regained sensitivity to within 3 dB of MTL (dead time) shall not exceed 125 microseconds.

(b) For transponders with improved dead time, the time interval beginning at the end of a reply transmission and ending when the receiver has regained sensitivity to within 3 dB of MTL (dead time) shall not exceed 20 microseconds.

(4) SUPPRESSION

Note. — This characteristic is used to prevent replies to interrogations received via the side lobes of the interrogator antenna, and to prevent Mode A/C transponders from replying to Mode S interrogations.

(a) The transponder shall be suppressed when the received amplitude of P2 is equal to, or in excess of, the received amplitude of P1 and spaced 2.0 plus or minus 0.15 microseconds. The detection of P3 is not required as a prerequisite for initiation of suppression action.

(b) The transponder suppression shall be for a period of 35 plus or minus 10 microseconds.

(c) The suppression shall be capable of being reinitiated for the full

duration within 2 microseconds after the end of any suppression period.

(d) Suppression in presence of S1 pulse. When an S1 pulse is detected 2.0 plus or minus 0.15 microseconds before the P1 of a Mode A or Mode C interrogation:

Note. — The S_1 *pulse is used in a technique employed by ACAS known as "whisper-shout" to facilitate ACAS surveillance of Mode A/C aircraft in higher traffic densities. The whisper-shout technique is explained in the* Airborne Collision Avoidance System (ACAS) Manual *(Doc 9863).*

(i) with S1 and P1 above MTL, the transponder shall be suppressed as specified in 23.4.3.1.1.7(2)(a);

(ii) with P1 at MTL and S1 at MTL, the transponder shall be suppressed and shall reply to no more than 10 per cent of Mode A/C interrogations;

(iii) with P1 at MTL and S1 at MTL –3 dB, the transponder shall reply to Mode A/C interrogations at least 70 per cent of the time; and

(iv) with P1 at MTL and S1 at MTL –6 dB, the transponder shall reply to Mode A/C interrogations at least 90 per cent of the time.

Note 1.— The suppression action is because of the detection of S*1 and* P*1 and does not require detection of a* P*2 or* P*3 pulse.*

Note 2.— S*1 has a lower amplitude than* P*1. Certain ACAS use this mechanism to improve target detection (23.4.4.3.7(1)).*

Note 3.— These requirements also apply to a Mode A/C only capable transponder when an S*1 precedes an intermode interrogation (23.4.2.1.2(1)).*

(5) RECEIVER SENSITIVITY AND DYNAMIC RANGE

(a) The minimum triggering level of the transponder shall be such that replies are generated to at least 90 per cent of the interrogation signals when:

(i) the two pulses P1 and P3 constituting an interrogation are of equal amplitude and P2 is not detected; and

(ii) the amplitude of these signals is nominally 73 dB below 1 mW, with limits between 69 dB and 77 dB below 1 mW.

(b) The reply and suppression characteristics shall apply over a received amplitude of P1 between minimum triggering level and 50 dB above that level.

(c) The variation of the minimum triggering level between modes shall not exceed 1 dB for nominal pulse spacings and pulse widths.

(6) **Pulse Duration Discrimination.**

Signals of received amplitude between minimum triggering level and –45 dBm ~~6 dB above this level,~~ and consisting of P1 and/or P3 with a duration less than 0.3 microsecond shall not cause the transponder to initiate reply or suppression action more than 10 per cent of the time. With the exception of single pulses with amplitude variations approximating an interrogation, any single pulse of a duration more than 1.5 microseconds shall not cause the transponder to initiate reply or suppression action more than 10 per cent of the time over the signal amplitude range of minimum triggering level (MTL) to 50 dB above that level

(7) **Echo suppression and recovery.**

The transponder shall contain an echo suppression facility designed to permit normal operation in the presence of echoes of signals-in-space. The provision of this facility shall be compatible with the requirements for suppression of side lobes given in 23.4.3.1.1.7(4).

(a) **Desensitization.** Upon receipt of any pulse more than 0.7 microsecond in duration, the receiver shall be desensitized by an amount that is within at least 9 dB of the amplitude of the desensitizing pulse but shall at no time exceed the amplitude of the desensitizing pulse, with the exception of possible overshoot during the first microsecond following the desensitizing pulse.

Note. — Single pulses of duration less than 0.7 microsecond are not required to cause the specified desensitization nor to cause desensitization of duration greater than permitted by 23.4.3.1.1.7(7) and 23.4.3.1.1.7(b).

(b) **Recovery**. Following desensitization, the receiver shall recover sensitivity (within 3 dB of minimum triggering level) within 15 microseconds after reception of a desensitizing pulse having a signal strength up to 50 dB above minimum triggering level. Recovery shall be at an average rate not exceeding 4.0 dB per microsecond.

(8) Spurious emissions and spurious responses

(a) Equipment random triggering rate. In the absence of valid interrogation signals, transponders shall not generate more than 5 unwanted Mode A or Mode C replies per second as integrated over an interval of at least 30 seconds.

(b) Installed random triggering rate. In the absence of valid interrogation signals, ~~Mode A/C~~ transponders shall not generate more than 30 unwanted Mode A or Mode C replies per second as integrated over an interval ~~equivalent to~~of at least ~~300 random triggers~~, or 30 seconds, ~~whichever is less~~. This installed random triggering rate shall not be exceeded when all possible interfering equipment

(c) installed in the same aircraft are operating at maximum interference levels.

(d) Random triggering rate in the presence of low-level in-band continuous wave (CW) interference. The total random trigger rate on all Mode A and/or Mode C replies shall not be greater than 10 reply pulse groups or suppressions per second, averaged over a period of 30 seconds, when operated in the presence of non-coherent CW interference at a frequency of 1 030 ±0.2 MHz and a signal level of –60 dBm or less.

(e) Spurious radiation. CW radiation should not exceed 70 dB below 1 W for the transponder.

(f) Spurious responses

(i) The response to signals not within the receiver pass band shall be at least 60 dB below normal sensitivity.

(ii) For transponders with spurious Mode A/C reply protection capability, the spurious Mode A/C reply ratio resulting from low-level Mode S interrogations shall be no more than:

(A) an average of 1 per cent in the input

interrogation signal range between –81 dBm and the Mode S MTL; and

(B) a maximum of 3 per cent at any given level in the input interrogation signal range between –81 dBm and the Mode S MTL.

Note 1. — For transponders that reply to Mode A/C/S all-call interrogations, failure to detect a low-level Mode S interrogation can also result in the transponder decoding a three-pulse Mode A/C/S all-call interrogation. This would result in the transponder responding with a Mode S all-call (DF = 11) reply. The above requirement will also control these DF = 11 replies since it places a limit on the probability of failing to correctly detect the Mode S interrogation.

Note 2.— More information about issuing a type certificate for aircraft and separate design approval can be found in the Airworthiness Manual (Doc 9760).

(9) Reply rate

(a) All transponders shall be capable of continuously generating at least 500 replies per second for a 15-pulse coded reply. Transponder installations used solely below 4 500 m (15 000 ft), or below a lesser altitude established by the appropriate authority or by regional air navigation agreement, and in aircraft with a maximum cruising true airspeed not exceeding 175 kt (324 km/h) shall be capable of generating at least 1 000 15-pulse coded replies per second for a duration of 100 milliseconds. Transponder installations operated above 4 500 m (15 000 ft) or in aircraft with a maximum cruising true airspeed in excess of 175 kt (324 km/h), shall be capable of generating at least 1 200 15-pulse coded replies per second for a duration of 100 milliseconds.

Note 1.— A 15-pulse reply includes 2 framing pulses, 12 information pulses, and the SPI pulse

.

Note 2.— The reply rate requirement of 500 replies per second establishes the minimum continuous reply rate capability of the transponder. As per the altitude and speed criteria above, the 100 or 120 replies in a 100-millisecond interval defines the peak capability of the transponder. The transponder must be capable of replying to this short-term burst rate, even though the transponder may not be capable of sustaining this rate. If the transponder is subjected to interrogation rates beyond its reply rate capability, the reply rate limit control of

23.4.3.1.1.7(9)(b) acts to gracefully desensitize the transponder in a manner that favours closer interrogators. Desensitization eliminates weaker interrogation signals.

(b) Reply rate limit control. To protect the system from the effects of transponder over-interrogation by preventing response to weaker signals when a predetermined reply rate has been reached, a sensitivity reduction type reply limit control shall be incorporated in the equipment. The limit ~~The range of this control~~ shall be set ~~permit adjustment, as a minimum, to any value~~ between 500 and 2 000 Mode A/C replies per second, ~~or to the maximum reply rate capability if less than 2 000 replies per second,~~ without regard to the number of pulses in each reply. Sensitivity reduction in excess of 3 dB shall not take effect until 90 per cent of the selected value is exceeded. ~~Sensitivity reduction shall be at least 30 dB for rates in excess of 150 per cent of the selected value.~~

(10) Reply delay and jitter. The time delay between the arrival, at the transponder receiver, of the leading edge of P3 and the transmission of the leading edge of the first pulse of the reply shall be 3 plus or minus 0.5 microseconds. The total jitter of the reply pulse code group, with respect to P3, shall not exceed 0.1 microsecond for receiver input levels between 3 dB and 50 dB above minimum triggering level. Delay variations between Mode A and Mode C shall not exceed 0.2 microsecond.

(11) Transponder power output and duty cycle

(a) The peak pulse power available at the antenna end of the transmission line of the transponder shall be at least 21 dB and not more than 27 dB above 1 W, except that for transponder installations used solely below 4 500 m (15 000 ft), or below a lesser altitude established by the appropriate authority or by regional air navigation agreement, a peak pulse power available at the antenna end of the transmission line of the transponder of at least 18.5 dB and not more than 27 dB above 1 W shall be permitted.

Note. — An extended squitter non-transponder device on an aerodrome surface vehicle may operate with a lower minimum power output as specified in 23.4.5.1(2).

(b) The peak pulse power specified in 23.4.3.1.1.7.11(a) shall be maintained over a range of replies from code 0000 at a rate of 400 replies per second to a maximum pulse content at a rate of 1 200 replies per second or a maximum value below 1 200 replies per

second of which the transponder is capable.

(12) Reply codes

(a) Identification. The reply to a Mode A interrogation shall consist of the two framing pulses specified in 23.4.3.1.1.6(1) together with the information pulses (Mode A code) specified in 23.4.3.1.1.6(2).

Note. — The Mode A code designation is a sequence of four digits in accordance with 23.4.3.1.1.6(6).

(b) The Mode A code shall be ~~manually~~ selected from the 4 096 codes available.

(c) Pressure-altitude transmission. The reply to Mode C interrogation shall consist of the two framing pulses specified in 23.4.3.1.1.6(1) above. When digitized pressure-altitude information is available, the information pulses specified in 23.4.3.1.1.6(2) shall also be transmitted.

(d) Transponders shall be provided with means to remove the information pulses but to retain the framing pulses when the provision of 23.4.3.1.1.7(12)(g) below is not complied with in reply to Mode C interrogation.

(e) The information pulses shall be automatically selected by an analog-to-digital converter connected to a pressure-altitude data source in the aircraft referenced to the standard pressure setting of 1 013.25 hectopascals.

Note. — The pressure setting of 1 013.25 hectopascals is equal to 29.92 inches of mercury.

(f) Pressure-altitude shall be reported in 100-ft increments by selection of pulses as shown in the IS: 23.4.3.1.1.7(12)(f).

(g) The digitizer code selected shall correspond to within plus or minus 38.1 m (125 ft), on a 95 per cent probability basis, with the pressure-altitude information (referenced to the standard pressure setting of 1 013.25 hectopascals), used on board the aircraft to adhere to the assigned flight profile.

(13) Transmission of the special position identification (spi) pulse. When required, this pulse shall be transmitted with Mode A replies, as specified in 23.4.3.1.1.6(3), for a period of between 18 plus or minus 1 seconds~~s~~.

(14) ANTENNA

(a) The transponder antenna system, when installed on an aircraft, shall have a radiation pattern which is essentially omni directional in the horizontal plane.

(b) The vertical radiation pattern shall be nominally equivalent to that of a quarter-wave monopole on a ground plane.

(15) SIMULTANEOUS SIGNALS.

If a P1 – P2 suppression pair and a Mode A or Mode C interrogation are recognized simultaneously, the transponder shall be suppressed. An interrogation shall not be recognized as Mode A or Mode C if the transponder is in suppression (23.4.3.1.2.4.2. If a Mode A and a Mode C interrogation are recognized simultaneously, the transponder shall complete the transaction cycle as if only a Mode C interrogation had been recognized.

(16) REPLY RATIO IN THE PRESENCE OF LOW-LEVEL IN-BAND CW INTERFERENCE.

In the presence of non-coherent CW interference at a frequency of 1 030 ±0.2 MHz at signal levels of 20 dB or more below the desired Mode A/C interrogation signal level, the transponder shall reply correctly to at least 90 per cent of the interrogations.

(17) UNWANTED OUTPUT POWER

(a) Inactive state transponder output power. When the transponder is in the inactive state, (refer to Figure 3-11), the peak power at 1 090 MHz plus or minus 3 MHz at the antenna end of the transmission line of the transponder, shall not exceed –50 dBm.

Note 1.— Inactive state transponder output power is constrained in this way to ensure that an aircraft, when located as near as 185 m (0.1 NM) to a Mode A/C or Mode S interrogator, does not cause interference to that installation.

Note 2.— Transponders with Mode S capability and installed with an ACAS unit have stricter requirements defined in 23.4.3.1.2.10(2)(e)(i).

(b) Active state transponder output power.

(i) The RF output power shall be less than or equal to the peak pulse power minus 50 dB for the interval starting 10 microseconds prior to the Mode A/C transmission and for the interval of 10 microseconds following a Mode A/C transmission.

(ii) For intervals between transmitted pulses that are greater than 0.5 microsecond, the power level at the lowest point within the interval shall be 50 dB or more below the peak pulse power.

Note 1.— These power limitations protect 1 090 MHz receivers from potential missed decodes when signals are received at close range and within desired detection range. In the absence of such limits, signal levels during non-pulse intervals can occur above receiver thresholds and can lead to unintended distortion of pulse positions or false pulse decodes preventing proper detection of transmitted signals. It also makes it more difficult for receivers to decode overlapped replies. 17

Note 2.— The presence of a signal at a level of 50 dB or more below the peak power may not be measurable within the first 0.5 microsecond following the transmission of a pulse because of the allowed decay time. It is possible that a signal transmitted 50 dB below the peak pulse power can still affect high sensitivity receivers when transmitted in close range. More information is available in Doc 9924.

Note 3.— Information on how to verify unwanted output power can be found in RTCA/DO-181F or EUROCAE/ED-73F.

(18) TRANSPONDER ANTENNA SYSTEM AND DIVERSITY OPERATION. Transponders equipped for diversity operation shall have two RF ports for operation with two antennas, one antenna on the top and the other on the bottom of the aircraft's fuselage. The received signal from one of the antennas shall be selected for acceptance and the reply shall be transmitted from the selected antenna only.

(a) Radiation pattern. The radiation pattern of antennas when installed on an aircraft shall be nominally equivalent to that of a quarter-wave monopole on a ground plane.

Note. — Transponder antennas designed to increase gain at the expense of vertical beamwidth are undesirable because of their poor performance during turns.

(b) Antenna location. The top and bottom antennas shall be mounted as near as possible to the centre line of the fuselage. Antennas shall be located so as to minimize obstruction to their fields in the horizontal plane.

(c) The horizontal distance between the top and bottom antennas shall not be greater than 7.6 m (25 ft).

Note. — This provision is intended to support the operation of any diversity transponder (including cables) with any diversity antenna installation and still satisfy the requirement of 23.4.3.1.2.10(4)(e).

(d) Antenna selection. Transponders equipped for diversity operation shall have the capability to evaluate a pulse sequence simultaneously received on both antenna channels to determine individually for each channel if the P1 pulse and the P3 pulse of a Mode A or Mode C interrogation meet the requirements for Mode A and Mode C interrogations as defined in 23.4.3.1.1.

(e) If the two channels simultaneously receive a P1 – P3 pulse pair that meets the requirements for a Mode A or Mode C interrogation, the antenna at which the signal strength is greater shall be selected for the transmission of the reply.

(f) If only one channel receives a pulse pair that meets the requirements for an interrogation, or if only one channel accepts an interrogation, the antenna associated with that channel shall be selected regardless of received signal strength.

(g) Selection threshold. If antenna selection is based on signal level, it shall be carried out at all signal levels between MTL and –21 dBm.

Note. — Either antenna may be selected if the difference in signal level is less than 3 dB.

(h) Received signal delay tolerance. If an interrogation is received at one antenna 0.125 microsecond or less in advance of reception at the other antenna, the interrogations shall be considered to be simultaneous interrogations, and the above antenna selection criteria applied. If an accepted interrogation is received at either antenna 0.375 microsecond or more in advance of reception at the other antenna, the antenna selected for the reply shall be that which received the earlier interrogation. If the relative time of receipt is between 0.125 and 0.375 microsecond, the

transponder shall select the antenna for reply either on the basis of the simultaneous interrogation criteria or on the basis of the earlier time of arrival.

(i) Diversity transmission channel isolation. The peak RF power transmitted from the selected antenna shall exceed the power transmitted from the non-selected antenna by at least 20 dB.

(j) Reply delay of diversity transponders. The total two-way transmission difference in mean reply delay between the two antenna channels (including the differential delay caused by transponder-to antenna cables and the horizontal distance along the aircraft centre line between the two antennas) shall not exceed 0.13 microsecond for interrogations of equal amplitude. This requirement shall hold for interrogation signal strengths between MTL +3 dB and –21 dBm. The jitter requirements on each individual channel shall remain as specified for non-diversity transponders.

Note. — This requirement limits apparent jitter caused by antenna switching and by cable delay differences.

(19) VARIABLE DIRECT DATA

(a) Variable direct data from the aircraft which can change in flight shall be:

(i) the Mode C altitude code (23.4.3.1.1.7.12(c);

(ii) the Mode A identity code (23.4.3.1.1.7.12(a); and

(iii) the SPI condition (23.4.3.1.1.6(3)).

(b) Interfaces for variable direct data

(i) A means shall be provided, while on the ground or during flight, for the SPI condition to be inserted by the pilot, without the entry or modification of other flight data.

(ii) A means shall be provided, while on the ground or during flight, for the Mode A identity code to be displayed to the pilot and modified without the entry or modification of other flight data.

Note. — Implementation of the pilot action for entry of

data will be as simple and efficient as possible in order to minimize the time required and reduce the possibility of errors in the data entry.

(c) Interfaces shall be included to accept the pressure-altitude.

Note. — A specific interface design for the variable direct data is not prescribed.

23.4.3.1.1.8 TECHNICAL CHARACTERISTICS OF GROUND INTERROGATORS WITH MODE A AND MODE C CAPABILITIES

(1) Interrogation repetition frequency. The maximum interrogation repetition frequency shall be 450 interrogations per second.

(2) To minimize unnecessary transponder triggering and the resulting high density of mutual interference, all interrogators shall use the lowest practicable interrogator repetition frequency that is consistent with the display characteristics, interrogator antenna beam width and antenna rotation speed employed.

(3) RADIATED POWER

(a) In order to minimize system interference, the effective radiated power of interrogators shall be reduced to the lowest value consistent with the operationally required range of each individual interrogator site.

(b) Inactive-state interrogator output power. For interrogator commissioned on or after 1 January 2030, when the interrogator is not transmitting an interrogation, its output shall not exceed –5 dBm effctive radiated power at any frequency between 960 MHz and 1 215 MHz.

Note. — This constraint ensures that aircraft flying near the interrogator (as close as 1.85 km (1 NM)) 19 will not receive interference that would prevent them from being tracked by another interrogator. In certain instances, even smaller interrogator-to-aircraft distances are of significance, for example, if Mode S surveillance on the airport surface is used. In such cases, a further restraint on inactive state interrogator output power may be necessary.

(c) When Mode C information is to be used from aircraft flying below transition levels, the altimeter pressure reference datum shall be

taken into account.

Note. — Use of Mode C below transition levels is in accordance with the philosophy that Mode C can usefully be employed in all environments.

(4) INTERROGATOR RADIATED FIELD PATTERN

The beam width of the directional interrogator antenna radiating P3 shall~~ould~~ not be wider than is operationally required. The side- and back-lobe radiation of the directional antenna shall be at least 24 dB below the peak of the main-lobe radiation.

Note. — This provision is to reduce transponder occupancy. More information can be found in Doc 9924, Appendices D and M.

(5) INTERROGATOR MONITOR

(a) The range and azimuth accuracy of the ground interrogator shall be monitored at sufficiently frequent intervals to ensure system integrity.

Note. — Interrogators that are associated with and operated in conjunction with primary radar may use the primary radar as the monitoring device; alternatively, an electronic range and azimuth accuracy monitor would be required.

(b) In addition to range and azimuth monitoring, provision shall be made to monitor continuously the other critical parameters of the ground interrogator for any degradation of performance exceeding the allowable system tolerances and to provide an indication of any such occurrence

(6) SPURIOUS EMISSIONS AND SPURIOUS RESPONSES

SPURIOUS RADIATION. CW radiation shall not exceed 76 dB below 1 W for the interrogator.

23.4.3.1.2 ~~SYSTEMS HAVING~~ MODE S AND INTERMODE CAPABILITIES.

23.4.3.1.2.1 INTERROGATION SIGNALS-IN-SPACE CHARACTERISTICS.

(1) The paragraphs herein describe the signals-in-space ~~as they can be expected to appear~~ at the antenna(s) of the interrogator.~~transponder.~~

(a) Interrogation carrier frequency. The carrier frequency of all interrogations (uplink transmissions) from ground facilities with Mode S capabilities shall be 1 030 plus or minus 0.01 MHz.

Note. — During the phase reversal the frequency of the signal may shift by several MHz before returning to the specified value.

(b) Interrogation spectrum. The spectrum of a Mode S interrogation about the carrier frequency shall not exceed the limits specified in Figure 3-2.

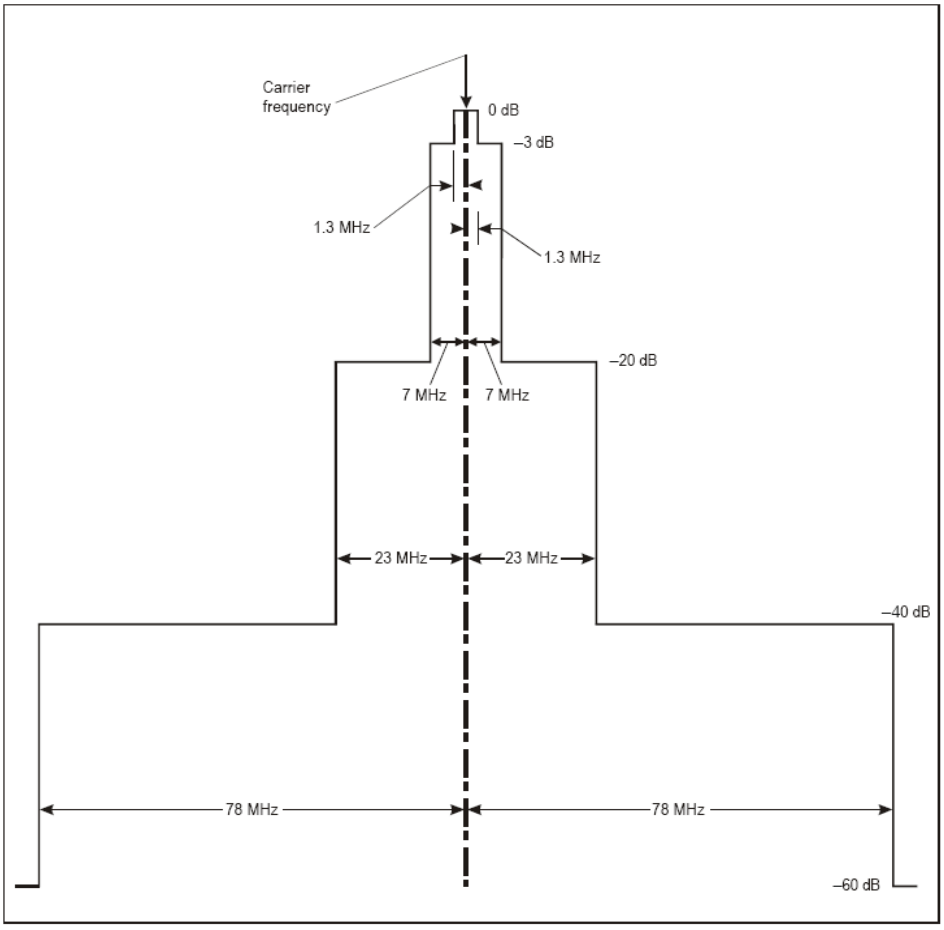


Figure 3-2. Required spectrum limits for interrogator transmitter

Note. — The Mode S interrogation spectrum is data dependent. The broadest spectrum is generated by an interrogation that

contains all binary ONEs.

(c) Polarization. Polarization of the interrogation and control transmissions shall be nominally vertical.

(d) Modulation. For Mode S interrogations, the carrier frequency shall be pulse modulated. In addition, the data pulse, P6, shall have internal phase modulation.

(i) Pulse modulation. Intermode and Mode S interrogations shall consist of a sequence of pulses as specified in 23.4.3.1.2(1)(e) and Tables 3-1, 3-3, and 3-4, as summarized in Table 3-11

Note. — The 0.8 microsecond pulses used in intermode and Mode S interrogations are identical in shape to those used in Modes A and C as defined in 23.4.3.1.1(4).

Table 3-1. Pulse shapes — Mode S and intermode interrogations

Pulse	*Duration*	*Duration tolerance*	*(Rise time)* *Min.*	*Max.*	*(Decay time)* *Min.*	*Max.*
P_1, P_2, P_3, P_5	0.8	±0.1	0.05	0.1	0.05	0.2
P_4 (short)	0.8	±0.1	0.05	0.1	0.05	0.2
P_4 (long)	1.6	±0.1	0.05	0.1	0.05	0.2
P_6 (short)	16.25	±0.25	0.05	0.1	0.05	0.2
P_6 (long)	30.25	±0.25	0.05	0.1	0.05	0.2

(ii) Phase modulation**.** The short (16.25-microsecond) and long (30.25-microsecond) P6 pulses of 23.4.3.1.2(1)(d) (i) shall have internal binary differential phase modulation consisting of 180- degree phase reversals of the carrier at a 4 megabit per second rate.

(iii) Phase reversal duration. The duration of the phase reversal shall be less than 0.08 microsecond, and the phase shall advance (or retard) monotonically throughout the transition region. There shall be no amplitude modulation applied during the phase

transition.

Note 1. — The minimum duration of the phase reversal is not specified. Nonetheless, the spectrum requirements of 23.4.3.1.2(1)(b) must be met.

Note 2. — The phase reversal can be generated using different methods. This includes hard keying with strong amplitude drop and rapid phase reversal or other techniques with little or no amplitude drop, but with frequency shift during the phase reversal and slow phase reversal (80ns). A demodulator cannot make any assumption on the type of modulation technology used and therefore cannot rely on the specificities of the signal during the phase reversal to detect a phase reversal.

(iv) Phase relationship. The tolerance on the 0 and 180degree phase relationship between successive chips and on the sync phase reversal (23.4.3.1.2.(1)(viii)) within the P6 pulse shall be plus or minus 5 degrees.

Note. — In Mode S a "chip" is the 0.25 microsecond carrier interval between possible data phase reversals.

(e) Pulse and phase reversal sequences. Specific sequences of the pulses or phase reversals described in 23.4.3.1.2.1(d) shall constitute interrogations.

(i) Intermode interrogation. Mode A/C/S all-call interrogation.

Note. —This interrogation consists of a minimum three pulses: P1, P3, and the long P4 as shown in Figure 3-3.

~~**23.4.3.1.2.1.5.1.1.1** Mode A/C/S all-call interrogations shall not be used on or after 1 January 2020.~~

(ii) Mode A/C-only all-call interrogation.

Note 1.— This interrogation is defined as P1, P3, and a short P4 as shown in Figure 3-3

Note 2. — The Mode A/C-only all-call interrogation

elicits a Mode A or Mode C reply from a Mode A/C transponder. A Mode S transponder recognizes the short P4 pulse and does not reply to this interrogation.

(iii) Pulse intervals. The pulse intervals between P1, P2 and P3 shall be as defined in 23.4.3.1.1.4(3) and. The pulse interval between P3 and P4 shall be 2 plus or minus 0.04 microsecond.

iv) Pulse amplitudes. Relative amplitudes between pulses P1, P2 and P3 shall be in accordance with 23.4.3.1.1.5. The amplitude of P4 shall be within 1 dB of the amplitude of P3.

(v) Sidelobe suppression. The pulse interval between P1 and P2 shall be 2 plus or minus 0.04 microsecond. Amplitude of P2 shall be in accordance with 23.4.3.1.1.5.

Note 1. — Side-lobe suppression is required for SSR interrogators per 2.1.2.4.1. ACAS and multilateration system interrogations may or may not include the P2 pulse.

Note 2.— When used, P2 is additionally radiated to prevent replies from aircraft in the side and back lobes of the antenna.

(vi) Mode S interrogation

Note 1.The Mode S interrogation consists of a minimum three pulses: P1, P2 and P6 as shown in Figure 3-4.

Note 2.— P6 is preceded by a P1 – P2 pair which suppresses replies from Mode A/C transponders to avoid synchronous garble due to random triggering by the Mode S interrogation. The sync phase reversal within P6 is the timing mark for demodulation of a series of time intervals (chips) of 0.25 microsecond duration. This series of chips starts 0.5 microsecond after the sync phase reversal and ends 0.5 microsecond before the trailing edge of P6. A phase reversal may or may not precede each chip to encode its

binary information value.

Figure 3-3. Intermode interrogation pulse sequence

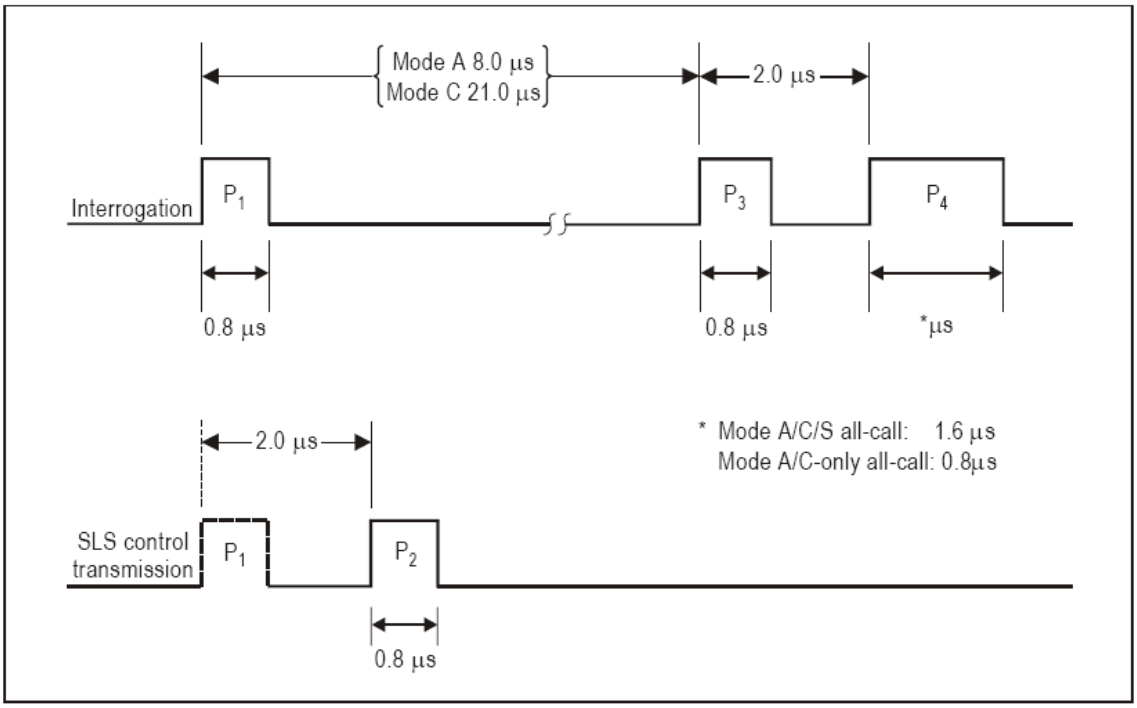
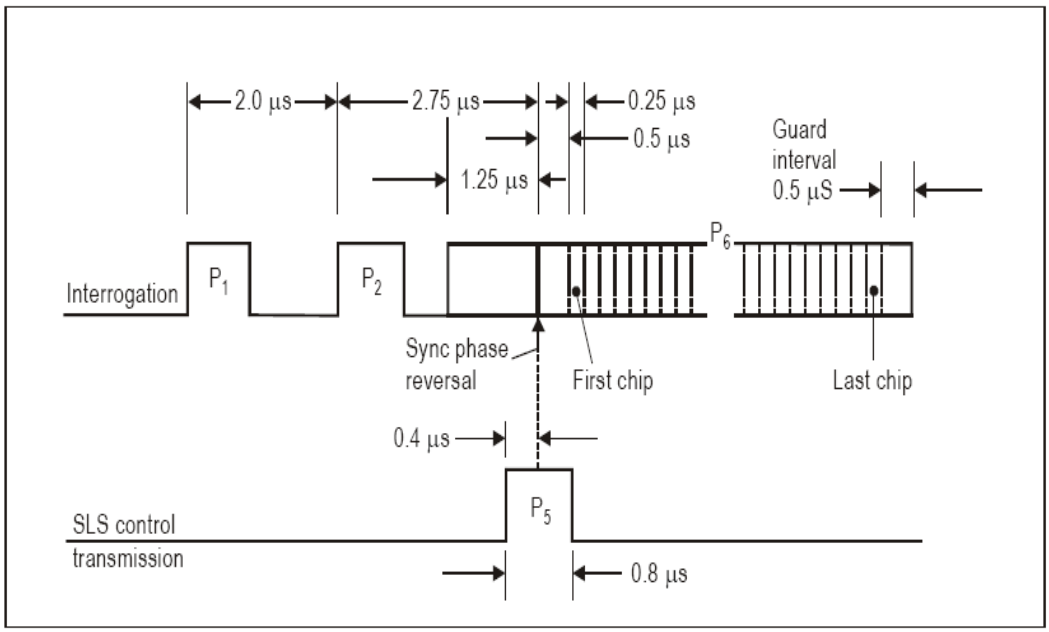


Figure 3-4. Mode S interrogation pulse sequence



(vii) Mode S side-lobe suppression. The P5 pulse shall be used with the Mode S-only all-call interrogation (UF = 11, see 23.4.3.1.2.5(2) to prevent replies from aircraft in the side and back lobes of the antenna (23.4.3.1.2.5(2)). When used, P5 shall be transmitted using a separate antenna pattern.

Note 1.— The action of P5 *is automatic. Its presence, if of sufficient amplitude at the receiving location, masks the sync phase reversal of* P6*.*

Note 2.— The P5 *pulse may be used with other Mode S interrogations.*

(viii) Sync phase reversal. The first phase reversal in the P6 pulse shall be the sync phase reversal. It shall be the timing reference for subsequent transponder operations related to the interrogation.

(ix) Data phase reversals. Each data phase reversal shall occur only at a time interval (N times 0.25) plus or minus 0.02 microsecond (N equal to, or greater than 2) after the sync phase reversal. The16.25-microsecond P6 pulse shall contain at most 56 data phase reversals. The 30.25-microsecond P6 pulse shall

contain at most 112 data phase reversals. The last chip, that is the 0.25microsecond time interval following the last data phase reversal position, shall be followed by a 0.5microsecond guard interval.

Note. — The 0.5-microsecond guard interval following the last chip prevents the trailing edge of P6 from interfering with the demodulation process.

(x) Intervals. The pulse interval between P1 and P2 shall be 2 plus or minus 0.04 microsecond. The interval between the leading edge of P2 and the sync phase reversal of P6 shall be 2.75 plus or minus 0.04 microsecond. The leading edge of P6 shall occur 1.25 plus or minus 0.04 microsecond before the sync phase reversal. P5, if transmitted, shall be centred over the sync phase reversal; the leading edge of P5 shall occur 0.4 plus or minus 0.04 microsecond before the sync phase reversal.

(xi) Pulse amplitudes**.** The amplitude of P2 and the amplitude of the first microsecond of P6 shall be greater than the amplitude of P1 minus 0.25 dB. Exclusive of the amplitude transients associated with phase reversals, the amplitude variation of P6 shall be less than 1 dB and the amplitude variation between successive chips in P6 shall be less than 0.25 dB. The radiated amplitude of P5 at the antenna of the transponder shall be:

(A) equal to or greater than the radiated amplitude of P6 from the side-lobe transmissions of the antenna radiating P6; and

(B) at a level lower than 9 dB below the radiated amplitude of P6 within the desired arc of interrogation.

23.4.3.1.2.2 REPLY SIGNALS-IN-SPACE CHARACTERISTICS

Note. — The paragraphs herein describe the signals-in-space at the antenna(s) of the transponder.

(1) Reply carrier frequency. Standard pulse position modulation (PPM) reply carrier frequency. The carrier frequency of all standard Mode S PPM replies (downlink transmissions) shall be 1 090 plus or minus 1 MHz.

(2) Phase overlay reply frequency. The carrier frequency of all phase overlay reply transmissions as defined in 23.4.3.1.2.3.1(1)(b) shall be 1 090 MHz plus or minus 25 KHz.

(3) Reply spectrum. The spectrum of a Mode S reply about the carrier frequency shall not exceed the limits specified in Figure 3-5.

(4) Polarization**.** Polarization of the reply transmissions shall be nominally vertical.

(5) Modulation. The Mode S reply shall consist of a preamble and a data block. The preamble shall be a 4pulse sequence, and the data block shall be binary pulse-position modulated at a 1 megabit per second data rate.

(6) Pulse shapes**.** Pulse shapes shall be as defined in Table 3-2. All values are in microseconds.

(7) Mode S reply**.** The Mode S reply shall be as shown in Figure 3-6. The data block in Mode S replies shall consist of either 56 or 112 information bits.

(a) Pulse intervals. All reply pulses shall start at a defined multiple of 0.5 microsecond from the first transmitted pulse. The tolerance in all cases shall be plus or minus 0.05 microsecond.

(i) Reply preamble. The preamble shall consist of four pulses, each with a duration of 0.5 microsecond. The pulse intervals from the first transmitted pulse to the second, third and fourth transmitted pulses shall be 1, 3.5 and 4.5 microseconds, respectively.

(ii) Reply data pulses. The reply data block shall begin 8 microseconds after the leading edge of the first transmitted pulse. Either 56 or 112 one- microsecond bit intervals shall be assigned to each transmission. A 0.5-microsecond pulse shall be transmitted either in the first or in the second half of each interval. When a pulse transmitted in the second half of one interval is followed by another pulse transmitted in the first half of the next interval, the two pulses merge and a one-microsecond pulse shall be transmitted.

(8) Pulse amplitudes. The pulse amplitude variation between one pulse and

any other pulse in a Mode S reply shall not exceed 2 dB.

(9) Reply phase overlay characteristics. Reply phase overlay modulation type. The phase modulation reply transmission defined in 23.4.3.1.2.3.1(1)(b) shall use 8 phase-shift keying (PSK) phase states to transmit 3-bits associated with a single-phase state for each PPM data bit and in each of the four preamble pulses.

(a) Phase error tolerance. The phase error of transmitted phase information shall be within 3.0 degrees root-mean-square (RMS) and 12.2 degrees peak for the duration of any 0.5 microsecond PPM reply pulse, excluding the leading and trailing edges of the pulse. When a one-microsecond pulse is transmitted as a result of a PPM ZERO data bit in the second half of one PPM bit interval followed by a PPM ONE bit in the first half of the next interval, the phase error for the phase information for each of the 2-phase states shall be within 3.0 degrees RMS and 12.2 degrees peak, except during the phase transition interval when a phase change is required between the 2-phase states, and the leading and trailing edges of the one-microsecond pulse. The phase error tolerance is in addition to the average frequency tolerance specified in 23.4.3.1.2.2(1), including the phase drift tolerance specified in 23.4.3.1.2.2(9)(c).

Note. — During transmitter pulse turn-on and turn-off, the phase of the transmitted signal is typically not stable until the final RF output power is reached at the top portion of the pulse. The phase overlay reception algorithm does not rely on a constant phase during the transient portions of the pulse.

(b) Phase modulation during the phase transition interval. For a 1.0 microsecond pulse which is formed by a PPM ZERO data bit followed by a PPM ONE data bit, the phase transition interval in which the phase is allowed to change between states shall be less than the 400-nanosecond intervals commencing 22 200 nanoseconds prior to the PPM bit interval transition at the centre of the 1.0 microsecond pulse.

Note 1.— To meet the pulse-to-pulse amplitude variation requirement in 23.4.3.1.2.2(8), the RF peak output power of any merged PPM pulses will not vary more than 1 dB due to PO for a receiver bandwidth of 8 MHz when linearly applying phase overlay (PO) across the 400-nanosecond phase transition interval.

Note 2.— The worst case for spectral growth is when the phase overlay frequency shifts are 180 degrees between symbols in 1

microsecond wide PPM data pulses as shown in Figure 3-9. To meet the spectrum requirement in 23.4.3.1.2.2(3), one method of reducing spectral growth in this case is to ensure the 180-degree phase transition is linear.

(c) Phase drift. The peak phase drift due to transmitter frequency drift shall be within ±43 degrees for the entire message duration. The phase drift tolerance is in addition to the average frequency tolerance specified in 23.4.3.1.2.2(2).

(d) Reply spectrum. The reply spectrum defined in 23.4.3.1.2.2(3) shall be met when phase overlay transmissions are active.

23.4.3.1.2.3 MODE S DATA STRUCTURE

23.4.3.1.2.3.1 DATA ENCODING

Interrogation data. The interrogation data block shall consist of the sequence of 56 or 112 data chips positioned after the data phase reversals within P6 (23.4.3.1.2.1(1)(e)(ix). A 180-degree carrier phase reversal preceding a chip shall characterize that chip as a binary ONE. The absence of a preceding phase reversal shall denote a binary ZERO.

(1) Reply data

(a) Standard PPM data. The reply data block shall consist of 56 or112 data bits formed by binary pulse position modulation encoding of the reply data as described in 23.4.3.1.2.2(7)(a)(ii). A pulse transmitted in the first half of the interval shall represent a binary ONE whereas a pulse transmitted in the second half shall represent a binary ZERO.

(b) Phase overlay modulated data. For phase overlay modulated signals, the PPM reply data shall additionally contain 8PSK modulated data within the bit interval containing the pulse, either the first half or the second half of the interval as per 23.4.3.1.2.3.1(1)(a).

(i) Phase overlay data definition. In addition to the binary ONE or binary ZERO represented by PPM, each data interval shall consist of three additional bit values representing the phase modulated reply data

as determined by the encoded phase of the pulse in the bit interval as shown in Table 3-7.

(ii) Sync phase reference pulses. The reference sync phase shall be encoded in the four preamble pulses and the data pulses of the first four PPM data bits by maintaining constant phase for these pulses.

(iii) Phase reference. The reference phase shall represent zero degrees. This reference established by the data pulses in 23.4.3.1.2.3.1(1)(b)(ii) is used to establish the phase for subsequent phase state determination.

(c) Bit numbering. The bits shall be numbered in the order of their transmission, beginning with bit 1. Unless otherwise stated, numerical values encoded by groups (fields) of bits shall be encoded using positive binary notation and the first bit transmitted shall be the most significant bit (MSB). Information shall be coded in fields which consist of at least one bit.

Note. — In the description of Mode S formats the decimal equivalent of the binary code formed by the bit sequence within a field is used as the designator of the field function or command.

23.4.3.1.2.3.2 FORMATS OF MODE S INTERROGATIONS AND REPLIES

Note. — A summary of all Mode S interrogation and reply formats is presented in Figures 3-7 and 3-8. A summary of all fields appearing in uplink and downlink formats is given in Table 3-3 and a summary of all subfields is given in Table 3-4.

(1) Essential fields. Every Mode S transmission shall contain two essential fields. One is a descriptor which shall uniquely define the format of the transmission. This shall appear at the beginning of the transmission for all formats. The descriptors are designated by the UF (uplink format) or DF (downlink format) fields. The second essential field shall be a 24-bit field appearing at the end of each transmission and shall contain parity information. In all uplink and in currently defined downlink formats parity information shall be overlaid either on the aircraft address (23.4.3.1.2.4.1.2.1(4)) or on the interrogator identifier according to

23.4.3.1.2.3.3(2). The designators are AP (address/parity) or PI (parity/interrogator identifier).

Note. — The remaining coding space is used to transmit the mission fields. For specific functions, a specific set of mission fields is prescribed. Mode S mission fields have two-letter designators. Subfields may appear within mission fields. Mode S subfields are labelled with three-letter designators.

(a) UF: Uplink format. This uplink format field (5 bits long except in format 24 where it is 2 bits long) shall serve as the uplink format descriptor in all Mode S interrogations and shall be coded according to Figure 3-7.

(b) DF: Downlink format. This downlink format field (5 bits long except in format 24 where it is 2 bits long) shall serve as the downlink format descriptor in all Mode S replies and shall be coded according to Figure 3-8.

(c) AP: Address/parity. This 24-bit (33-56 or 89-112) field shall appear in all uplink and currently defined downlink formats except the Mode S-only all-call reply, DF = 11. The field shall contain parity overlaid on the aircraft address according to 23.4.3.1.2.3.3(2).

(d) PI: Parity/interrogator identifier. 24-bit (33-56) or (89-112) downlink field shall have parity overlaid on the interrogator's identity code according to 23.4.3.1.2.3.3(2) and shall appear in the Mode S all-call reply, DF = 11 and in the extended squitter, DF = 17 or DF = 18. If the reply is made in response to a Mode S-only all-call with CL field 3. (23.4.3.1.2.5(2)(a)(iii)) and IC field (23.4.3.1.2.5(2)(a)(ii)) equal to 0 or is an acquisition or an extended squitter (23.4.3.1.2.8(5), 23.4.3.1.2.8.6 or 23.4.3.1.2.8.7), the II and the SI codes shall be 0.

(e) *DP: Data parity.* This 24-bit (89-112) downlink field shall contain the parity overlaid on a "Modified AA" field which is established by performing a modulo-2 summation (e.g. Exclusive-Or function) of the discrete address most significant 8 bits and BDS1, BDS2, where BDS1 (23.4.3.1.2.6.11(2)(b))and BDS2 (23.4.3.1.2.6.11(2)(iii)) are provided by the "RR" (23.4.3.1.2.6.1(2)) and "RRS" ((23.4.3.1.2.6.1(4)(a)) as specified in 23.4.3.1.2.6.11(2)(b) and 23.4.3.1.2.6.11(2)(c)

Example:

Discrete address = AA AA AA Hex = 1010 1010 1010 1010 1010 1010

BDS1, BDS2 = 5F 00 00 Hex = 0101 1111 0000 0000 0000 0000

Discrete address ⊕ BDS1, BDS2 Hex = 1111 0101 1010 1010 1010 1010

"Modified AA" = F5 AA AA Hex = 1111 0101 1010 1010 1010 1010

where "⊕" prescribes modulo-2 addition

The resulting "Modified AA" field then represents the 24-bit sequence (a1, a2...a24) that shall be used to generate the DP field in accordance with paragraph 23.4.3.1.2.3.2(4).

The DP field shall be used in DF=20 and DF=21 replies if the transponder is capable of supporting the DP field and if the overlay control (OVC - 23.4.3.1.2.6.1(4)(a)(ix)) bit is set to one (1) in the interrogation requesting downlink of GICB registers.

(2) Unassigned coding space**.** Unassigned coding space shall contain all ZEROs as transmitted by interrogators and transponders.

Note. — Certain coding space indicated as unassigned in this section is reserved for other applications such as ACAS, data link, etc.

(3) Zero and unassigned codes. A zero-code assignment in all defined fields shall indicate that no action is required by the field. In addition, codes not assigned within the fields shall indicate that no action is required

Note. — The provisions of 23.4.3.1.2.3.2(2) and 23.4.3.1.2.3.2(3) ensure that future assignments of previously unassigned coding space will not result in ambiguity. That is, Mode S equipment in which the new coding has not been implemented will clearly indicate that no information is being transmitted in newly assigned coding space.

(4) Formats reserved for military use. States shall ensure that uplink formats are only used for selectively addressed interrogations and that transmissions of uplink or downlink formats do not exceed the RF power, interrogation rate, reply rate and squitter rate requirements of Part 23.

(a) Through investigation and validation, States shall ensure that military applications do not unduly affect the existing 1 030/1 090 MHz civil aviation operations environment.

(5) Phase overlay reply data formats. An overview of the transmitted phase overlay data message structure is shown in Figure 3-10.

(a) Phase overlay message data. Phase data (PD) message bits shall be contained in bits 1 through 204 of the 324-bit phase data message. If phase overlay is not enabled for the reply or extended squitter, the message data field shall be zero filled.

(b) Phase overlay message type field. Phase overlay bits 1 through 8 of the 324-bit phase data message shall contain the message type defining the PO message as shown in Table 3-12.

Note. — The data format of the ADS-B State and Status Message, phase overlay Mode S GICB Data Messages and phase overlay Interrogation/Reply Monitor Messages ADS-R, ADS-SLR and TIS-B are described in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

(c) Phase overlay parity correction data. Phase overlay bits 205 through 324 of the phase data message shall contain the 120-bit forward error correction (FEC) data encoded in accordance with either 23.4.3.1.2.3.2(5)(c)(i) or 23.4.3.1.2.3.2(5)(c)(ii), as specified by the Message Type value in Table 3-12.

(i) Reed-Solomon. When transmitting phase overlay message types 1-6 (RS Message Type Block), the transmitted phase overlay shall use a Reed Solomon RS (54, 34) code with 6-bit symbols where two adjacent phase states (two adjacent PPM pulse data bits) are used as one 6-bit symbol (3 phase bits per 1 PPM bit). The RS (54, 34) code is shortened from a 63 symbol (2N-1) code. The first nine 6-bit symbols of the 63-symbol code that is used for the RS (54, 34) code shall have all bits set to zero. The Reed -Solomon shall use a generator polynomial start value of 1 to compute the parity error correction value. The Reed Solomon shall use a field polynomial of $x^6 + x + 1$.

Note. — Example of Reed-Solomon encodings are shown in Doc 9924.

(ii) Low Density Parity Code (LDPC). When transmitting phase overlay message types 7-12 (LDPC Message Type Block), the transmitted phase overlay parity data shall be established by a cyclic LDPC (54, 34) code

with 6 blocks of binary data as shown in Table 3-13, with each block of 54 bits input to the LDPC parity check matrix independently, and after encoding the parity of each block, the message and parity bits are assembled back in order. The LDPC encoder shall use a field polynomial of $x^{20} + x^{18} + x^{11} + x^{9} + x^{2} + 1$.

Note. — The parity check matrix is presented in Doc 9924.

23.4.3.1.2.3.3 ERROR PROTECTION

(1) Technique. Parity check coding shall be used within Mode S interrogations and replies to provide protection against the occurrence of errors.

(a) Parity check sequence**.** A sequence of 24 parity check bits shall be generated by the rule described in 23.4.3.1.2.3.3(1)(b) and shall be incorporated into the field formed by the last 24 bits of all Mode S transmissions. The 24 parity check bits shall be combined with either the address coding or the interrogator identifier coding as described in23.4.3.1.2.3.3(2). The resulting combination then forms either the AP (address/parity, 23.4.3.1.2.3.2(1)(c) field or the PI (parity/interrogator identifier, 23.4.3.1.2.3.2(1)(d) field.

(b) Parity check sequence generation. The sequence of 24 parity bits (p1, p2,..., p24) shall be generated from the sequence of information bits (m1, m2,..., mk) where k is 32 or 88 for short or long transmissions respectively. This shall be done by means of a code generated by the polynomial:

$$G(x) = 1 + x^{3} + x^{10} + x^{12} + x^{13} + x^{14} + x^{15} + x^{16} + x^{17} + x^{18} + x^{19} + x20 + x21 + x22 + x23 + x24$$

When by the application of binary polynomial algebra, x^{24} [M(x)] is divided by G(x) where the information sequence M(x) is:

$$mk + mk\text{-}1x + mk\text{-}2x2 + \ldots + m1xk\text{-}1$$

the result is a quotient and a remainder R(x) of degree less than 24. The bit sequence formed by this remainder

represents the parity check sequence. Parity bit pi, for any i from 1 to 24, is the coefficient of x24-i in R(x).

Note. — The effect of multiplying M(x) by x24 is to append 24 ZERO bits to the end of the sequence.

(2) AP and PI field generation. Different address parity sequences shall be used for the uplink and downlink.

Note. — The uplink sequence is appropriate for a transponder decoder implementation. The downlink sequence facilitates the use of error correction in downlink decoding.

(a) The code used in uplink AP field generation shall be formed as specified below from either the aircraft address (23.4.3.1.2.4.1.2.1(5)), the all-call address (23.4.3.1.2.4.1.2.1(6)) or the broadcast address 23.4.3.1.2.4.1.2.1(7)).

(b) The code used in downlink AP field generation shall be formed directly from the sequence of 24 Mode S address bits (a1, a2,..., a24), where ai is the i-th bit transmitted in the aircraft address (AA) field of an all-call reply (23.4.3.1.2.5(2)(b)(ii) .

(c) The code used in downlink PI field generation shall be formed by a sequence of 24 bits (a1, a2,..., a24), where the first 17 bits are ZEROs, the next three bits are a replica of the code label (CL) field (23.4.3.1.2.5(2)(a)(iii)) and the last four bits are a replica of the interrogator code (IC) field (23.4.3.1.2.5(2)(a)(ii)).

Note. — The PI code is not used in uplink transmissions.

(d) A modified sequence (b1, b2,..., b24) shall be used for uplink AP field generation. Bit bi is the coefficient of x48-i in the polynomial G(x)A(x), where:

A(x) = a1x23 + a2x22 +... + a24 and G(x) is as defined in (23.4.3.1.2.3.3(1)(b)

(e) In the aircraft address ai shall be the i-th bit transmitted in the AA field of an all-call reply. In the all-call and broadcast addresses ai shall equal 1 for all values of i.

(f) Uplink transmission order. The sequence of bits transmitted in

the uplink AP field is:

tk + 1, tk + 2... tk + 24

where the bits are numbered in order of transmission, starting with k + 1.
In uplink transmissions:
tk + i = bi ⊕ pi

where "⊕" prescribes modulo-2 addition: i equals 1 is the first bit transmitted in the AP field.

(g) Downlink transmission order. The sequence of bits transmitted in the downlink AP and PI field is: tk + 1, tk + 2... tk + 24 where the bits are numbered in order of transmission, starting with k + 1. In downlink transmissions: tk + i = ai ⊕ pi where "⊕" prescribes modulo-2 addition: i equals 1 is the first bit transmitted in the AP or PI field.

23.4.3.1.2.4 GENERAL INTERROGATION-REPLY PROTOCOL

23.4.3.1.2.4.1 TRANSPONDER TRANSACTION CYCLE.

(1) A transponder transaction cycle shall begin when the SSR Mode S transponder has recognized an interrogation. The transponder shall then evaluate the interrogation and determine whether it shall be accepted. If accepted, it shall then process the received interrogation and generate a reply, if appropriate. The transaction cycle shall end when:

(a) any one of the necessary conditions for acceptance has not been met, or

(b) an interrogation has been accepted and the transponder has either:

(i) completed the processing of the accepted interrogation if no reply is required, or

(ii) completed the transmission of a reply. A new transponder transaction cycle shall not begin until the previous cycle has ended.

(2) A new transponder transaction cycle shall not begin until the previous cycle has ended.

(3) Interrogation recognition. SSR Mode S transponders shall be capable of recognizing the following distinct types of interrogations:

(a) Modes A and C;

(b) intermode; and

(c) Mode S.

Note. — The recognition process is dependent upon the signal input level and the specified dynamic range (23.4.3.1.2.10(1)).

(d) Mode A and Mode C interrogation recognition. A Mode A or Mode C interrogation shall be recognized when a P1 - P3 pulse pair meeting the requirements of 23.4.3.1.1.4(1) has been received, and the leading edge of a P4 pulse with an amplitude that is greater than a level 6 dB below the amplitude of P3 is not received within the interval from 1.3 to 2.7 microseconds following the leading edge of P3.

(e) Intermode interrogation recognition.

(i) A Mode A/C-only all-call interrogation shall be recognized when with a P4 pulse being of any duration greater than 0.7 microsecond and occurring 2 ± 0.1 microsecond from P3.

(ii) A Mode A/C-only all-call interrogation shall be recognized if the received power of P4 is above P3 minus 1 dB at any signal level of P1 – P3 from MTL+1 dB to –21 dBm.

(iii) An interrogation shall not be recognized as an intermode interrogation if:

(A) the received amplitude of the pulse in the P4 position is smaller than 6 dB below the amplitude of P3; or

(B) the pulse interval between P3 and P4 is larger than 2.7 microseconds or shorter than 1.3 microseconds; or

(C) the received amplitude of P1 and P3 is

between MTL and -45 dBm and the pulse duration of P1 or P3 is less than 0.3 microsecond; or

(D) the transponder is in suppression (23.4.3.1.2.4.2) ; or

(E) the pulse interval between P1 and P3 differs from the nominal spacing by 1.0 microsecond or more; or

(F) the pulse duration of P4 is less than 0.3 microsecond.

(f) Mode S interrogation recognition. A Mode S interrogation shall be recognized when a P6 pulse is received with a sync phase reversal within the interval from 1.20 to 1.30 microseconds following the leading edge of P6. A Mode S interrogation shall not be recognized if a sync phase reversal is not received within the interval from 1.05 to 1.45 microseconds following the leading edge of P6.

23.4.3.1.2.4.1.2 INTERMODE INTERROGATION ACCEPTANCE.

23.4.3.1.2.4.1.2.1 Recognition according to 23.4.3.1.2.4.1 shall be a prerequisite for acceptance of any interrogation.

(1) Mode A and Mode C interrogation acceptance. Mode A and Mode C interrogations shall be accepted when recognized (23.4.3.1.2.4.1(3)(d)).

(2) Inter mode interrogation acceptance

(a) Mode A/C/S all-call interrogation acceptance. A ~~Mode A/C/S all-call interrogation shall be accepted if the trailing edge of P4 is received within 3.45 to 3.75 microseconds following the leading edge of P3 and no lockout condition (23.4.3.1.2.6.9) prevents acceptance. A Mode A/C/S all-call shall not be accepted if the trailing edge of P4 is received earlier than 3.3 or later than 4.2 microseconds following the leading edge of P3, or if a lockout condition (23.4.3.1.2.6.9)~~

~~prevents acceptance.~~

Note. — Mode A/C/S all-call interrogations are no longer useable. If a transponder receives a Mode A/C/S all-call interrogation, it will be recognized as a Mode A/C-only all-call interrogation.

(b) Mode A/C-only all-call interrogation acceptance. A Mode A/C- only all-call interrogation shall not be accepted by a Mode S transponder.

(3) Mode S interrogation acceptance. A Mode S interrogation shall only be accepted if:

(a) the transponder is capable of processing the uplink format (UF) of the interrogation (23.4.3.1.2.3.2(1)(a));

(b) the address of the interrogation matches one of the addresses as defined in 23.4.3.1.2.4.1.2.1(4) implying that parity is established, as defined in 23.4.3.1.2.3.3;

(c) in the case of an all-call interrogation, no all-call lockout condition applies, as defined in 23.4.3.1.2.6.9; and

(d) the transponder is capable of processing the up linked data and presenting it at an output interface as prescribed in 23.4.3.1.2.10.5(2)(b)(i).

Note. — A Mode S interrogation may be accepted if the conditions specified in 23.4.3.1.2.4.1.2.1(3)(a) and (b) are met and the transponder is not capable of both processing the uplinked data of a Comm-A interrogation (UF=20 and 21) and presenting it at an output interface as prescribed in 23.4.3.1.2.10.5(2)(b)(i)..

(4) Addresses. Mode S interrogations shall contain either:

(a) aircraft address; or

(b) the all-call address; or

(c) the broadcast address.

(5) Aircraft address. If the aircraft's address is identical to the address extracted from a received interrogation according to the procedure of

23.4.3.1.2.3(3)(d) and 23.4.3.1.2.3(3)(e), the extracted address shall be considered correct for purposes of Mode S interrogation acceptance.

(6) All-call address. A Mode S-only all-call interrogation (uplink format UF = 11) shall contain an address, designated the all-call address, consisting of twenty-four consecutive ONEs. If the all-call address is extracted from a received interrogation with format UF = 11 according to the procedure of 23.4.3.1.2.3.3(4) and 23.4.3.1.2.3.3(5), the address shall be considered correct for Mode S-only all-call interrogation acceptance.

(7) Broadcast address. To broadcast a message to all Mode S transponders within the interrogator beam, a Mode S interrogation uplink format 20 or 21 shall be used and an address of twenty-four consecutive ONEs shall be substituted for the aircraft address. If the UF code is 20 or 21 and this broadcast address is extracted from a received interrogation according to the procedure of 23.4.3.1.2.3.3(4) and 23.4.3.1.2.3.3(5), the address shall be considered correct for Mode S broadcast interrogation acceptance.

Note. — Transponders associated with airborne collision avoidance systems also accept a broadcast with UF = 16.

23.4.3.1.2.4.1.3 TRANSPONDER REPLIES

(1) Mode S transponders shall transmit the following reply types:

(a) Mode A and Mode C replies; and

(b) Mode S replies.

(2) Replies to intermode interrogations

Note 1.—A Mode S reply with downlink format 11 is transmitted in accordance with the provisions of 23.4.3.1.2.5(2)(b) when a Mode A/C/S all-call interrogation has been accepted. by a transponder certified before 1 January 2020

Note 2. — Since Mode S transponders do not accept Mode A/C-only all-call interrogations, no reply is generated.

(3) Replies to Mode S interrogations. The information content of a Mode S reply shall reflect the conditions existing in the transponder after completion of all processing of the interrogation eliciting that reply.

The correspondence between uplink and downlink formats shall be as summarized in Table 3-5.

Note. — Four categories of Mode S replies may be transmitted in response to Mode S interrogations:

(a) *Mode S all-call replies (DF = 11);*

(b) *surveillance and standard-length communications replies (DF = 4, 5, 20 and 21);*

(c) *extended length communications replies (DF = 24); and*

(d) *air-air surveillance replies (DF = 0 and 16).*

(4) Replies to SSR Mode S-only all-call interrogations. The downlink format of the reply to a Mode S-only all-call interrogation (if required) shall be DF = 11. The reply content and rules for determining the requirement to reply shall be as defined in 23.4.3.1.2.5.

Note. — A Mode S reply may or may not be transmitted when a Mode S interrogation with UF = 11 has been accepted.

(5) Replies to surveillance and standard length communications interrogations. A Mode S reply shall be transmitted when a Mode S interrogation with UF = 4, 5, 20 or 21 and an aircraft address has been accepted. The contents of these interrogations and replies shall be as defined in 23.4.3.1.2.6.

Note. — If a Mode S interrogation with UF = 20 or 21 and a broadcast address is accepted, no reply is transmitted (23.4.3.1.2.4.1.2.1(7)).

(6) Replies to extended length communications interrogations. A series of Mode S replies ranging in number from 0 to 16 shall be transmitted when a Mode S interrogation with UF = 24 has been accepted. The downlink format of the reply (if any) shall be DF = 24. Protocols defining the number and content of the replies shall be as defined in 23.4.3.1.2.7.

(7) Replies to air-air surveillance interrogations. A Mode S reply shall be transmitted when a Mode S interrogation with UF = 0 and an aircraft address has been accepted. The contents of these interrogations and replies shall be as defined in 23.4. 3.1.2.8

23.4.3.1.2.4.2 SUPPRESSION

(1) Effects of suppression. A Mode S-capable transponder in suppression (23.4.3.1.1.7(4)) shall not recognize Mode A, Mode C or Inter mode interrogations if either the P1 pulse alone or both the P1 and P3 pulses of the interrogation are received during the suppression interval. Suppression shall not affect the recognition of, acceptance of, or replies to Mode S interrogations.

(2) Suppression pairs. The two-pulse Mode A/C suppression pair defined in 23.4.3.1.1.7(4)(a) shall initiate suppression in a Mode S transponder regardless of the position of the pulse pair in a group of pulses, provided the transponder is not already suppressed or in a transaction cycle.

Note. — The transponder may optionally initiate suppression from a P3 – P4 pulse pair of a Mode A/C only all-call interrogation according to the criteria of recognition of an intermode interrogation in 23.4.3.1.2.4.1(3)(e). If the P3 – P4 pair of the Mode A/C-only all-call interrogation is processed as a suppression, the pulse pair both prevents a reply and initiates suppression. Likewise, the P1 – P2 preamble of a Mode S interrogation initiates suppression independently of the waveform that follows it.

23.4.3.1.2.4.3 DECLARATION OF AIRCRAFT STATUS

Note. — Certain fields in downlink format (DF) 4, 5, 11, 17, 20 and 21 messages are based on whether the aircraft is determined, by the transponder, to be on-the-ground or airborne. Transponders determine and express whether the aircraft is on-the-ground or airborne using multiple approaches. Level 2 and above transponders report a declared air/ground status via the capability (CA) field (see 23.4.3.1.2.5(2)(b)(i). All transponders report an effective air/ground state via the vertical status (VS) field (see 23.4.3.1.2.8(2)(a)). The effective air/ground state is also reflected in the flight status (FS) field (see 23.4.3.1.2.6.5(1)).

(1) Declared air/ground status determination. Declared air/ground status shall be restricted to “on-the-ground”, “airborne” or “unknown”.

(a) If an automatic means of determining the on-the-ground condition is available and indicates “on-the ground”, the

declared air/ground status shall be "on-the-ground".

(b) If an automatic means of determining the on-the-ground condition is available and does not indicate "on-the ground", the declared air/ground status shall be "airborne".

(c) If an automatic means of determining the on-the-ground condition is unavailable, the declared air/ground status shall be "unknown".

Note. — The declared air/ground status may be set by air/ground data input (see 23.4.3.1.2.10.5(1)(c)) provided by an automatic means of determining the on-the-ground condition. Automatic means of determining the on-the-ground condition may include, for example, a weight on wheels switch, a strut switch or an airframe-specific air/ground algorithm output.

(2) Declared air/ground status validation. Aircraft with an automatic means of determining the on-the-ground condition and whose transponders have access to at least one of ground speed, radio altitude or airspeed, shall perform the following validation check:

(a) If an automatic means of determining the on-the-ground condition is available and indicates "on-the-ground", the declared air/ground status shall be changed to "airborne" if:

Ground Speed > Speed Threshold OR Airspeed > Speed Threshold OR Radio Altitude > 50 feet

Where Speed Threshold is the lesser of 100 knots or the typical rotation speed of the aircraft (if available).

Note 1. — If an automatic means of determining the on-the-ground condition is not available or the declared air/ground status is "airborne", no validation check is required.

Note 2. — Modern aircraft with integrated avionics suites commonly contain sophisticated algorithms for determining the declared air/ground status based on multiple aircraft sensors. These algorithms are customized to the airframe and designed to overcome individual sensor failures. These algorithms are an acceptable means to determine the declared air/ground status and do not require the additional validation in this section.

(3) Effective air/ground state determination. Effective air/ground state shall be restricted to "on-the-ground" or "airborne".

(a) When the declared air/ground status is "airborne" or "unknown", the effective air/ground state shall be "airborne".

(b) When the declared air/ground status is "on-the-ground", the effective air/ground state 27 shall be "on-the ground".

23.4.3.1.2.5 INTERMODE AND MODE S ALL-CALL TRANSACTIONS

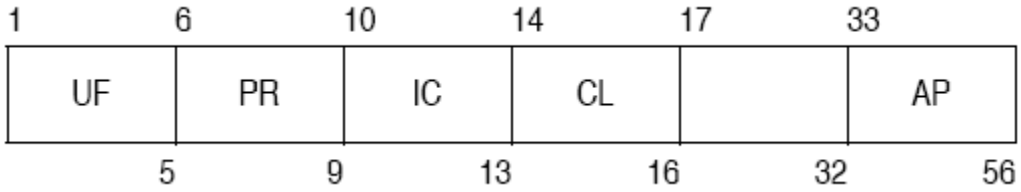
(1) INTERMODE TRANSACTIONS

Note. — The Mode A/C-only all-call interrogation makes it possible to elicit replies only from Mode A/C transponders. In multisite scenarios, the interrogator must transmit its identifier code in the Mode S only all-call interrogation. Thus, a pair of Mode S-only and Mode A/C-only all-call interrogations are used. The intermode interrogations are defined in 23.4.3.1.2.(1)(e)(i) and the corresponding interrogation-reply protocols are defined in 23.4.3.1.2.4.

(2) MODE S-ONLY ALL-CALL TRANSACTIONS

Note. — These transactions allow the ground to acquire Mode S aircraft by use of an interrogation addressed to all Mode S-equipped aircraft. The reply is via downlink format 11 which returns the aircraft address. The interrogation-reply protocols are defined in 23.4.3.1.2.4.

(a) Mode S-only all-call transactions, uplink format 11



The format of this interrogation shall consist of these fields:

Field	Reference
UF uplink format	23.4.3.1.2.3.2(1)(a)

PR probability of reply	23.4.3.1.2.5(2)(a)(i)
IC interrogator code	23.4.3.1.2.5(2)(a)(ii)
CL code label	23.4.3.1.2.5(2)(a)(iii)
spare -- 16 bits	
AP address/parity	23.4.3.1.2.3.2(1)(c)

(i) PR: Probability of reply. This 4-bit (6-9) uplink field shall contain commands to the transponder specifying the probability of reply to that interrogation (23.4.3.1.2.5(4)). Codes are as follows:

0 signifies reply with probability of 1
1 signifies reply with probability of 1/2
2 signifies reply with probability of 1/4
3 signifies reply with probability of 1/8
4 signifies reply with probability of 1/16
5, 6, 7 not assigned
8 signifies disregard lockout, reply with probability of 1
9 signifies disregard lockout, reply with probability of 1/2
10 signifies disregard lockout, reply with probability of 1/4
11 signifies disregard lockout, reply with probability of 1/8
12 signifies disregard lockout, reply with probability of 1/16
13, 14, 15 not assigned.

(ii) IC: Interrogator code. This 4-bit (10-13) uplink field shall contain either the 4-bit interrogator identifier code 23.4.3.1.2.5(2)(a)(ii)(C) or the lower 4 bits of the 6-bit surveillance identifier code 23.4.3.1.2.5(2)(a)(ii)(D) depending on the value of the CL field (23.4.3.1.2.5(2)(a)(iii)

(A) It is recommended that whenever possible an interrogator shall operate using a single interrogator code.

(B) The use of multiple interrogator codes by one interrogator. An interrogator may use more than one interrogator code and may use different interrogator codes in different interrogations. An interrogator shall only use multiple interrogator codes on a sector basis and shall not use more than two interrogator codes.

Note. — An explanation of RF interference issues, sector size and impact on data link transactions is presented in the Aeronautical Surveillance Manual *(Doc 9924).*

(C) II: Interrogator identifier. This 4-bit value shall define an interrogator identifier (II) code. These II codes shall be assigned to interrogators in the range from 0 to 15. ~~The II code value of 0 shall only be used for supplementary acquisition in conjunction with acquisition based on lockout override (~~23.4.3.1.2.5.2.1.4When multiple~~two~~ II codes are assigned to one interrogator only, one II code shall be used for full data link purposes. ~~Limited data link activity including single segment Comm-A, uplink and downlink broadcast protocols and GICB extraction may be performed by both II codes.~~

Note. — Limited data link activity including single segment Comm-A, uplink and downlink broadcast protocols and GICB extraction may be performed by both II codes.

(D) SI: Surveillance identifier. This 6-bit value shall define a surveillance identifier (SI) code. These SI codes shall be assigned to interrogators in the range from 1 to 63. The SI code value of 0 shall not be used. The SI codes shall be used with the multi site lockout protocols (23.4.3.1.2.6.9(1)). The SI codes shall not be used with the multi site communications protocols (23.4.3.1.2.6.11.3(2), 23.4.3.1.2.7(4) or 23.4.3.1.2.7.7).

(iii) **CL: Code label.** This 3-bit (14-16) uplink field shall define the contents of the IC field. *Coding* (in binary)

000 signifies that the IC field contains the II code

001 signifies that the IC field contains SI codes 1 to 15
010 signifies that the IC field contains SI codes 16 to 31
011 signifies that the IC field contains SI codes 32 to 47
100 signifies that the IC field contains SI codes 48 to 63

The other values of the CL field shall not be used.

(A) Surveillance identifier (SI) code capability report. Transponders which process the SI codes (23.4.3.1.2.5(2)(a)(ii)(D) shall report this capability by setting bit 35 to 1 in the surveillance identifier capability (SIC) subfield of the MB field of the data link capability report (23.4.3.1.2.6.10(2)(b)).

(iv) Operation based on lockout override

Note 1. — The Mode S-only all-call lockout override provides the basis for acquisition of Mode S aircraft for interrogators that have not been assigned a unique IC (II or SI code) for full Mode S operation (protected acquisition by ensuring that no other interrogator on the same IC can lock out the target in the same coverage area).

Note 2. — Lockout override is possible using any interrogator code.

(A) Maximum Mode S-only all-call interrogation rate. The maximum rate of Mode S-only all-call interrogations made by an interrogator using acquisition based on lockout override shall depend on the reply probability as follows:

(I) for a reply probability equal to 1.0:

the smaller of 3 interrogations per 3 dB beam dwell or 30 interrogations per second;

(II) for a reply probability equal to 0.5: the smaller of 5 interrogations per 3

dB beam dwell or 60 interrogations per second; and

(III) for a reply probability equal to 0.25 or less:

the smaller of 10 interrogations per 3 dB beam dwell or 125 interrogations per second.

Note. — These limits have been defined in order to minimize the RF pollution generated by such a method while keeping a minimum of replies to allow acquisition of aircraft within a beam dwell.

(B) *Passive acquisition without using all-call interrogations ~~sho~~shall~~uld~~ be used in the place of lockout override.*

Note. — The Aeronautical Surveillance Manual *(Doc 9924) provides guidance on different passive acquisition methods.*

(v) Supplementary acquisition

Note 1.— The acquisition technique defined in 23.4.3.1.2.5(2(a)(iv) provides rapid acquisition for most aircraft. Due to the probabilistic nature of acquiring aircraft with a reduced reply probability (3.1.2.5.2.1.4.1) , it may take many interrogations to acquire the last aircraft of a large set of aircraft in the same beam dwell and near the same range (termed a local garble zone). Acquisition performance is greatly improved for the acquisition of these aircraft through the use of limited selective lockout referred to here as supplementary acquisition . .

Note 2. — Supplementary acquisition consists of locking out acquired aircraft followed by acquisition by means of the Mode S-only all-call interrogation without lockout override . Only the

aircraft not yet acquired and not yet locked-out will reply resulting in an easier acquisition. Additional guidance material can be found in Doc 9924.

Note 3.- Supplementary acquisition used to augment operation based on lockout override (23.4.1.2.5(2)(a)(iv)) is possible using any assigned, supplementary acquisition uses II equals 0 (25.4.3.1.2.5(2)(a)(v)(III)).

(A) Lockout within a beam dwell.
When lockout is used to supplement the acquisition method described in 23.4.3.1.2.5(2)(a)(iv), all aircraft within the beam dwell of the aircraft being acquired shall be commanded to lock out not just those in the garble zone.

Note. — Lockout of all aircraft in the beam dwell will reduce the amount of all-call fruit replies generated to the II equals 0 all-call interrogations.

(B) Duration of lockout

(I) Interrogators performing supplementary acquisition using II equals 0 shall perform acquisition by transmitting a lockout command for no more than two consecutive scans to each of the aircraft already acquired in the beam dwell containing the garble zone and shall not repeat it before 48 seconds have elapsed.

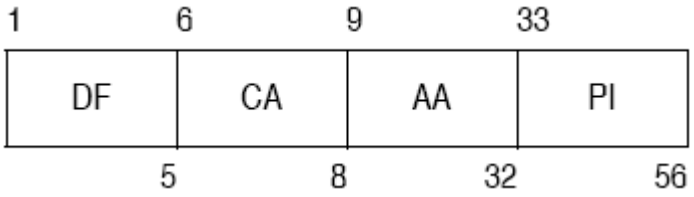
Note. — Minimizing the lockout time reduces the probability of conflict with the acquisition activities of a neighbouring interrogator that is using the same IC

(II) Mode S-only all-call interrogations for the purpose of supplementary acquisition shall ~~should~~ take place

~~place within a garble zone~~ over ~~no more than two consecutive scans or~~ a maximum of 18 seconds.

(III) Interrogator without assigned interrogator code (IC). An interrogator authorized to transmit that has not been assigned an IC and is unable to ensure that its lockout region will not overlap with the lockout region of another interrogator using the same IC, shall use II code 0 for supplementary acquisition.

(b) All-call reply, downlink format 11



The reply to the Mode S-only all-call or the Mode A/C/S all-call interrogation shall be the Mode S all-call reply, downlink format 11. The format of this reply shall consist of these fields:

Note. — Mode S all-call reply may be transmitted by transponders certified before 1 January 2020 in response to Mode A/C/S all-call interrogation (see 23.4.2.1.6(4)(d)

Field	Reference
DF downlink format	23.4.3.1.2.3.2(1)(b)
CA capability	23.4.3.1.2.5(2)(b)i)
AA address announced	23.4.3.1.2.5(2)(b)(ii)
PI parity/interrogator identifier	23.4.3.1.2.3.2(1)(d)

(i) CA: Capability. This 3-bit (6-8) downlink field shall convey information on the transponder level, the additional information below, and shall be used in formats DF = 11 and DF = 17.

Coding

0 signifies Level 1 transponder (surveillance only), and no ability to set CA code 7 and either airborne or on the ground

1 reserved

2 reserved

3 reserved

4 signifies Level 2 or above transponder and ability to set CA code 7 and a declared air/ground status of "on-the-ground" (see 23.4.3.1.2.8.6(7))

5 signifies Level 2 or above transponder and ability to set CA code 7 and a declared air/ground status of "airborne" (see 23.4.3.1.2.8.6(7))

6 signifies Level 2 or above transponder and ability to set CA code 7 and a declared air/ground status of "unknown" (see 23.4.3.1.2.8.6(7))~~either airborne~~ or on the ground

7 signifies the DR field is not equal to 0 or the FS field equals 2, 3, 4 or 5,

Note. — Refer to 23.4.2.1.6(2)(c) for the status of Level 1 transponders.

~~with automatic on-the-ground determination shall use CA code 4 when on the ground and 5 when airborne.~~ Data link capability reports (23.4.3.1.2.6.10.2(b)) shall be available from aircraft installations that set CA code 4, 5, 6 or 7.

Note. — CA codes 1 to 3 are reserved to maintain backward compatibility.

(ii) AA: Address announced. This 24-bit (9-32) downlink field shall contain the aircraft address which provides unambiguous identification of the aircraft.

(3) Lockout protocol. The all-call lockout protocol defined in 23.4.3.1.2.6.9 shall be used by the interrogator with respect to an aircraft once the address of that specific aircraft has been acquired by an interrogator provided that:

(a) the interrogator is using an IC code different from zero; and

(b) the aircraft is located in an area where the interrogator is authorized to use lockout.

Note 1. — Following acquisition, a transponder is interrogated by discretely addressed interrogations as prescribed in 23.4.3.1.2.6, 23.4.3.1.2.7 and 23.4.3.1.2.8 and the all-call lockout protocol is used to inhibit replies to further all-call interrogations.

Note 2. — Regional IC allocation bodies may define rules limiting the use of selective interrogation and lockout protocol (e.g. no lockout in defined limited area, use of intermittent lockout in defined areas, and no lockout of aircraft not yet equipped with SI code capability).

(4) Stochastic all-call protocol. The transponder shall execute a random process upon acceptance of a Mode S-only all-call with a PR code equal to 1 to 4 or 9 to 12. A decision to reply shall be made in accordance with the probability specified in the interrogation. A transponder shall not reply if a PR code equal to 5, 6, 7, 13, 14 or 15 is received (23.4.3.1.2.5(2)(a)(i)).

Note. — The random occurrence of replies makes it possible for the interrogator to acquire closely spaced aircraft, replies from which would otherwise synchronously garble each other.

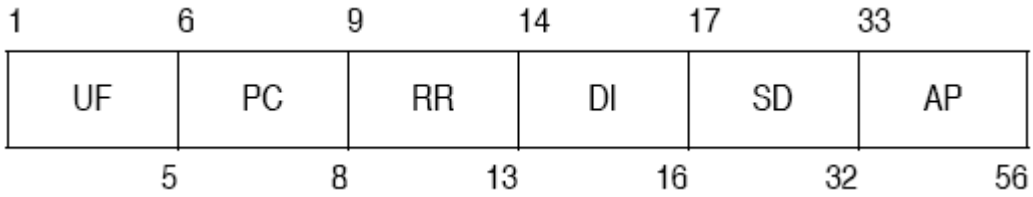
23.4.3.1.2.6 ADDRESSED SURVEILLANCE AND STANDARD-LENGTH COMMUNICATION TRANSACTIONS

Note 1. — The interrogations described in this Subpart are addressed to specific aircraft. There are two basic interrogation and reply types, short and long. The short interrogations and replies are UF 4 and 5 and DF 4 and 5, while the long interrogations and replies are UF 20

and 21 and DF 20 and 21.

Note 2. — The communications protocols are given in 23.4.3.1.2.6.11. These protocols describe the control of the data exchange.

23.4.3.1.2.6.1 SURVEILLANCE, ALTITUDE REQUEST, UPLINK FORMAT 4



The format of this interrogation shall consist of these fields:

Field	Reference
UF uplink format	23.4.3.1.2.3.2(1)(a)
PC protocol	23.4.3.1.2.6.1(1)
RR reply request	23.4.3.1.2.6.1(2)
DI designator identification	23.4.3.1.2.6.1(3)
SD special designator	23.4.3.1.2.6.1(4)
AP address/parity	23.4.3.1.2.3.2(1)(c)

(1) PC: Protocol. This 3-bit, (6-8) uplink field shall contain operating commands to the transponder. The PC field values 2 through 7 shall be ignored and the values 0 and 1 shall be processed for surveillance or Comm-A interrogations containing DI =3 (23.4.3.1.2.6.1(4)(a)).

Coding
0 signifies no action
1 signifies non-selective all-call lockout (23.4.3.1.2.6.9(2))
2 not assigned
3 not assigned
4 signifies close out Comm-B (23.4.3.1.2.6.11.3(2)(d))
5 signifies close out uplink ELM (23.43.1.2.7(4)(b)(xi))
6 signifies close out downlink ELM (23.4.3.1.2.7.7(3))
7 not assigned

(2) RR: Reply request. This 5-bit, (9-13) uplink field shall command the length and content of a requested reply. The last four bits of the 5- bit RR code, transformed into their decimal equivalent, shall designate the BDS1 code (23.4.3.1.2.6.11(2) or 23.4.3.1.2.6.11.3) of the requested Comm-B message if the most significant bit (MSB) of the

RR code is 1 (RR is equal to or greater than 16).

Coding

RR = 0-15 shall be used to request a reply with surveillance format (DF = 4 or 5);

RR = 16-31 shall be used to request a reply with Comm-B format (DF = 20 or 21);

RR = 16 shall be used to request transmission of an air-initiated Comm-B according to 23.4.3.1.2.6.11.3;

RR = 17 shall be used to request a data link capability report according to 23.4.3.1.2.6.10.2(b);

RR = 18 shall be used to request aircraft identification according to 23.4.3.1.2.9; 19-31 are not assigned in section 23.4.3.1

Note. — Codes 19-31 are reserved for applications such as data link communications, airborne collision avoidance systems (ACAS), etc.

(3) DI: Designator identification. This 3-bit (14-16) uplink field shall identify the structure of the SD field (23.4.3.1.2.6.1(4)).

Coding

0 signifies SD not assigned except for IIS, bits 21-27 and 29-32 are not assigned, and bit 28 contains the “OVC” (overlay control - 23.4.3.1.2.6.1.4.1(9))

1 signifies SD contains multisite and communications control information

2 signifies SD contains control data for extended squitter

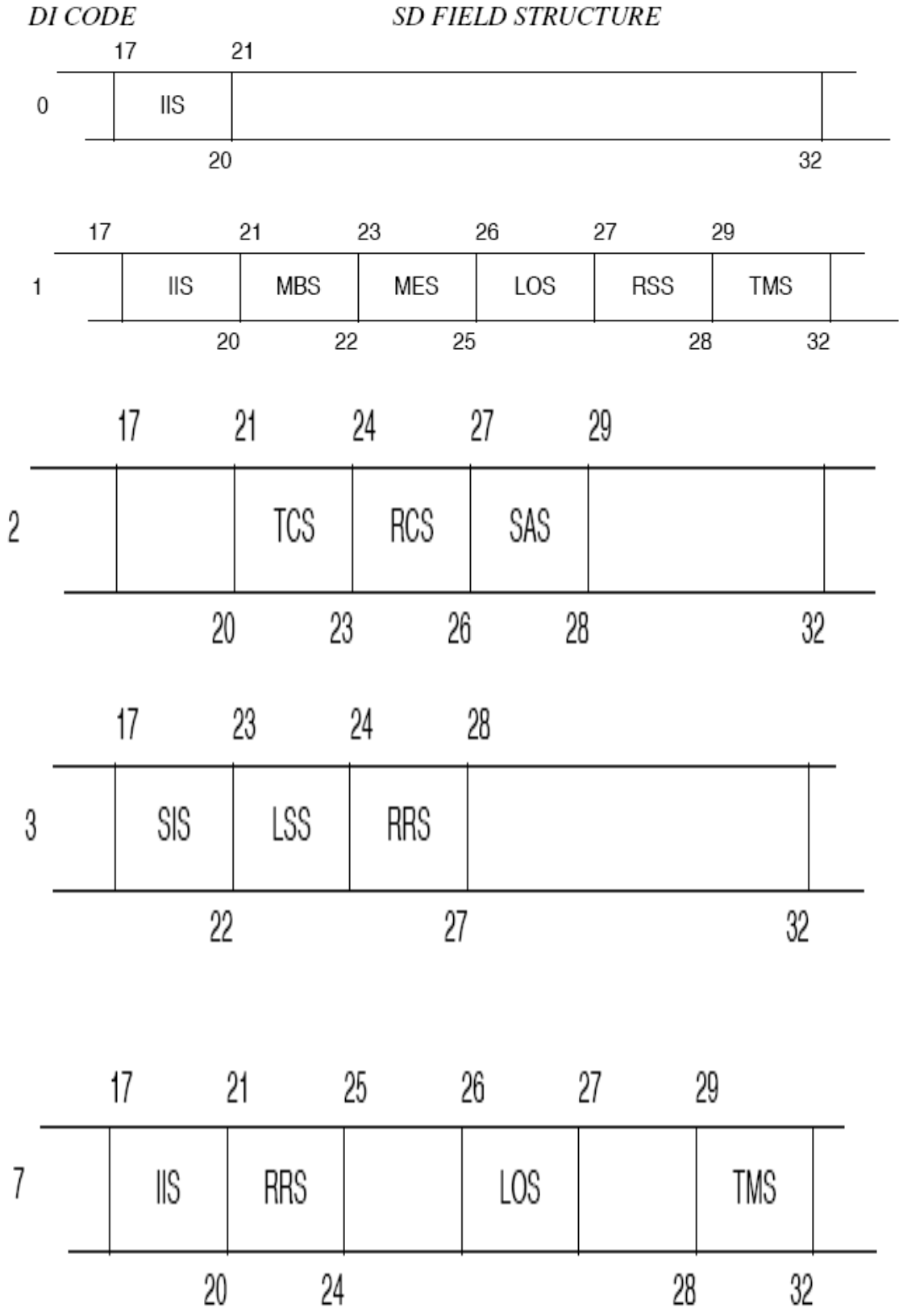
3 signifies SD contains SI multisite lockout, braodcast and GICB control information, and bit 28 contains the “OVC” (overlay control - 23.4.3.1.2.6.1.4.1(9))

4-6 signifies SD not assigned

7 signifies SD contains extended data readout request, multisite and communications control information, and bit 28 contains the “OVC” (overlay control - 23.4.3.1.2.6.1(4)(a)(ix))

(4) SD: Special designator. This 16-bit (17-32) uplink field shall contain control codes which depend on the coding in the DI field.

Note. — The special designator (SD) field is provided to accomplish the transfer of multisite, lockout and communications control information from the ground station to the transponder.


DI CODE
SD FIELD STRUCTURE
0
17
21
IIS
20
32
1
17
21
23
26
27
29
IIS
MBS
MES
LOS
RSS
TMS
20
22
25
28
32
2
17
21
24
27
29
TCS
RCS
SAS
20
23
26
28
32
3
17
23
24
28
SIS
LSS
RRS
22
27
32
7
17
21
25
26
27
29
IIS
RRS
LOS
TMS
20
24
28
32

(a) Subfields in SD. The SD field shall contain information as follows:

(i) If DI = 0, 1 or 7:

IIS, the 4-bit (17-20) interrogator identifier subfield shall contain an assigned identifier code of the interrogator (23.4.3.1.2.5(2)(a)(ii)(C)).

Note. — The IIS is intended to match the II code used by the interrogator in the Mode S-only all-call interrogation (23.4.3.1.2.5(2)(a)). Interrogators that do not use Mode S-only all-call interrogations, all-call lockout protocol or multisite data link protocol can use any IC in the IIS fields of their selective interrogations without coordination with neighbouring systems. The use of coordinated values differentiates interrogations transmitted by the different systems operating in the same area and facilitates the understanding of their respective contribution to the 1 090 MHz environment.

(ii) If DI = 0:
bits 21-32 are not assigned.

(iii) If DI = 1:
MBS, the 2-bit (21, 22) multisite Comm-B subfield shall have the following codes:

0 signifies no Comm-B action
1 signifies air-initiated Comm-B reservation request (23.4.3.1.2.6.11.3(1))
2 signifies Comm-B closeout (23.4.3.1.2.6.11.3(2)(d))
3 not assigned.

MES, the 3-bit (23-25) multi site ELM subfield shall contain reservation and closeout commands for ELM as follows:

0 signifies no ELM action
1 signifies uplink ELM reservation request (23.4.3.1.2.7.4(1))

2 signifies uplink ELM closeout (23.4.3.1.2.7(4)(b)(xi))
3 signifies downlink ELM reservation request (23.4.3.1.2.7.7(1)(a))
4 signifies downlink ELM closeout (23.4.3.1.2.7.7(3))
5 signifies uplink ELM reservation request and downlink ELM closeout
6 signifies uplink ELM closeout and downlink ELM reservation request
7 signifies uplink ELM and downlink ELM closeouts.

RSS, the 2-bit (27, 28) reservation status subfield shall request the transponder to report its reservation status in the UM field. The following codes have been assigned:

0 signifies no request
1 signifies report Comm-B reservation status in UM
2 signifies report uplink ELM reservation status in UM
3 signifies report downlink ELM reservation status in UM.

(iv) If DI = 1 or

LOS, the 1-bit (26) lockout subfield, if set to 1, shall signify a multisite lockout command from the interrogator indicated in IIS.

LOS set to 0, shall be used to signify that no change in lockout state is commanded.

TMS, the 4-bit (29-32) tactical message subfield shall contain communications control information used by the data link avionics.

(v) If DI = 7:

RRS, the 4-bit (21-24) reply request subfield in SD shall give the BDS2 code of a requested Comm-B reply.
Bits 25, 27 and 28 are not assigned.

(vi) If DI = 2:

SD is not assigned. The SD field when DI = 2 was previously used to control the

squitter format type and rate reported by the transponder through the deprecated type of control subfield (TCS), rate control subfield (RCS), and squitter antenna subfield (SAS) commands.

(vii) If DI = 3:

SIS, the 6-bit (17-22) surveillance identifier subfield in SD shall contain an assigned surveillance identifier code of the interrogator 23.4.3.1.2.5(2)(a)(ii)(D))

Note. — The SIS is intended to match the SI code used by the interrogator in the Mode S-only all-call interrogation (23.4.3.1.2.5(2)(a)). Interrogators that do not use Mode S-only all-call interrogations, all-call lockout protocol or multisite data link protocol can use any IC in the SIS fields of their selective interrogations without coordination with neighbouring systems. The use of coordinated values differentiates interrogations transmitted by the different systems operating in the same area and facilitates the understanding of their respective contribution to the 1 090 MHz environment.

LSS, the 1-bit (23) lockout surveillance subfield, if set to 1, shall signify a multisite lockout command from the interrogator indicated in SIS. If set to 0, LSS shall signify that no change in lockout state is commanded.

RRS, the 4-bit (24-27) reply request subfield in SD shall contain the BDS2 code of a requested GICB register.

Bits 28 to 32 are not assigned.

(viii) If DI=4, 5 or 6 then the SD field has no meaning and shall not impact other transaction

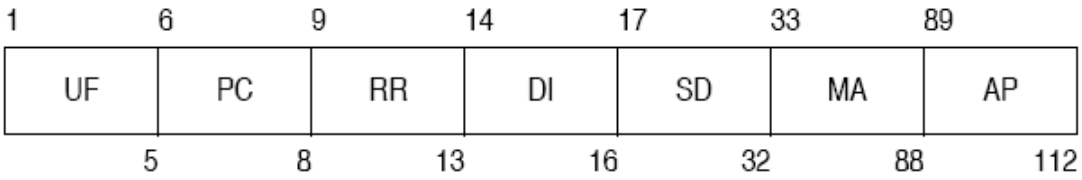
cycle protocols. These DI codes remain reserved until future assignment of the SD field.

(ix) If DI = 0, 3 or 7:
In addition to the requirements provided above, the "SD" shall contain the following:

"OVC": The 1-bit (bit 28) "overlay control" subfield in "SD" is used by the interrogator to command that the data parity ("DP" 23.4.3.1.2.3.2(1)(e)) be overlaid upon the resulting reply to the interrogation in accordance with paragraph 23.4.3.1.2.6.11(2)(e).

(5) PC and SD field processing**.** When DI = 1, PC field processing shall be completed before processing the SD field.

23.4.3.1.2.6.2 COMM-A ALTITUDE REQUEST, UPLINK FORMAT 20



The format of this interrogation shall consist of these fields:

Field	*Reference*
UF uplink format	23.4.3.1.2.3.2(1)(a)
PC protocol	23.4.3.1.2.6.1(1)
RR reply request	23.4.3.1.2.6.1(2)
DI designator identification	23.4.3.1.2.6.1(3)
SD special designator	23.4.3.1.2.6.1(4)
MA message, Comm-A	23.4.3.1.2.6.2(1)
AP address/parity	23.4.3.1.2.3.2(1)(c)

(1) *MA: Message, Comm-A.* This 56-bit (33-88) field shall contain a

data link message to the aircraft.

23.4.3.1.2.6.3 SURVEILLANCE IDENTITY REQUEST, UPLINK FORMAT

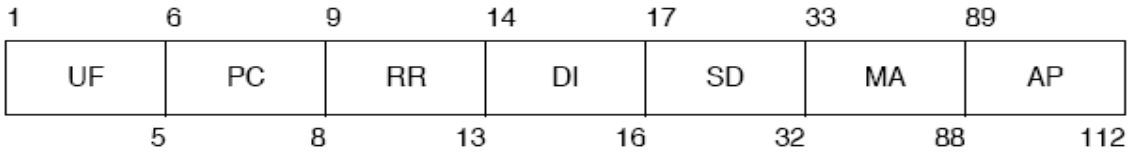


5

The format of this interrogation shall consist of these fields:

Field	Reference
UF uplink format	23.4.3.1.2.3.2(1)(a)
PC protocol	23.4.3.1.2.6.1(1)
RR reply request	23.4.3.1.2.6.1(2)
DI designator identification	23.4.3.1.2.6.1(3)
SD special designator	23.4.3.1.2.6.1(4)
AP address/parity	23.4.3.1.2.3.2(1)(c)

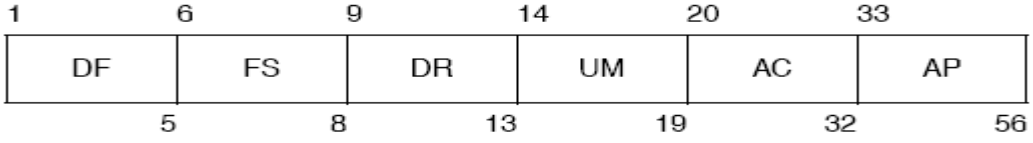
23.4.3.1.2.6.4 COMM-A IDENTITY REQUEST, UPLINK FORMAT 21



The format of this interrogation shall consist of these fields:

Field	Reference
UF Uplink format	23.4.3.1.2.3.2(1)(a)
PC protocol	23.4.3.1.2.6.1(1)
RR reply request	23.4.3.1.2.6.1(2)
DI designator identification	23.4.3.1.2.6.1(3)
SD special designator	23.4.3.1.2.6.1(4)
MA message, Comm-A	23.4.3.1.2.6.2(1)
AP address/parity	23.4.3.1.2.3.2(1)(c)

23.4.3.1.2.6.5 SURVEILLANCE ALTITUDE REPLY, DOWNLINK FORMAT



4

This reply shall be generated in response to an interrogation UF 4 or 20 with an RR field value less than 16. The format of this reply shall consist of these fields:

Field	Reference
DF downlink format	23.4.3.1.2.3.2(1)(b)
FS flight status	23.4.3.1.2.6.5(1)
DR downlink request	23.4.3.1.2.6.5(2)
UM utility message	23.4.3.1.2.6.5(3)
AC altitude code	23.4.3.1.2.6.5(4)
AP address/parity	23.4.3.1.2.3.2(1)(c)

(1) FS: Flight status**.** This 3-bit (6-8) downlink field shall contain the following information:

Coding

0 signifies no alert and no SPI, vertical status (VS) indicates "airborne"

1 signifies no alert and no SPI, VS indicates ~~aireraft is~~ "on-the-ground"

2 signifies alert, no SPI, VS indicates ~~aireraft is~~ "airborne"

3 signifies alert, no SPI, VS indicates ~~aireraft is~~ "on-the-ground"

4 signifies alert and SPI, VS indicates~~aireraft is~~ "airborne"~~airorne~~ or "on-the-ground"

5 signifies no alert and SPI, VS indicates "airborne" or "on-the-ground"

6 reserved

7 not assigned

Note. — The conditions which cause an alert are given in 23.4.3.1.2.6.10(1)(a).

(2) DR: Downlink request. This 5-bit (9-13) downlink field shall contain requests to downlink information.

Coding

0 signifies no downlink request

1 signifies request to send Comm-B message

2 reserved for ACAS

3 reserved for ACAS

4 signifies Comm-B broadcast message 1 available

5 signifies Comm-B broadcast message 2 available

6	reserved for ACAS
7	reserved for ACAS
8-15	not assigned
16-31	see downlink ELM protocol (23.4.3.1.2.7.7(1))

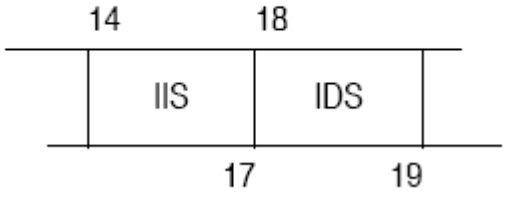
Codes 1-15 shall take precedence over codes 16-31.

Note. — Giving precedence to codes 1-15 permits the announcement of a Comm-B message to interrupt the announcement of a downlink ELM. This gives priority to the announcement of the shorter message.

(3) UM: Utility message**.** This 6-bit (14-19) downlink field shall contain transponder communications status information as specified in 23.4.3.1.2.6.1(4)(a) and 23.4.3.1.2.6.5(3)(a).

(a) subfields in UM for multisite protocols

UM FIELD STRUCTURE



The following subfields shall be inserted by the transponder into the UM field of the reply if a surveillance or Comm-A interrogation (UF equals 4, 5, 20, 21) contains DI = 1 and RSS other than 0:

IIS: The 4-bit (14-17) interrogator identifier subfield reports the identifier of the interrogator that is reserved for multi site communications.

IDS: The 2-bit (18, 19) identifier designator subfield reports the type of reservation made by the interrogator identified in IIS.
Assigned coding is:

0	signifies no information
1	Signifies IIS contains Comm-B II code

2 Signifies IIS contains Comm-C II code
3 Signifies IIS contains Comm-D II code.

(b) Multisite reservation status. The interrogator identifier of the ground station currently reserved for multi site Comm-B delivery (23.4.3.1.2.6.11.3(1)) shall be transmitted in the IIS subfield together with code 1 in the IDS subfield if the UM content is not specified by the interrogation (when DI = 0 or 7, or when DI = 1 and RSS = 0).

(c) The interrogator identifier of the ground station reserved for downlink ELM delivery (23.4.3.1.2.7(6)(a)), if any, shall be transmitted in the IIS subfield together with code 3 in the IDS subfield if the UM content is not specified by the interrogation and there is no current Comm-B reservation.

(4) **AC: Altitude code.** This 13-bit (20-32) field shall contain altitude coded as follows:

(a) But 26 is designated as the M bit and shall be 0 if the altitude is reported in feet. M equals 1 shall be reserved to indicate that the altitude reporting is in metric units.

(b) If M equals 0, then bit 28 is designated as the Q bit. Q equals 0 shall be used to indicate that the altitude is reported in 100-foot increments. Q equals 1 shall be used to indicate that the altitude is reported in 25-foot increments.

(c) If the M bit (bit 26) and the Q bit (bit 28) equal 0, the altitude shall be coded according to the pattern for Mode C replies of 23.4.3.1.1.7.12(f). Starting with bit 20 the sequence shall be C1, A1, C2, A2, C4, A4, ZERO, B1, ZERO, B2, D2, B4, D4.

(d) If the M bit equals 0 and the Q bit equals 1, the 11-bit field represented by bits 20 to 25, 27 and 29 to 32 shall represent a binary coded field with a least significant bit (LSB) of 25 ft. The binary value of the positive decimal integer “N” shall be encoded to report pressure-altitude in the range [(25 N - 1 000) plus or minus 12.5 ft]. The coding of 23.4.3.1.2.6.5(4)(c) shall be used to report pressure-altitude above 50 187.5 ft.

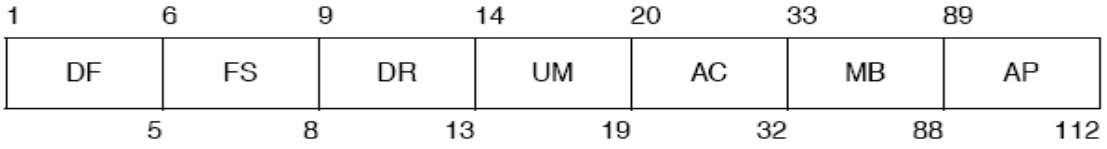
Note 1.— This coding method is only able to provide values between minus 1 000 ft and plus 50 175 ft.

Note 2.— The most significant bit (MSB) of this field is bit 20 as required by 23.4.3.1.2.3(1)(c).

(e) If the M bit equals 1, the 12-bit field represented by bits 20 to 25 and 27 to 32 shall be reserved for encoding altitude in metric units.

(f) 0 shall be transmitted in each of the 13 bits of the AC field if altitude information is not available or if the altitude has been determined invalid.

23.4.3.1.2.6.6 COMM-B ALTITUDE REPLY, DOWNLINK FORMAT 20

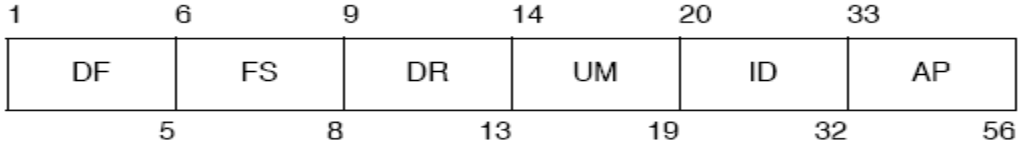


This reply shall be generated in response to an interrogation UF 4 or 20 with an RR field value greater than 15. The format of this reply shall consist of these fields:

Field	Reference
DF downlink format	23.4.3.1.2.3.2(1)(b)
FS flight status	23.4.3.1.2.6.5(1)
DR downlink request	23.4.3.1.2.6.5(2)
UM utility message	23.4.3.1.2.6.5(3)
AC altitude code	23.4.3.1.2.6.5(4)
MB message, Comm-B	23.4.3.1.2.6.6(1)
AP address/parity	23.4.3.1.2.3.2(1)(c)

(1) MB: Message, Comm-B. This 56-bit (33-88) downlink field shall be used to transmit data link messages to the ground.

23.4.3.1.2.6.7 SURVEILLANCE IDENTITY REPLY, DOWNLINK FORMAT 5

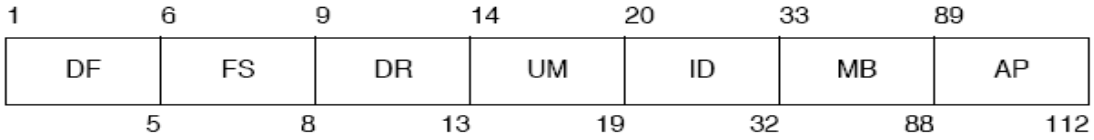


This reply shall be generated in response to an interrogation UF 5 or 21 with an RR field value less than 16. The format of this reply shall consist of these fields:

Field	Reference
DF downlink format	23.4.3.1.2.3.2(1)(b)
FS flight status	23.4.3.1.2.6.5(1)
DR downlink request	23.4.3.1.2.6.5(2)
UM utility message	23.4.3.1.2.6.2(1)
ID identity	23.4.3.1.2.6.7(1)
AP address/parity	23.4.3.1.2.3.2(1)(c)

(1) ID: Identity (Mode A code). This 13-bit (20-32) field shall contain aircraft identity code, in accordance with the pattern for Mode A replies in 23.4.3.1.1.6. Starting with bit 20, the sequence shall be C1, A1, C2, A2, C4, A4, ZERO, B1, D1, B2, D2, B4, D4.

23.4.3.1.2.6.8 COMM-B IDENTITY REPLY, DOWNLINK FORMAT 21



This reply shall be generated in response to an interrogation UF 5 or 21 with an RR field value greater than 15. The format of this reply shall consist of these fields:

Field	Reference
DF downlink format	23.4.3.1.2.3.2(1)(b)
FS flight status	23.4.3.1.2.6.5(1)
DR downlink request	23.4.3.1.2.6.5(2)
UM utility message	23.4.3.1.2.6.5(3)
ID identity	23. 4.3.1.2.6.7(1)
MB message, Comm-B	23.4.3.1.2.6.2(1)
AP address/parity	23.4.3.1.2.3.2(1)(c)

23.4.3.1.2.6.9 LOCKOUT PROTOCOLS

Note. — Non-selective all-call lockout and multisite lockout are not

mutually exclusive. Interrogators using multisite lockout protocols for interrogator networking coordination may use non-selective lockout commands in the same interrogation. For example, the non-selective lockout may be used to prevent Mode S transponder replies with DF=11 to wrongly detected Mode A/C/S all-call interrogations from Mode A/C-only all-call interrogations. This is because of the misinterpretation of the narrow P4 *pulse as a wide* P4 *pulse.*

(1) Multi-site all-call lockout.

Note. — The multisite lockout protocol prevents transponder acquisition from being denied one ground station by lockout commands from an adjacent ground station that has overlapping coverage.

(a) The multisite lockout command shall be transmitted in the SD field (23.4.3.1.2.6.1.(4)(a)). A lockout command for an II code shall be transmitted in an SD with DI = 1 or DI = 7. An II lockout command shall be indicated by LOS code equals 1 and the presence of a non-zero interrogator identifier in the IIS subfield of SD. A lockout command for an SI code shall be transmitted in an SD with DI = 3. SI lockout shall be indicated by LSS equals 1 and the presence of a non-zero interrogator identifier in the SIS subfield of SD. After a transponder has accepted an interrogation containing a multisite lockout command, that transponder shall commence to lock out (i.e. not accept) any Mode S-only all-call interrogation which includes the identifier of the interrogator that commanded the lockout. The lockout shall persist for an interval TL (23.4.3.1.2.10(3)(j)) after the last acceptance of an interrogation containing the multisite lockout command. Multisite lockout shall not prevent acceptance of a Mode S-only all-call interrogation containing PR codes 8 to 12. If a lockout command (LOS = 1) is received together with IIS = 0, it shall be interpreted as a non- selective all-call lockout (23.4.3.1.2.6.9(2)).

Note 1. — Fifteen interrogators can send independent multisite II lockout commands. In addition, 63 interrogators can send independent SI lockout commands. Each of these lockout commands must be timed separately.

Note 2. — Multisite lockout (which only uses

non-zero II codes) does not affect the response of the transponder to Mode S-only all-call interrogations containing II equals 0 or to Mode A/C/S all-call interrogations.

(2) Non-selective all-call lockout

Note 1. — In cases where the multisite lockout protocol for II codes is not required (e.g. there is no overlapping coverage or there is ground station coordination via ground-to-ground communications) the non-selective lockout protocol may be used.

(b) On acceptance of an interrogation containing code 1 in the PC field, a transponder shall commence to lock out (i.e. not accept) ~~two types of all-call interrogations:~~ the Mode S-only all-call (UF = 11), with II equals 0,

Note 2.— On acceptance of an interrogation containing code 1 in the PC field transponders certified before 1 January 2020 also do not reply to the Mode A/C/S all-call of 23.4.3.1.2.1(1)(e)(i).

This lockout condition shall persist for an interval T_D (23.4.3.1.2.10(3)(j)) after the last receipt of the command. Non-selective lockout shall not prevent acceptance of a Mode S-only all-call interrogation containing PR codes 8 to 12.

Note 3.— non-selective lockout does not affect the response of the transponder to Mode S-only all-call interrogations containing II not equal to 0.

23.4.3.1.2.6.10 BASIC DATA PROTOCOLS

(1) Flight status protocol. Flight status shall be reported in the FS field 23.4.3.1.2.6.5(1).

(a) Alert. An alert condition shall be reported in the FS field if the Mode A identity code transmitted in Mode A replies and in downlink formats DF equals 5 and DF equals 21 are changed by the pilot.

(i) Permanent alert condition. The alert condition

shall be maintained if the Mode A identity code is changed to any of the codes contained in one of the two Mode A code sets defined as follows:

(A) Mode A code set 1 for special purposes shall contain Mode A code 7500, 7600 or 7700.

(B) Mode A code set 2 for special purposes shall contain Mode A code 7400, 7500, 7600 or 7700.

(ii) Temporary alert condition. The alert condition shall be temporary and shall cancel itself after T_C seconds if the Mode A identity code is changed to a value other than those listed in 23.4.3.1.2.6.10(1)(a)(i). The T_C *shall* be retriggered and continued for *TC* seconds after any change has been accepted by the transponder function.

Note 1. — This retriggering is performed to ensure that the ground interrogator obtains the desired Mode A identity code before the alert condition is cleared.

Note 2.— The value of TC *is given in 23.4.3.1.2.10(3)(j).*

(iii) Termination of the permanent alert condition. The permanent alert condition shall be terminated and replaced by a temporary alert condition when the Mode A identity code is set to a value ~~other than~~ those defined in Mode A code set 1 or set 2 listed in 23.4.3.1.2.6.10(1)(a)(i), (A) and (B).

(iv)

(b) Special position identification (SPI). An equivalent of the SPI pulse shall be transmitted by Mode S transponders in the FS field and the surveillance status subfield (SSS) when manually activated. This pulse shall be transmitted for T_I seconds after initiation (23.4.3.1.1.6(3),

23.4.3.1.1.7(13) and 23.4.3.1.2.8.6(3)(a)(i)).

Note. — The value of TI *is given in 23.4.3.1.2.10(3)(j).*

(2) Capability reporting protocol. The data structure and content of the data link capability report registers shall be implemented in such a way that interoperability is ensured.

Note 1. — Aircraft capability is reported in special fields as defined in the following paragraphs.

Note 2.— The data format of the registers for reporting capability is specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

(a) Capability report. The 3-bit CA field, contained in the all-call reply, DF equals 11, shall report the basic capability of the Mode S transponder as described in 23.4.3.1.2.5(2)(b)(i).

(b) Data link capability report. The data link capability report shall provide the interrogator with a description of the data link capability of the Mode S installation.

Note. — The data link capability report is contained in register 1016 with a possible extension in registers 1116 to 1616 when any continuation will be required.

(i) Extraction Subfields in MB for data link capability report.

(A) Extraction of the data link capability report contained in register 10_{16}. The report shall be obtained by a ground-initiated Comm-B reply in response to an interrogation containing RR equals 17 and DI is not equal to 7 or DI equals 7 and RRS equals 0 (23.4.3.1.2.6.11(2)).

(B) Sources of data link capability. Data link capability reports shall contain the capabilities provided by the transponder, and the ACAS unit.~~transponder, the ADLP and the ACAS unit. If external inputs are lost, the transponder shall zero the~~

~~corresponding bits in the data link report.~~

(C) The data link capability report shall contain information on the following capabilities as specified in Table 3-6.

Note. — The content of the data link capability report differs between subnetwork versions. See Doc 9871 for further details.

(D) The Mode S subnetwork version number shall contain information to ensure interoperability with older airborne equipment.

(I) The Mode S subnetwork version number shall indicate that all implemented subnetwork functions are in compliance with the requirements of the indicated version number. The Mode S subnetwork version number shall be set to a non-zero value if at least one DTE or Mode S specific service is installed.

Note. — The version number does not indicate that all possible functions of that version are implemented

(ii) Updating of the data link capability report. The transponder shall, at intervals not exceeding four seconds, compare the current data link capability status (bits 41-88 in the data link capability report) with that last reported and shall, if a difference is noted, initiate a revised data link capability report by Comm-B broadcast (23.4.3.1.2.6.11.4) for BDS1 = 1 (33-36) and BDS 2 = 0 (37-40). The transponder shall initiate, generate and announce the revised capability report even if the aircraft data link capability is degraded or lost. The transponder shall ensure that the BDS code for

the data link capability report in all cases, including a loss of the interface.

Note. — The setting of the BDS code by the transponder ensures that a broadcast change of capability report will contain the BDS code for all cases of data link failure (e.g. the loss of the transponder data link interface)

(iii) Zeroing of bits in the data link capability report. If a particular data field within the data link capability report (transponder register 1016) cannot be updated within 8 seconds, the data field shall be set to ZERO.

Note 1. —. See Doc 9871 for further details.

Note 2.— Transponders maintaining aircraft identification upon the loss of the interface providing aircraft identification do not reset to zero bit 33 (23.4.2.1.6(4)(g) and 23.4.2.1.6(4)(h)

(c) Common usage GICB capability report. Common usage GICB services which are being actively updated shall be indicated in transponder register 17_{16}.

(d) Mode S specific services GICB capability reports. GICB services that are installed shall be reported in registers 18_{16} to $1C_{16}$.

(e) Mode S specific services MSP capability reports. MSP services that are installed shall be reported in registers $1D_{16}$ to $1F_{16}$.

(3) Basic data flash protocol ~~Validation of on the ground status declared by an automatic means~~.

Note. - The basic dataflash provides a protocol that allows the Mode S ground stations to be advised of changes that occur infrequently in various transponder registers of interest. The ground stations are advised of changes via Comm-B Broadcast

of register 1016 and then extract as needed or desired the register or registers of interest.

(a) Basic dataflash capability report. Transponders which monitor at least one of the registers subject to basic dataflash protocol and report their changes through the basic dataflash protocol, shall report this capability in the data link capability report (23.4.3.1.2.6.10(2)(b)(ii)) by setting bit 42 and bit 9 of the MB subfield to 1.

Note 1.— The registers for which changes can be reported using the basic dataflash protocol are defined in Doc 9871.

Note 2.— The setting of bit 9 to 1 indicates that the content of register 1016 continues in register 1116. This is what is expected when the basic dataflash option is implemented even if the basic dataflash state bits report zero because no information is provided to the monitored registers.

(b) Mode S subnetwork version. Transponders which monitor register changes and report their changes through the basic dataflash protocol shall support a Mode S subnetwork Version 6 or above.

Note. — The basic dataflash protocol uses register formats that have been defined with Mode S Subnetwork Version 6. More information can be found in Doc 9871.

(c) Each basic dataflash register that is implemented shall have its contents updated at an interval not to exceed its update interval.

Note. — The register update intervals are defined in Doc 9871.

(d) Register basic dataflash state

(i) The basic dataflash state for each of the registers defined in register 1116 shall contain

its associated monitoring states as follows:

Coding
0: Register not monitored or not implemented
1: Register monitored and implemented but no change yet detected
2: Register monitored and change 1 detected
3: Register monitored and change 2 detected

(ii) Each register shall be monitored for a change according to its update period.

Note. — The register update periods are defined in Doc 9871.

(iii) Upon first entry into the monitored state, the transponder shall set the monitoring bits allocated in register 1116 for that basic dataflash register to "1", meaning register monitored and implemented but no change yet detected.

(iv) Once a change has been detected, the basic dataflash state of the corresponding register shall be toggled between 2 and 3 with each change.

Note. — Toggle means if the register basic dataflash state was 2, at the next change it becomes 3 and if it was 3, it becomes 2.

(v) Monitoring change and announcing a change to ground state

(A) At intervals not exceeding 1 second, the transponder shall determine if the contents 36 of register 1116 have changed since the last update.

(B) If the contents of register 1116 have changed, bit 51 of register 1016 shall be toggled and the F-timer shall be started (see Table 3-9).

Note. — The toggling (1→ 0 or 0→1) of bit 51 in register 1016 will trigger a

Comm-B broadcast of register 1016.

(C) All basic dataflash monitoring activity (comparison of register contents and setting of bits in register 1116) shall be suspended until the F-timer expires.

Note 1. — The suspension of basic dataflash monitoring avoids the Comm-B broadcast channel saturation.

Note 2.— Dataflash monitoring suspension means that the current content of monitored registers are retained and the detection of a change with the new contents of these registers will re-start after the 30s timer. The monitored registers themselves continue to be updated at their update periodicity.

Note 3.— The use of basic dataflash protocol by ground systems is described in Doc 9924. This allows reduction of periodic GICB extraction of registers.

Determination of airborne status					
A/V category	*Ground Speed*		*Airspeed*		*Radio Altitude*
No information	No change to on-the-ground status				
Weight < 15 500 lbs (7 031 kg)	No change to on-the-ground status				
Weight ≥15 500 lbs (7 031 kg)	>100 knots	or	>100 knots	or	>50 feet
High performance (>5 g acceleration and >400 knots)	>100 knots	or	>100 knots	or	>50 feet
Rotorcraft	No change to on-the-ground status				

23.4.3.1.2.6.11 STANDARD LENGTH COMMUNICATIONS PROTOCOLS

Note 1. — The two types of standard length communications protocols are Comm-A and Comm-B; messages using these protocols are transferred under the control of the interrogator. Comm-A messages are sent directly to the transponder and are completed within one transaction. A Comm-B message is used to transfer information from air to ground and can be initiated either by the interrogator or the transponder. In the case of ground-initiated Comm-B transfers, the interrogator requests data to be read out from the transponder, which delivers the message in the same transaction. In the case of air- initiated Comm-B transfers, the transponder announces the intention to transmit a message; in a subsequent transaction an interrogator will extract the message.

Note 2. — In a non-selective air-initiated Comm-B protocol all transactions necessary can be controlled by any interrogator.

Note 3. — In some areas of overlapping interrogator coverage there may be no means for coordinating interrogator activities via ground communications. Air-initiated Comm-B communications protocols require more than one transaction for completion. Provision is made to ensure that a Comm-B message is closed out only by the interrogator that actually transferred the message. This can be accomplished through the use of the multisite Comm-B communications protocols or through the use of the enhanced Comm-B communications protocols.

Note 4. — The multisite and the non-selective communications protocols cannot be used simultaneously in a region of overlapping interrogator coverage unless the interrogators coordinate their communications activities via ground communications.

Note 5. — The multisite communications protocol is

independent of the multisite lockout protocol. That is, the multisite communications protocol may be used with the non-selective lockout protocol and vice versa. The choice of lockout and communications protocols to be used depends upon the network management technique being used.

Note 6. — The broadcast Comm-B protocol can be used to make a message available to all active interrogators.

Note 7.— When implemented, the technical provisions for phase overlay capability introduced in this section will provide means for increased data transmission capacity by the 1 090 extended squitters.

(1) Comm-A.
The interrogator shall deliver a Comm-A message in the MA field of an interrogation UF = 20 or 21.

(a) Comm-A technical acknowledgement. Acceptance of a Comm-A interrogation shall be automatically technically acknowledged by the transponder, by the transmission of the requested reply (23.4.3.1.2.10.5(2)(b)(i)).

Note. — The receipt of a reply from the transponder according to the rules of 23.4.3.1.2.4.1.2.1(3)(d) and 23.4.3.1.2.4.1.3(5) is the acknowledgement to the interrogator that the interrogation has been accepted by the transponder. If either uplink or downlink fail, this reply will be missing and the interrogator will normally send the message again. In the case of downlink failure, the transponder may receive the message more than once.

(b) Comm-A broadcast. If a Comm-A broadcast interrogation is accepted (23.4.3.1.2.4.1.2.1(7) information transfer shall be handled according to 23.4.3.1.2.10.5(2)(a)(i) but other transponder functions shall not be affected and a reply shall not be transmitted.

Note 1. — There is no technical acknowledgement to a Comm-A broadcast message.

Note 2.— Since the transponder does not process the control fields of a Comm-A broadcast interrogation, the 27 bits following the UF field are also available for user data.

(2) Ground-initiated Comm-B

(a) Comm-B data selector, BDS. The 8-bit BDS code shall determine the register whose contents shall be transferred in the MB field of the Comm-B reply. It shall be expressed in two groups of 4 bits each, BDS1 (most significant 4 bits) and BDS2 (least significant 4 bits).

Note. — The transponder register allocation is specified in Doc 9871.

(b) BDS1 code. The BDS1 code shall be as defined in the RR field of a surveillance or Comm-A interrogation.

(c) BDS2 code. The BDS2 code shall be as defined in the RRS subfield of the SD field (23.4.3.1.2.6.1(4)(a)) when DI = 7. If no BDS2 code is specified (i.e. DI is not equal to 7) it shall signify that BDS2 = 0.

(d) Protocol. On receipt of such a request, the MB field of the reply shall contain the contents of the requested ground-initiated Comm- B register.

(i) If the requested register is not serviced by the aircraft installation, the transponder shall reply and the MB field of the reply shall contain all ZEROs

(e) *Overlay control.* If the "DI" code of the Comm-B requesting interrogation is 0, 3 or 7, the "SD" contains the overlay control (OVC) field in accordance with paragraph 23.4.3.1.2.6.1.4(a)(ix).

(i) If the "OVC" is equal to "1," then the reply to the interrogation shall contain the "DP" (data parity) field in accordance with paragraph 23.4.3.1.2.3.2(1)(e); and

(ii) If the "OVC" is equal to "0," then the reply to the interrogation shall contain the "AP" field in accordance with paragraph 23.4.3.1.2.3.2(1)(c).

(f) Phase overlay ground-initiated Comm-B. For equipment that support phase overlay on Mode S replies, when the

reply contains the contents of the requested ground-initiated Comm-B register, phase data shall be encoded data in accordance with the register requested in the interrogation (that is, requested BDS code) and as defined for that register.

(i) PO message type field. The phase overlay message type field in PD data bits 1–8 shall be set to 2 for phase overlay Mode S GICB data with Reed-Solomon FEC and to 8 to indicate phase overlay Mode S GICB data with LDPC FEC.

(ii) PO message subtype field. PD data bits 9–12 shall contain the phase overlay message subtype field and is set to 1. The subfield is defined as shown in Table 3-14. 37

Note. — Future UF codes may contain commands to force the transmission of other data in the phase overlay data block overlaid on Mode S long replies.

(iii) PO-BDS field. PD data bits 13–20 shall contain the BDS register number requested as per 23.4.3.1.2.6.11.2(1)

(iv) PO data-block field. PD data bits 21–204 shall contain the content of the corresponding phase overlay data associated with the requested BDS register. When there is no phase overlay data defined for the requested BDS register, all bits shall be set to ZERO except the PO message type field is set to 2 or 8, PO message subtype = 1, PO-BDS = BDS number of requested BDS register, and the 24-bit address is contained in the aircraft address (PD bits 181 through 204).

23.4.3.1.2.6.11.3 AIR-INITIATED COMM-B

(1) General protocol.

The transponder shall announce the presence of an air-initiated Comm-B message with the insertion of code 1 in the DR field. To extract an air-initiated Comm-B message, the interrogator shall transmit a request for a Comm-B message reply in a subsequent

interrogation with RR equal to 16 and, if DI equals 7, RRS must be equal to 0 (23.4.3.1.2.6.11.3(2)(b) and 23.4.3.1.2.6.11.3(3)(a)). Receipt of this request code shall cause the transponder to transmit the air-initiated Comm-B message. If a command to transmit an air-initiated Comm-B message is received while no message is waiting to be transmitted, the reply shall contain all ZEROs in the MB field.

For equipment that support phase overlay on Mode S replies, when an air-initiated Comm-B message is transmitted, PD data bits 1–204 shall be set to ZERO.

(a) The reply that delivers the message shall continue to contain code 1 in the DR field. After a Comm-B closeout has been accomplished, the message shall be cancelled and the DR code belonging to this message immediately removed. If another air-initiated Comm-B message is waiting to be transmitted, the transponder shall set the DR code to 1, so that the reply contains the announcement of this next message.

Note. — The announcement and cancellation protocol ensures that an air-initiated message will not be lost due to uplink or downlink failures that occur during the delivery process.

(b) An interrogator that has either not been assigned an IC or cannot ensure that its interrogation region will not overlap with the interrogation region of another interrogator using the same IC, shall not attempt to extract an air-initiated Comm-B message announced by DR equals 1 or 3.

(c) Phase overlay data. When an air-initiated Comm-B message is transmitted, for equipment supporting phase overlay on Mode S replies, PD data bits 1–204 shall be set to ZERO.

(2) Additional protocol for multi-site air-initiated Comm-B

Note. — The announcement of an air-initiated Comm-B message waiting to be delivered may be accompanied by a multisite reservation status report in the UM field (23.4.3.1.2.6.5(3)(b)).

(a) An interrogator shall not attempt to extract a message if it has determined that it is not the reserved site.

(b) Message transfer. An interrogator shall request a Comm-B reservation and extract an air-initiated Comm-B message by transmitting a surveillance or Comm-A interrogation UF equals 4, 5, 20 or 21 containing:

RR = 16
DI = 1
IIS = assigned interrogator identifier
MBS = 1 (Comm-B reservation request)

Note. — A Comm-B multisite reservation request is normally accompanied by a Comm-B reservation status request (RSS = 1). This causes the interrogator identifier of the reserved site to be inserted in the UM field of the reply.

(i) Protocol procedure in response to this interrogation shall depend upon the state of the B-timer which indicates if a Comm-B reservation is active. This timer shall run for T_R seconds.

Note 1.— The value of TR *is given in 23.4.3.1.2.10(3)(j)..*

(A) If the B-timer is not running, the transponder shall grant a reservation to the requesting interrogator by:

(I) storing the IIS of the interrogation as the Comm-B II; and

(II) starting the B-timer.

(B) A multisite Comm-B reservation shall not be granted by the transponder unless an air-initiated Comm-B message is waiting to be transmitted and the requesting interrogation contains RR equals 16, DI equals 1, MBS equals 1 and IIS is not 0.

(C) If the B-timer is running and the IIS of the interrogation equals the Comm-B II, the

transponder shall restart the B-timer.

(D) If the B-timer is running and the IIS of the interrogation does not equal the Comm-B II, then there shall be no change to the Comm-B II or the B-timer.

Note 2. — In case c) the reservation request has been denied.

(ii) In each case the transponder shall reply with the Comm-B message in the MB field.

(iii) An interrogator shall determine if it is the reserved site for this message through coding in the UM field. If it is the reserved site it shall attempt to close out the message in a subsequent interrogation. If it is not the reserved site it shall not attempt to close out the message.

(c) Multisite-directed Comm-B transmissions. To direct an air- initiated Comm-B message to a specific interrogator, the multisite Comm-B protocol shall be used. When the B-timer is not running, the interrogator identifier of the desired destination shall be stored as the Comm-B II. Simultaneously the B-timer shall be started and the DR code shall be set to 1. For a multisite-directed Comm-B message, the B-timer shall not automatically time out but shall continue to run until:

(i) the message is read and closed out by the reserved site; or

(ii) the message is cancelled (23.4.3.1.2.10.5(4)) by the data link avionics.

Note. — The protocols of 23.4.3.1.2.6.5(3) and 23.4.3.1.2.6.11.3(2)(b) will then result in delivery of the message to the reserved site. The data link avionics may cancel the message if delivery to the reserved site cannot be accomplished.

(d) Multisite Comm-B closeout. The interrogator shall close

out a multisite air-initiated Comm-B by transmitting either a surveillance or a Comm-A interrogation containing:

either DI = 1
IIS = assigned interrogator identifier MBS = 2 (Comm-B closeout)

or DI = 0, 1 or 7
IIS = assigned interrogator identifier PC = 4 (Comm-B closeout)

(e) The transponder shall compare the IIS of the interrogation to the Comm-B II and if the interrogator identifiers do not match, the message shall not be cleared and the status of the Comm-B II, B- timer, and DR code shall not be changed. If the interrogator identifiers match, the transponder shall set the Comm-B II to 0, reset the B-timer, clear the DR code for this message and clear the message itself. The transponder shall not close out a multisite air- initiated Comm-B message unless it has been read out at least once by the reserved site.

(f) Automatic expiration of Comm-B reservation. If the B-timer period expires before a multisite closeout has been accomplished, the Comm-B II shall be set to 0 and the B-timer reset. The Comm- B message and the DR field shall not be cleared by the transponder.

Note. — This makes it possible for another site to read and clear this message

(3) Additional protocol for non-selective air-initiated Comm-B

Note. — In cases where the multisite protocols are not required (i.e. no overlapping coverage or sensor coordination via ground-to-ground communication), the non-selective air-initiated Comm-B protocol may be used.

(a) Message transfer. The interrogator shall extract the message by transmitting either RR equals 16 and DI is not equal to 7, or RR equals 16, DI equals 7 and RRS equals 0 in a surveillance or Comm-A interrogation.

(b) Comm-B closeout**.** The interrogator shall close out a non-selective air-initiated Comm-B message by transmitting PC equals 4 (Comm-B closeout). On receipt of this command, the transponder shall perform closeout, unless the B-timer is running. If the B- timer is running, indicating that a multisite reservation is in effect, closeout shall be accomplished as per 23.4.3.1.2.6.11.3(2)(d). The transponder shall not close out a non-selective air-initiated Comm- B message unless it has been read out at least once by an interrogation using non-selective protocols.

(4) Enhanced air-initiated Comm-B protocol.

Note. — The enhanced air-initiated Comm-B protocol provides a higher data link capacity by permitting parallel delivery of air-initiated Comm-B messages by up to sixteen interrogators, one for each II code. Operation without the need for multisite Comm-B reservations is possible in regions of overlapping coverage for interrogators equipped for the enhanced air-initiated Comm-B protocol. The protocol is fully conformant to the standard multisite protocol and thus is compatible with interrogators that are not equipped for the enhanced protocol

(a) The transponder shall be capable of storing two or more messages for each of the sixteen II codes: (1) an air-initiated or multi–site-directed Comm-B message and (2) the contents of GICB registers 2 through 4.

(b) Enhanced multisite air-initiated Comm-B protocol

(i) Initiation. An air-initiated Comm-B message input into the transponder shall be stored in the registers assigned to II = 0.

(ii) Announcement and extraction. A waiting air-initiated Comm-B message shall be announced in the DR field of the replies to all interrogators for which a multisite directed Comm-B message is not waiting. The UM field of the announcement reply shall indicate that the message is not reserved for any II code, i.e., the IIS subfield shall be set to 0. When a command

to read this message is received from a given interrogator, the reply containing the message shall contain an IIS subfield content indicating that the message is reserved for the II code contained in the interrogation from that interrogator. After readout and until closeout, the message shall continue to be assigned to that II code. Once a message is assigned to a specific II code, announcement of this message shall be no longer made in the replies to interrogators with other II codes. If the message is not closed out by the assigned interrogator for the period of the B-timer, the message shall revert back to multisite air-initiated status and the process shall repeat. Only one multisite air-initiated Comm-B message shall be in process at a time.

(iii) Closeout. A closeout for a multisite air-initiated message shall only be accepted from the interrogator that is currently assigned to transfer the message.

(iv) Announcement of the next message waiting. The DR field shall indicate a message waiting in the reply to an interrogation containing a Comm-B closeout if an unassigned air-initiated message is waiting and has not been assigned to a II code, or if a multisite-directed message is waiting for that II code (23.4.3.1.2.6.11.4(c)).

(c) Enhanced multisite directed Comm-B protocol.

(i) Initiation. When a multisite directed message is input into the transponder, it shall be placed in the Comm-B registers assigned to the II code specified for the message. If the registers for this II code are already occupied, (i.e. a multisite directed message is already in process to this II code) the new message shall be queued until the current transaction with that II code is closed out.

(ii) Announcement. Announcement of a Comm-B message waiting transfer shall be made using the DR field as specified in 23.4.3.1.2.6.5(2) with

the destination interrogator II code contained in the IIS subfield as specified in 23.4.3.1.2.6.5(3)(b). The DR field and IIS subfield contents shall be set specifically for the interrogator that is to receive the reply. A waiting multisite directed message shall only be announced in the replies to the intended interrogator. It shall not be announced in the replies to other interrogators.

Note 1.— If a multisite-directed message is waiting for II = 2, the surveillance replies to that interrogator will contain DR = 1 and IIS = 2. If this is the only message in process, replies to all other interrogators will indicate that no message is waiting.

Note 2. — In addition to permitting parallel operation, this form of announcement enables a greater degree of announcement of downlink ELMs. The announcements for the downlink ELM and the Comm-B share the DR field. Only one announcement can take place at a time due to coding limitations. In case both a Comm-B and a downlink ELM are waiting, announcement preference is given to the Comm-B. In the example above, if an air-directed Comm-B was waiting for II = 2 and a multisite-directed downlink ELM was waiting for II = 6, both interrogators would see their respective announcements on the first scan since there would be no Comm-B announcement to II = 6 to block the announcement of the waiting downlink ELM.

(iii) Closeout. Closeout shall be accomplished as specified in 23.4.3.1.2.6.11.3(2)(d).

(iv) Announcement of the next message waiting. The DR field shall indicate a message waiting in the reply to an interrogation containing a Comm-B closeout if another multisite directed message is waiting for that II code, or if an air-initiated message is waiting and has not been assigned to a II code. (See 23.3.1.2.6.11.3(4)(c))

(d) Enhanced non-selective Comm-B protocol. The availability of a non-selective Comm-B message shall be announced to all interrogators. Otherwise, the protocol shall be as specified in 23.4.3.1.2.6.11.3(3).

23.4.3.1.2.6.11.4 COMM-B BROADCAST

Note 1. — A Comm-B message may be broadcast to all active interrogators within range. Messages are alternately numbered 1 and 2 and are self-cancelling after 18 seconds. Interrogators have no means to cancel Comm-B broadcast messages.

Note 2. — Use of the Comm-B broadcast is restricted to transmission of information which does not require a subsequent ground-initiated uplink response.

Note 3. — The timer used for the Comm-B broadcast cycle is the same as that used for the Comm-B multisite protocol.

Note 4. — Data formats for Comm-B broadcast are specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

(1) Initiation

(a) A Comm-B broadcast cycle shall begin with:

(i) the loading of the broadcast message into the Comm-B buffer;

(ii) the starting of the B-timer for the current Comm-B message; and

Note. — If there is more than one Comm-B message waiting for transmission, the timer is only started once the message becomes the current Comm-B broadcast.

(iii) the selection of DR code 4 or 5 (see 3.1.2.6.5(2)), for insertion into future replies with DF 4, 5, 20 or 21 when ACAS information is not available, or DR code 6 or 7 when ACAS information is available.

(b) The DR field shall be changed to the next value each time a new Comm-B broadcast message is initiated by the transponder.

Note. — The change of the DR value is used by the interrogator to detect that a new Comm-B broadcast message is announced and to extract the new Comm-B message.

(c) A Comm-B broadcast cycle shall not be initiated when an air-initiated Comm-B message is waiting to be transmitted.

(d) A new Comm-B broadcast cycle shall not interrupt a current Comm-B broadcast cycle.

(2) Extraction

(a) To extract the broadcast message, an interrogator shall transmit RR equals 16 and DI not equal to 7 or RR equals 16 and DI equals 7 with RRS equals 0 in a subsequent interrogation.

(b) For equipment that support phase overlay on Mode S replies, PD message bits 1 through 204 shall contain the data as specified in 3.1.2.6.11(2)(f) for the register that is broadcast or all ZEROs for other broadcast channels.

(3) Expiration. When the B-timer period expires, the transponder shall clear the DR code for this message, discard the present broadcast message and change the broadcast message number (from 1 to 2 or 2 to 1) in preparation for a subsequent Comm-B broadcast.

(4) Interruption. In order to prevent a Comm-B broadcast cycle from delaying the delivery of an air-initiated Comm-B message, provision shall be made for an air-initiated Comm-B to interrupt a Comm-B broadcast cycle. If a broadcast cycle is interrupted, the B-timer shall be reset, the interrupted broadcast message shall be retained, and the message number shall not be changed. Delivery of the interrupted broadcast message shall recommence when no air- initiated Comm-B transaction is in effect. The message shall then be broadcast for the full duration of the B-timer.

(5) Enhanced broadcast Comm-B protocol. A broadcast Comm-B message shall be announced to all interrogators using II codes. The

message shall remain active for the period of the B-timer for each II code. The provision for interruption of a broadcast by non-broadcast Comm-B as specified in 23.4.3.1.2.6.11.4(4) shall apply separately to each II code. When the B-timer period has been achieved for all II codes, the broadcast message shall be automatically cleared as specified in23.4.3.1.2.6.11.4(3). A new broadcast message shall not be initiated until the current broadcast has been cleared.

Note. — Due to the fact that broadcast message interruption occurs independently for each II code, it is possible that the broadcast message timeout will occur at different times for different II codes.

(6) Management of Comm-B messages waiting for transmission. If the content of a waiting Comm-B broadcast message is updated, only the most recent value for each downlink broadcast identifier shall be retained and broadcast once the current Comm-B broadcast is finished.

Note. — Downlink broadcast identifiers are defined in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

23.4.3.1.2.7 EXTENDED LENGTH COMMUNICATION TRANSACTIONS

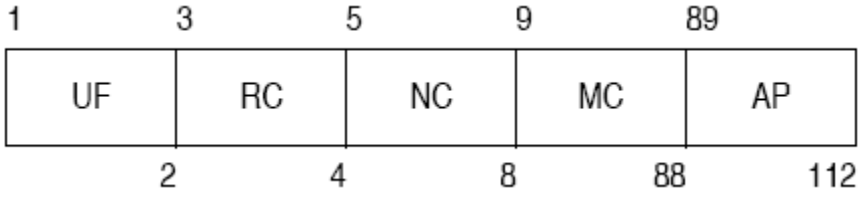
Note 1.— Long messages, either on the uplink or the downlink, can be transferred by the extended length message (ELM) protocols through the use of Comm-C (UF = 24) and Comm-D (DF = 24) formats respectively. The ELM uplink protocol provides for the transmission on the uplink of up to sixteen 80-bit message segments before requiring a reply from the transponder. They also allow a corresponding procedure on the downlink.

Note 2. — In some areas of overlapping interrogator coverage there may be no means for coordinating interrogator activities via ground communications. However, the ELM communication protocols require more than one transaction for completion; coordination is thus necessary to ensure that segments from different messages are not interleaved and that transactions are not inadvertently closed out by the wrong interrogator. This can be accomplished through the use of the multisite communications protocols or through the use of the enhanced ELM protocols.

Note 3. — Downlink extended length messages are transmitted only after authorization by the interrogator. The segments to be transmitted are contained in Comm-D replies. As with air-initiated Comm-B messages, downlink ELMs are either announced to all interrogators or directed to a specific interrogator. In the former case an individual interrogator can use the multisite protocol to reserve for itself the ability to close out the downlink ELM transaction. A transponder can be instructed to identify the interrogator that has reserved the transponder for an ELM transaction. Only that interrogator can close out the ELM transaction and reservation.

Note 4. — The multisite protocol and the non-selective protocol cannot be used simultaneously in a region of overlapping interrogator coverage unless the interrogators coordinate their communications activities via ground communications.

(1) COMM-C, UPLINK FORMAT 24



The format of this interrogation shall consist of these fields:

Field	**Reference**
UP uplink format	23.4.3.1.2.3.2(1)(a)
RC reply control	23.4.3.1.2.7(1)(a)
NC number of C-segment	23.4.3.1.2.7(1)(b)
MC message, Comm-C	23.4.3.1.2.7(1)(c)
AP address/parity	23.4.3.1.2.3.2(1)(c)

(a) RC: Reply control. This 2-bit (3-4) uplink field shall designate segment significance and reply decision.

Coding

RC = 0 signifies uplink ELM initial segment in MC
= 1 signifies uplink ELM intermediate segment inMC
= 2 signifies uplink ELM final segment in MC
= 3 signifies a request for downlink ELM delivery (23.4.3.1.2.7.7(2))

(b) NC: Number of C-segment. This 4-bit (5-8) uplink field shall designate the number of the message segment contained in MC (23.4.3.1.2.7(4)(b)(i)). NC shall be coded as a binary number.

(c) MC: Message, Comm-C. This 80-bit (9-88) uplink field shall contain:

(i) one of the segments of a sequence used to transmit an uplink ELM to the transponder containing the 4-bit (9-12) IIS subfield; or

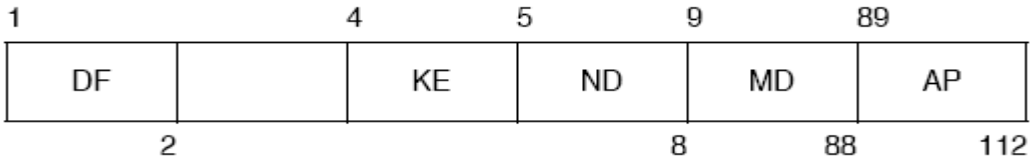
(ii) control codes for a downlink ELM, the 16-bit (9-24) SRS subfield (23.4.3.1.2.7.7(2)(a)) and the 4-bit (25-28) IIS subfield.

Note. — Message content and codes are not included in this chapter except for 23.4.3.1.2.7.7(2)(a)

(2) INTERROGATION- REPLY PROTOCOL FOR UF 24

Note. — Interrogation-reply coordination for the above format follows the protocol outlined in Table 3-5 (23.4.3.1.2.4.1.3(3)).

(3) COMM-D, DOWNLINK FORMAT 24
The format of this reply shall consist of these fields:



Field	**Reference**
DF downlink format	23.4.3.1.2.3.2(1)(b)
spare - 1 bit	
KE control, ELM	23.4.3.1.2.7(3)(a)
ND number of D-segment	23.4.3.1.2.7(3)(b)
MD message, Comm-D	23.4.3.1.2.7(3)(c)
AP address/parity	23.4.3.1.2.3.2(1)(c)

(a) KE: Control, ELM. This 1-bit (4) downlink field shall define

the content of the ND and MD fields.

Coding

KE = 0 signifies downlink ELM transmission
=1 signifies uplink ELM acknowledgement

(b) ND: Number of D-segment. This 4-bit (5-8) downlink field shall designate the number of the message segment contained in MD (23.4.3.1.2.7.7(2)). ND shall be coded as a binary number.

(c) MD: Message, Comm-D. This 80-bit (9-88) downlink field shall contain:

(i) one of the segments of a sequence used to transmit a downlink ELM to the interrogator; or

(ii) control codes for an uplink ELM.

(4) MULTISITE UPLINK ELM PROTOCOL

(a) Multisite uplink ELM reservation. An interrogator shall request a reservation for an uplink ELM by transmitting a surveillance or Comm-A interrogation containing:

DI = 1

IIS = assigned interrogator identifier

MES = 1 or 5 (uplink ELM reservation request)

Note. — A multisite uplink ELM reservation request is normally accompanied by an uplink ELM reservation status request (RSS = 2). This causes the interrogator identifier of the reserved site to be inserted in the UM field of the reply.

(i) Protocol procedure in response to this interrogation shall depend upon the state of the C-timer which indicates if an uplink ELM reservation is active. This timer shall run for TR seconds.

Note 1.— The value of TR is given in 23.4.3.1.2.10(3)(j).

(A) If the C-timer is not running the transponder shall grant a reservation to the requesting interrogator by:

(I) storing the interrogation as the Comm-C II and, IIS of the

(II) starting the C-timer.

(B) If the C-timer is running and the IIS of the interrogation equals the Comm-C II, the transponder shall restart the C-timer.

(C) If the C-timer is running and the IIS of the interrogation does not equal the Comm-C II, there shall be no change to the Comm-C II or the C-timer.

Note 2. — In case c) the reservation request has been denied.

(ii) An interrogator shall not start ELM activity unless, during the same scan, having requested an uplink ELM status report, it has received its own interrogator identifier as the reserved interrogator for uplink ELM in the UM field.

Note. — If ELM activity is not started during the same scan as the reservation, a new reservation request may be made during the next scan.

(iii) If uplink ELM delivery is not completed on the current scan, the interrogator shall ensure that it still has a reservation before delivering additional segments on a subsequent scan.

(b) Multisite uplink ELM delivery. The minimum length of an uplink ELM shall be 2 segments; the maximum length shall be 16 segments.

(i) Initial segment transfer. The interrogator shall begin the ELM uplink delivery for an n-segment message (NC values from 0 to n-1) by a Comm-C

transmission containing RC equals 0. The message segment transmitted in the MC field shall be the last segment of the message and shall carry NC equals n-1.

(ii) On receipt of an initializing segment (RC = 0) the transponder shall establish a "setup" defined as:

(A) clearing the number and content of previous segment storage registers and the associated TAS field;

(B) assigning storage space for the number of segments announced in NC of this interrogation; and

(C) storing the MC field of the segment received.

(iii) The transponder shall not reply to this interrogation.

(iv) Receipt of another initializing segment shall result in a new setup within the transponder.

(v) Transmission acknowledgement. The transponder shall use the TAS subfield to report the segments received so far in an uplink ELM sequence. The information contained in the TAS subfield shall be continually updated by the transponder as segments are received.

Note. — Segments lost in uplink transmission are noted by their absence in the TAS report and are retransmitted by the interrogator which will then send further final segments to assess the extent of message completion.

TAS, transmission acknowledgement subfield in MD This 16- bit (17-32) downlink subfield in MD reports the segment numbers received so far in an

uplink ELM sequence. Starting with bit 17, which denotes segment number 0, each of the following bits shall be set to ONE if the corresponding segment of the sequence has been received. TAS shall appear in MD if KE equals 1 in the same reply.

(vi) Intermediate segment transfer. The interrogator shall transfer intermediate segments by transmitting Comm-C interrogations with RC equals 1. The transponder shall store the segments and update TAS only if the setup of 23.4.3.1.2.7(4)(b)(i) is in effect and if the received NC is smaller than the value stored at receipt of the initial segment. No reply shall be generated on receipt of an intermediate segment.

Note. — Intermediate segments may be transmitted in any order.

(vii) Final segment transfer. The interrogator shall transfer a final segment by transmitting a Comm-C interrogation with RC equals 2. This interrogation may contain any message segment. The transponder shall store the content of the MC field and update TAS if the setup of 23.4.3.1.2.7(4)(b)(i) is in effect and if the received NC is smaller than the value of the initial segment NC. The transponder shall reply under all circumstances as per 23.4.3.1.2.7(4)(b)(viii).

Note 1. — This final segment transfer interrogation can contain any message segment.

Note 2.— RC equals 2 is transmitted any time that the interrogator wants to receive the TAS subfield in the reply. Therefore, more than one "final" segment may be transferred during the delivery of an uplink ELM.

(viii) Acknowledgement reply. On receipt of a final segment, the transponder shall transmit a Comm-D reply (DF = 24), with KE equals 1 and with the TAS subfield in the MD field. This reply shall be transmitted at 128 microseconds plus or minus 0.25 microsecond following the sync phase reversal of the interrogation delivering the final segment.

(ix) Completed message. The transponder shall deem the message complete if all segments announced by NC in the initializing segment have been received. If the message is complete, the message content shall be delivered to the outside via the ELM interface of 23.4.3.1.2.10.5(2)(a)(iii) and cleared. No later-arriving segments shall be stored. The TAS content shall remain unchanged until either a new setup is called for (23.4.3.1.2.7(4)(b)(i)) or until closeout (23.4.3.1.2.7(4)(b)(iii)(xi)).

(x) C-timer restart. The C-timer shall be restarted each time that a received segment is stored, and the Comm-C II is not 0.

Note. — The requirement for the Comm-C II to be non-zero prevents the C-timer from being restarted during a non- selective uplink ELM transaction.

(xi) Multisite uplink ELM closeout. The interrogator shall close out a multisite uplink ELM by transmitting either a surveillance or a Comm-A interrogation containing:

either DI = 1
ILS = assigned interrogator identifier
MES = 2, 6 or 7 (uplink ELM closeout)

or DI = 0, 1 or 7
IIS = assigned interrogator identifier
PC = 5 (uplink ELM closeout)

(xii) The transponder shall compare the IIS of the interrogation to the Comm-C II and if the interrogator identifiers do not match, the state of the ELM uplink process shall not be changed.

(xiii) If the interrogator identifiers match, the transponder shall set the Comm-C II to 0, reset the C-timer, clear the stored TAS and discard any stored segments of an incomplete message.

(xiv) Automatic multisite uplink ELM closeout. If the C-timer period expires before a multisite closeout has been accomplished the closeout actions described in 23.4.3.1.2.7(4)(b)(iii)(xi) shall be initiated automatically by the transponder.

(5) NON-SELECTIVE UPLINK ELM

Note. — In cases where the multisite protocols are not required (for example, no overlapping coverage or sensor coordination via ground-to-ground communication), the non-selective uplink ELM protocol may be used.

Non-selective uplink ELM delivery shall take place as for multisite uplink ELMs described in 23.4.3.1.2.7.4(b).The interrogator shall close out an uplink ELM by transmitting PC equals 5 (uplink ELM closeout) in a surveillance or Comm-A interrogation. On receipt of this command, the transponder shall perform closeout, unless the C-timer is running. If the C- timer is running, indicating that a multisite reservation is in effect, the closeout shall be accomplished as per 23.4.3.1.2.7(4)(b)(iii)(xi). An uncompleted message, present when the closeout is accepted, shall be cancelled.

(6) ENHANCED UPLINK ELM PROTOCOL

Note. — The enhanced uplink ELM protocol provides a higher data link capacity by permitting parallel delivery of uplink ELM messages by up to sixteen interrogators, one for each II code. Operation without the need for multisite uplink ELM reservations is possible in regions of overlapping coverage for interrogators equipped for the

enhanced uplink ELM protocol. The protocol is fully conformant to the standard multisite protocol and thus is compatible with interrogators that are not equipped for the enhanced protocol.

(a) General

(i) The interrogator shall determine from the data link capability report whether the transponder supports the enhanced protocols. If the enhanced protocols are not supported by both the interrogator and the transponder, the multisite reservation protocols specified in 23.4.3.1.2.7.4(a) shall be used.

Note. — If the enhanced protocols are supported, uplink ELMs delivered using the multisite protocol may be delivered without a prior reservation.

(ii) If the transponder and the interrogator are equipped for the enhanced protocol, the interrogator shall use the enhanced uplink protocol.

(iii) The transponder shall be capable of storing a sixteen-segment message for each of the sixteen II codes.

(b) Reservation processing. The transponder shall support reservation processing for each II code as specified in 23.4.3.1.2.7.4(a)

Note 1. — Reservation processing is required for interrogators that do not support the enhanced protocol.

Note 2. — Since the transponder can process simultaneous uplink ELMs for all sixteen II codes, a reservation will always be granted.

(c) Enhanced uplink ELM delivery and closeout. The transponder shall process received segments separately by II code. For each value of II code, uplink ELM delivery and closeout shall be performed as specified in 23.4.3.1.2.7.4(b) except that the MD field used to transmit the technical acknowledgment shall also contain the 4-bit

(33-36) IIS subfield.

Note. — The interrogator may use the II code contained in the technical acknowledgement in order to verify that it has received the correct technical acknowledgement.

23.4.3.1.2.7.7 MULTISITE DOWNLINK ELM PROTOCOL

(1) **Initialization.** The transponder shall announce the presence of a downlink ELM of *n* segments by making the binary code corresponding to the decimal value 15 + n available for insertion in the DR field of a surveillance or Comm-B reply, DF equals 4, 5, 20, 21. This announcement shall remain active until the ELM is closed out (23.4.3.1.2.7.7(3), 23.4.3.1.2.7.8(2)).

(a) Multisite downlink ELM reservation. An interrogator shall request a reservation for extraction of a downlink ELM by transmitting a surveillance or Comm-A interrogation containing:

DI = 1
IIS = assigned interrogator identifier
MES = 3 or 6 (downlink ELM reservation request)

Note. — A multisite downlink ELM reservation request is normally accompanied by a downlink ELM reservation status request (RSS = 3). This causes the interrogator identifier of the reserved interrogator to be inserted in the UM field of the reply.

(i) Protocol procedure in response to this interrogation shall depend upon the state of the D-timer which indicates if a downlink ELM reservation is active. This timer shall run for T_R seconds.

Note 1.— The value of TR *is given in 23.4.3.1.2.10(3)(j).*

(A) if the D-timer is not running, the transponder shall grant a reservation to the requesting interrogator by:

(I) storing the IIS of the interrogation as the Comm-D II; and

(II) starting the D-timer.

A multisite downlink ELM reservation shall not be granted by the transponder unless a downlink ELM is waiting to be transmitted.

(B) if the D-timer is running and the IIS of the interrogation equals the Comm-D II, the transponder shall restart the D-timer; and

(C) if the D-timer is running and the IIS of the interrogation does not equal the Comm-D II, there shall be no change to the Comm-D II or D-timer.

Note 2. — In case c) the reservation request has been denied.

(ii) An interrogator shall determine if it is the reserved site through coding in the UM field and, if so, it may proceed to request delivery of the downlink ELM. Otherwise, ELM activity shall not be started during this scan.

Note. — If the interrogator is not the reserved site, a new reservation request may be made during the next scan.

(iii) If downlink ELM activity is not completed on the current scan, the interrogator shall ensure that it still has a reservation before requesting additional segments on a subsequent scan.

(b) Multisite-directed downlink ELM transmissions. To direct a downlink ELM message to a specific interrogator, the multisite downlink ELM protocol shall be used. When the D-timer is not running, the interrogator identifier of the desired destination shall be stored as the Comm-D II.

Simultaneously, the D-timer shall be started and the DR code (23.4.3.1.2.7.7(1)) shall be set. For a multisite-directed downlink ELM, the D-timer shall not automatically time out but shall continue to run until:

(i) the message is read and closed out by the reserved site; or

(ii) the message is cancelled (23.4.3.1.2.10.5(4)) by the data link avionics.

Note. — The protocols of 23.4.3.1.2.7.7(1) will then result in the delivery of the message to the reserved site. The data link avionics may cancel the message if delivery to the reserved site cannot be accomplished.

(2) Delivery of downlink ELMs. The interrogator shall extract a downlink ELM by transmitting a Comm-C interrogation with RC equals 3. This interrogation shall carry the SRS subfield which specifies the segments to be transmitted. On receipt of this request, the transponder shall transfer the requested segments by means of Comm-D replies with KE equals 0 and ND corresponding to the number of the segment in MD. The first segment shall be transmitted 128 microseconds plus or minus 0.25 microsecond following the sync phase reversal of the interrogation requesting delivery and subsequent segments shall be transmitted at a rate of one every 136 microseconds plus or minus 1 microsecond. If a request is received to transmit downlink ELM segments and no message is waiting, each reply segment shall contain all ZEROs in the MD field.

Note 1. — The requested segments may be transmitted in any order.

Note 2. — Segments lost in downlink transmissions will be requested again by the interrogator on a subsequent interrogation carrying the SRS subfield. This process is repeated until all segments have been transferred.

(a) SRS, segment request subfield in MC. This 16-bit (9-24) uplink subfield in MC shall request the transponder to transfer downlink ELM segments. Starting with bit 9, which denotes segment number 0, each of the following bits shall be set to ONE if the transmission of the corresponding segment is requested. SRS shall appear in MC if RC equals 3 in the same interrogation.

(b) D-timer restart. The D-timer shall be restarted each time that a request for Comm-D segments is received if the Comm-D II is non- zero.

Note. — The requirement for the Comm-D II to be non-zero prevents the D-timer from being restarted during a non-selective downlink ELM transaction.

(3) Multisite downlink ELM closeout. The interrogator shall close out a multisite downlink ELM by transmitting either a surveillance or a Comm-A interrogation containing:

either DI = 1
IIS =assigned interrogator identifier
MES = 4, 5 or 7 (downlink ELM closeout)

Or DI = 0, 1or 7
IIS = assigned interrogator identifier PC = 6 (downlink ELM closeout)

The transponder shall compare the IIS of the interrogation to the Comm-D II and if the interrogator identifiers do not match, the state of the downlink process shall not be changed.

If the interrogator identifiers match, and if a request for transmission has been complied with at least once, the transponder shall set the Comm-D II to 0, reset the D-timer, clear the DR code for this message and clear the message itself.

If another downlink ELM is waiting to be transmitted, the transponder shall set the DR code (if no Comm-B message is waiting to be delivered) so that the reply contains the announcement of the next message.

(4) Automatic expiration of downlink ELM reservation. If the D-timer period expires before a multisite closeout has been accomplished, the Comm-D II shall be set to 0, and the D-timer reset. The message and DR code shall not be cleared.

Note. — This makes it possible for another site to read and clear this message.

23.4.3.1.2.7.8 NON-SELECTIVE DOWNLINK ELM

Note. — In cases where the multisite protocols are not required (i.e. no overlapping coverage or sensor coordination via ground-to-ground communication), the non-selective downlink ELM protocol may be used.

(1) Non-selective downlink ELM delivery shall take place as described in 23.4.3.1.2.7.7(2).

(2) Non-Selective Downlink Elm Closeout
The interrogator shall close out a non-selective downlink ELM by transmitting PC equals 6 (downlink ELM closeout) in a surveillance or Comm-A interrogation. On receipt of this command, and if a request for transmission has been complied with at least once, the transponder shall perform closeout unless the D-timer is running. If the D-timer is running, indicating that a multisite reservation is in effect, the closeout shall be accomplished as per 23.4.3.1.2.7.7(3).

23.4.3.1.2.7.9 ENHANCED DOWNLINK ELM PROTOCOL

Note. — The enhanced downlink ELM protocol provides a higher data link capacity by permitting parallel delivery of downlink ELM messages by up to sixteen interrogators, one for each II code. Operation without the need for multisite downlink ELM reservations is possible in regions of overlapping coverage for interrogators equipped for the enhanced downlink ELM protocol. The protocol is fully conformant to the standard multisite protocol and thus is compatible with interrogators that are not equipped for the enhanced protocol.

(1) General

(a) The interrogator shall determine from the data link capability report whether the transponder supports the enhanced protocols. If the enhanced protocols are not supported by both the interrogator and the transponder, the multisite reservation protocols specified in 23.4.3.1.2.6.11 shall be used for multisite and multisite-directed downlink ELMs.

Note. — If the enhanced protocols are supported, downlink ELMs delivered using the multisite-directed protocol can be delivered without a prior reservation.

(b) If the transponder and the interrogator are equipped for the enhanced protocol, the interrogator shall use the enhanced downlink protocol.

(2) Enhanced multi-site downlink ELM protocol.

(a) The transponder shall be capable of storing a sixteen segment message for each of the sixteen II codes

(b) Initialization. A multisite message input into the transponder shall be stored in the registers assigned to II = 0.

(c) Announcement and extraction. A waiting multisite downlink ELM message shall be announced in the DR field of the replies to all interrogators for which a multisite directed downlink ELM message is not waiting. The UM field of the announcement reply shall indicate that the message is not reserved for any II code, i.e. the IIS subfield shall be set to 0. When a command to reserve this message is received from a given interrogator, the message shall be reserved for the II code contained in the interrogation from that interrogator. After readout and until closeout, the message shall continue to be assigned to that II code. Once a message is assigned to a specific II code, announcement of this message shall no longer be made in the replies to interrogators with other II codes. If the message is not closed out by the associated interrogator for the period of the D-timer, the message shall revert back to multisite status and the process shall repeat. Only one multisite downlink ELM message shall be in process at a time.

(d) Closeout. A closeout for a multi-site message shall only be accepted from the interrogator that was assigned most recently to transfer the message.

(e) Announcement of the next message waiting. The DR field shall indicate a message waiting in the reply to an interrogation containing a downlink ELM closeout if an unassigned multisite downlink ELM is waiting, or if a multisite directed message is waiting for that II code

(23.4.3.1.2.7.9(2)).

(3) Enhanced multi-site directed downlink ELM protocol

(a) Initialization. When a multisite directed message is input into the transponder, it shall be placed in the downlink ELM registers assigned to the II code specified for the message. If the registers for this II code are already in use (i.e. a multisite directed downlink ELM message is already in process for this II code), the new message shall be queued until the current transaction with that II code is closed out.

(b) Announcement. Announcement of a downlink ELM message waiting transfer shall be made using the DR field as specified in 23.4.3.1.2.7.7(1) with the destination interrogator II code contained in the IIS subfield as specified in 23.4.3.1.2.6.5(3)(b). The DR field and IIS subfield contents shall be set specifically for the interrogator that is to receive the reply. A waiting multisite directed message shall only be announced in the replies to the intended interrogator. It shall not be announced in replies to other interrogators.

(c) Delivery. An interrogator shall determine if it is the reserved site through coding in the UM field and, if so, it may proceed to request delivery of the downlink ELM. The delivery shall be performed as specified in 23.4.3.1.2.7.7(2). The transponder shall transmit the message contained in the buffer associated with the II code specified in the IIS subfield of the segment request interrogation.

(d) Closeout. Closeout shall be accomplished as specified in 23.4.3.1.2.7.7(3) except that a message closeout shall only be accepted from the interrogator with a II code equal to the one that transferred the message.

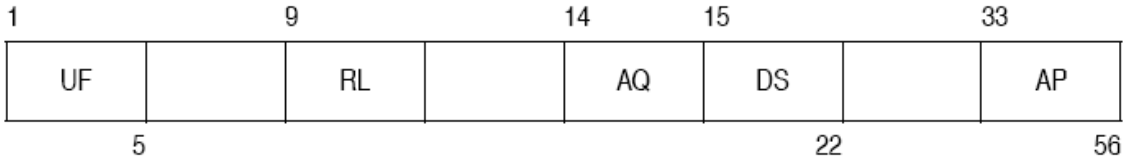
(e) Announcement of the next message waiting. The DR field shall indicate a message waiting in the reply to an interrogation containing a downlink ELM closeout if another multisite directed message is waiting for that II code, or if a downlink message is waiting that has not been assigned a II code (23.4.3.1.2.7.9(2)).

(4) Enhanced non-selective downlink ELM protocol.
The availability of a non-selective downlink ELM message shall be announced to all interrogators. Otherwise, the protocol shall be as specified in 23.4.3.1.2.7.7.

23.4.3.1.2.8 AIR-AIR SERVICE AND SQUITTER TRANSACTIONS

Note. — Airborne collision avoidance system (ACAS) equipment uses the formats UF or DF equals 0 or 16 for air-air surveillance.

(1) SHORT AIR-AIR SURVEILLANCE, ULINK FORMAT 0



The format of this interrogation shall consist of these fields:

Field	**Reference**
UF uplink format	23.4.3.1.2.3.2(1)(a)
spares - 3 bits	
RL reply length	23.4.3.1.2.8(1)(b)
spare - 4 bits	
AQ acquisition	23.4.3.1.2.8(1)(a)
DS data selector	23.4.3.1.2.8(1)(c)
spare - 10 bits	
AP address/parity	23.4.3.1.2.3.2(1)(e)

(a) AQ: Acquisition. This 1-bit (14) uplink field shall contain a code which controls the content of the RI field.

(b) RL: Reply length. This 1-bit (9) uplink field shall command the format to be used for the reply.

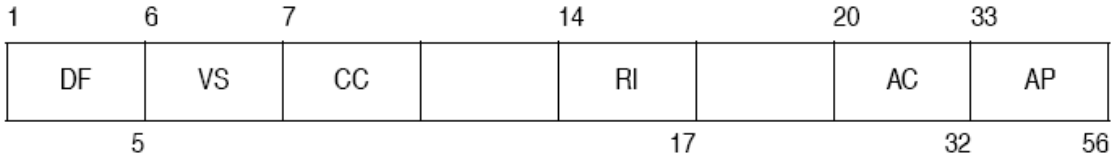
Coding
0 signifies a reply with DF= 0
1 signifies a reply with DF = 16

Note. — A transponder that does not support DF = 16 (i.e. transponder which does not support the ACAS cross-link

capability and is not associated with airborne collision avoidance equipment) would not reply to a UF=0 interrogation with RL=1.

(c) DS: Data selector. This 8-bit (15-22) uplink field shall contain the BDS code (23.4.3.1.2.6.11(2)(a)) of the GICB register whose contents shall be returned to the corresponding reply with DF = 16.

(2) SHORT AIR-AIR SURVEILLANCE, DOWNLINK FORMAT 0



This reply shall be sent in response to an interrogation with UF equals 0 and RL equals 0. The format of this reply shall consist of these fields:

Field	**Reference**
DF downlink format	23.4.3.1.2.3.2(1)(b)
VS vertical status	23.4.3.1.2.8(2)(a)
CC cross-link capability	23.4.3.1.2.8(2)(c)
spare – 1 bit	
RI reply information	23.4.3.1.2.8(2)(b)
spare - 2 bits	
AC altitude code	23.4.3.1.2.6.5(4)
AP address/parity	23.4.3.1.2.3.2(1)(c)

(a) VS: Vertical status: This 1-bit (6) downlink field shall indicate the effective air/ground states (23.4.3.1.2.4.3(3)).

Coding

0 signifies that the effective air/ground state~~aircraft~~ is "airborne"

1 signifies that the effective air/ground state~~aircraft~~ is "on-the-ground"

2

(b) RI: Reply information, air-air. This 4-bit (14-17) downlink field shall report the aircraft's maximum cruising true airspeed capability and type of reply to interrogating aircraft. The coding shall be as follows:

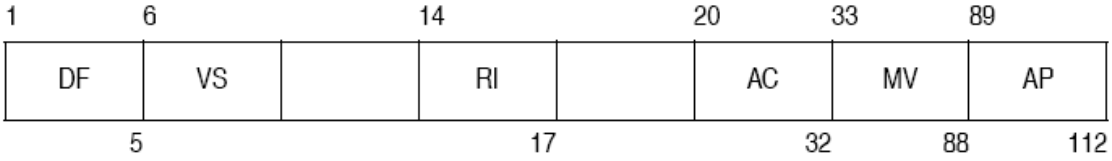
0 signifies a reply to an air-air interrogation UF = 0 with AQ = 0, no operating ACAS
1-7 reserved for ACAS
8-15 signifies a reply to an air-air interrogation UF = 0 with AQ = 1 and that the maximum airspeed is as follows:
8 no maximum airspeed data available
9 maximum airspeed is. LE. 140 km/h (75 kt)
10 maximum airspeed is GT.140 and. LE. 280 km/h (75 and 150kt)
11 maximum airspeed is GT.280 and. LE. 560 km/h (150 and 300kt)
12 maximum airspeed is GT.560 and. LE.1110 km/h (300 and 600kt)
13 maximum airspeed is GT1110 and. LE. 2 220 km/h (600 and 1200 kt)
14 maximum airspeed is more than 2 220 km/h (1 200 kt)
15 not assigned.

Note. — ".LE." means "less than or equal to" and ".GT." means "greater than".

(c) CC: Cross-link capability. This 1-bit (7) downlink field shall indicate the ability of the transponder to support the cross-link capability, i.e. decode the contents of the DS field in an interrogation with UF equals 0 and respond with the contents of the specified GICB register in the corresponding reply with DF equals 16.

Coding
0 signifies that the transponder cannot support the cross-link capability
1 signifies that the transponder supports the crosslink capability.

(3) LONG AIR-AIR SURVEILLANCE, DOWNLINK FORMAT 16



This reply shall be sent in response to an interrogation with UF equals 0 and RL equals 1. The format of this reply shall consist of these fields:

Field	Reference
DF down link format	23.4.3.1.2.3.2(1)(b)
VS vertical status	23.4.3.1.2.8(2)(a)
spare - 7 bits	
SL sensitivity level, ACAS	23.4.4.3.8.4.2.5
spare — 2 bits	
RI reply information	23.4.3.1.2.8(2)(b)
spare - 2 bits	
AC altitude code	23.4.3.1.2.6.5(4)
MV message, ACAS	23.4.3.1.2.8(3)(a)
AP address/parity	23.4.3.1.2.3.2(1)(c)

(a) MV: Message, ACAS. This 56-bit (33-88) downlink field shall contain GICB information as requested in the DS field of the UF 0 interrogation that elicited the reply.

Note. — The MV field is also used by ACAS for air-air coordination (23.4.4.3.8.4.2.4).

(4) AIR-AIR TRANSACTION PROTOCOL

Note. — Interrogation-reply coordination for the air-air formats follows the protocol outlined in Table 3-5 (23.4.3.1.2.4.1.3(3)).

The most significant bit (bit 14) of the RI field of an air-air reply shall replicate the value of the AQ field (bit 14) received in an interrogation with UF equals 0.

If AQ equals 0 in the interrogation, the RI field of the reply shall contain the value 0.

If AQ equals 1 in the interrogation, the RI field of the reply shall contain the maximum cruising true airspeed capability of the aircraft as defined in 23.4.3.1.2.8(2)(b).

In response to a UF = 0 with RL = 1 and DS ≠ 0, the transponder shall reply with a DF = 16 reply in which the MV field shall contain the contents of the GICB register designated by the DS value. If the requested register is not serviced by the aircraft installation, the transponder shall reply and the MV field of the reply shall contain all ZEROs.

(5) ACQUISITION SQUITTER

Note. — SSR Mode S transponders transmit acquisition squitters (unsolicited downlink transmissions) to permit passive acquisition by interrogators with broad antenna beams, where active acquisition may be hindered by all-call synchronous garble. Examples of such interrogators are an airborne collision avoidance system and an airport surface surveillance system.

(a) Acquisition squitter format. The format used for acquisition squitter transmissions shall be the all-call reply, (DF = 11) with II = 0.

(b) Acquisition squitter rate. Acquisition squitter transmissions shall be emitted at random intervals that are uniformly distributed over the range from 0.8 to 1.2 seconds using a time quantization of no greater than 15 milliseconds relative to the previous acquisition squitter, with the following exceptions:

(i) the scheduled acquisition squitter shall be delayed if the transponder is in a transaction cycle (23.4.3.1.2.4.1);

(ii) the acquisition squitter shall be delayed if an extended squitter is in process;

(iii) The scheduled acquisition squitter shall be delayed if a mutual suppression interface is active or

(iv) when the effective air/ground state is "on-the-ground", acquisition squitters shall transmitted only when ~~on the surface if the transponder is not reporting~~ the surface position ~~type of Mode S~~ extended squitter ADS-B messages are not being transmitted (23.4.3.1.2.8.6(3)(b)).

(v)

An acquisition squitter shall not be interrupted by link transactions or mutual suppression activity after the squitter transmission has begun.

Note .— A mutual suppression system may be used to connect onboard equipment operating in the same frequency band in order to prevent mutual interference. Acquisition squitter action resumes as soon as practical after a mutual suppression interval.

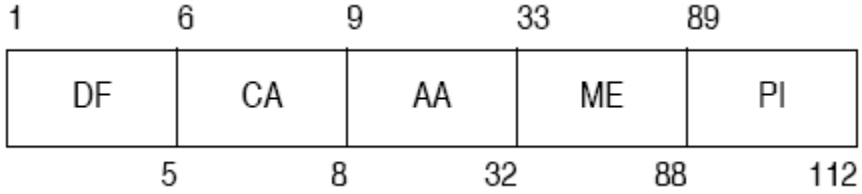
(c) Acquisition squitter antenna selection. Transponders operating with antenna diversity (23.4.3.1.2.10(4)) shall transmit acquisition squitters as follows:

(i) when the effective air/ground state is "airborne" (23.4.3.1.2.4.3(3)), the transponder shall transmit acquisition squitters alternately from the two antennas; and

(ii) when the effective air/ground state is "on-the-ground" ~~on the surface~~ (23.4.3.1.2.4.3(3)), the transponder shall transmit acquisition squitters from ~~under control of SAS 23.4.3.1.2.6.1.4.1 f)). In the absence of any SAS commands, use~~ of the top antenna only ~~shall be the default.~~

Note. — Acquisition squitters are not transmitted if the effective air/ground state is "on-the-ground" (23.4.3.1.2.4.3(3)) and the transponder is transmitting surface position extended squitter ADS-B messages (23.4.3.1.2.8.6(4)(c)).

23.4.3.1.2.8.6 EXTENDED SQUITTER DOWNLINK FORMAT 17



Note. — SSR Mode S transponders transmit extended squitters to support the broadcast of aircraft-derived position for surveillance purposes. The broadcast of this type of information is a form of automatic dependent surveillance (ADS) known as ADS-broadcast (ADS-B).

(1) Extended squitter format. The format used for the extended squitter shall be a 112-bit downlink format (DF = 17) containing the following fields:

Field	Reference
DF downlink format	23.4.3.1.2.3.2(1)(b)
CA capability	23.4.3.1.2.5(2)(b)(i)
AA address, announced	23.4.3.1.2.5(2)(b)(ii)
ME message, extended squitter	23.4.3.1.2.8.6(2)
PI parity/interrogator identifier	23.4.3.1.2.3.2(1)(d))

The PI field shall be encoded with II equal to 0.

(2) ME: Message, extended squitter. This 56-bit (33-88) downlink field in DF = 17 shall be used to transmit broadcast messages. The Extended squitter shall be supported by registers 05, 06, 07, 08, 09, 0A {HEX} and 61-6F {HEX} and shall conform to either version 0, version 1, version 2 or version 3 message formats as described below:

(a) Version 0 ES message formats and related requirements report surveillance quality by navigation uncertainty category (NUC), which can be an indication of either the accuracy or integrity of the navigation data used by ADS-B. However, there is no indication as to which of these, integrity or accuracy, the NUC value is providing an indication of.

(b) Version 1 ES message formats and related requirements report surveillance accuracy and integrity separately as navigation accuracy category (NAC), navigation integrity category (NIC) and surveillance integrity level (SIL).

Version 1 ES formats also include provisions for enhanced reporting of status information.

(c) Version 2 ES message formats and related requirements contain the provisions of version 1 but further enhance integrity and parameter reporting. Version 2 ES formats separately report position source integrity from the integrity of the ADS-B transmitting equipment. Version 2 ES formats also separate vertical accuracy reporting from horizontal position accuracy, remove vertical integrity from position integrity, and provide for the reporting of the SSR Mode A code, GNSS antenna offset and additional horizontal position integrity values. Version 2 ES formats also modify the target state report to include selected altitude, selected heading, and barometric pressure setting.

(d) Version 3 ES message formats and related requirements contain the provisions of Version 2 and incorporate additional capabilities. Version 3 ES improves reporting of geometric altitude, supports the broadcast of weather and aircraft parameters in support of air-to-air and air-to-ground weather application as well as improves emitter category classifications. Version 3 also includes support for UAS/RPAS operations as well as position and velocity reporting to accommodate altitude and velocities not supported by previous versions. To enable monitoring of interrogation rates detected and transmitted reply rates by a transponder, Version 3 supports the broadcast of such transponder activity. Version 3 additionally reports transponder antenna offset, an indication of Mode S reply rate limiting status as well as ACAS coordination capability reporting.

Note 1.— The formats and update rates of each register are specified (Doc 9871). The formats and update rates for individual squitters are defined by the version number of the extended squitter.

Note 2. — The formats for the four different versions are interoperable. An extended squitter receiver can recognize and decode signals of its own version, as well as lower versions' message formats. The receiver, however, can decode higher version signals according to its own capability.

Note 3.— Guidance material on transponder register formats and data sources is included in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871).*

(3) Extended squitter types.

Note. — Extended squitter types described from 23.4.3.1.2.8.6(3)(a) to 23.4.3.1.2.8.6(3)(o) are defined in Doc 9871.

(a) Airborne position squitter. The airborne position extended squitter type shall use format DF = 17 with the contents of GICB register 05 {HEX} inserted in the ME field.

(i) SSS, surveillance status subfield in ME. The transponder shall report the surveillance status of the transponder in this 2-bit (38, 39) subfield of ME when ME contains an airborne position squitter report.

Coding

0	signifies no status information
1	signifies transponder reporting permanent alert condition (23.4.3.1.2.6.10(1)(a)(i))
2	signifies transponder reporting a temporary alert condition (23.4.3.1.2.6.10(1)(a)(ii))
3	signifies transponder reporting SPI condition (23.4.3.1.2.6.10(1)(c))

Codes 1 and 2 shall take precedence over code 3.

(ii) ACS, altitude code subfield in ME. The transponder shall report either navigation-derived altitude, or the barometric altitude code in this 12-bit (41-52) subfield of ME when ME contains an airborne position message. When barometric altitude is reported, the contents of the ACS shall be as specified for the 13-bit AC field (23.4.3.1.2.6.5(4)) except that the M-bit (bit 26) shall be omitted.

(b) Surface position squitter. The surface position extended squitter type shall use format DF = 17 with the contents of

GICB register 06 {HEX} inserted in the ME field.

(c) Aircraft identification squitter. The aircraft identification extended squitter type shall use format DF = 17 with the contents of GICB register 08 {HEX} inserted in the ME field.

(d) Airborne velocity squitter. The airborne velocity extended squitter type shall use format DF = 17 with the contents of GICB register 09 {HEX} inserted in the ME field.

(e) Aircraft operational status squitter. The aircraft operational status extended squitter type shall use format DF = 17 with the contents of GICB register 65 {HEX} inserted in the ME field.

(f) Target state and status squitter. The target state and status extended squitter type shall use format DF = 17 with the contents of GICB register 62 {HEX} inserted in the ME field.

(g) "Emergency/priority status" squitter. The "emergency/priority status" extended squitter type shall use format DF = 17 with the contents of GICB register 61 {HEX} inserted in the ME field.

(h) TCAS RA broadcast squitter. The TCAS RA broadcast extended squitter type shall use format DF = 17 with the contents of GICB register 30 {HEX} inserted in the ME field.

Note. — In ADS-B Version 2, the TCAS RA broadcast extended squitter information was transmitted using the contents in GICB register 61 {HEX} subtype equal to 2.

(i) HVA position squitter. The HVA position extended squitter type shall use format DF = 17 with the contents of GICB register 6E {HEX} inserted in the ME field.

(j) HVA velocity squitter. The HVA velocity extended squitter type shall use format DF = 17 with the contents of GICB register 6F {HEX} inserted in the ME field.

(k) "UAS/RPAS contingency" current/next TCP squitters. The "UAS/RPAS contingency" current/next TCP extended squitter type shall use format DF = 17 with the contents of

GICB register 63 {HEX} to 64 {HEX} inserted in the ME field.

(l) ADS-B Wx AIREP squitters. The ADS-B Wx AIREP extended squitter types shall use the contents of GICB register 68 {HEX} to 6A {HEX}, as applicable, to insert the appropriate aircraft or weather state information in the ME field.

(m) ADS-B Wx PIREP squitters. The ADS-B Wx PIREP extended squitter types shall use the contents of GICB registers 6B {HEX} to 6D {HEX}, as applicable, to insert the appropriate aircraft or weather state information in the ME field.

(n) Extended Squitter event-driven information. The event-driven message shall use format DF = 17 with the contents of GICB register 0A {HEX} inserted in the ME field.

Note. — Although labeled as extended squitter, prior to Version 3, this message would only be broadcast once each time the register was loaded with information. ADS-B Version 3 removed the implementation of this register.

(o) Interrogation/reply monitor squitters. The interrogation/reply monitor squitter types shall use format DF = 17 with the contents of GICB registers 66 {HEX} to 67 {HEX} inserted in the ME field.~~Periodic status and event-driven squitter.~~

(p)

(4) Extended squitter rate.

(a) Initialization. At power up initialization, the transponder shall commence operation in a mode in which it does not transmit extended squitters. The initialization determination shall be made individually for each squitter type.

Note. — Initialization is described in Doc 9871

(b) Airborne position squitter rate. Airborne position squitter transmissions shall be emitted when the broadcast message format (see 23.4.3.1.2.8.6(7))~~aircraft~~ is

"airborne"~~airborne~~ and the HVA position squitter is not transmitted. Airborne position squitter transmissions shall be emitted at random intervals that are uniformly distributed over the range from 0.4 to 0.6 seconds using a time quantization of no greater than 15 milliseconds relative to the previous airborne position squitter, with the exceptions as specified in 23.4.3.1.2.8.6.4(g).

Note. — Selection criteria for the airborne and HVA position squitters are specified in Doc 9871.

(c) Surface position squitter rate. Surface position squitter transmissions shall be emitted when the broadcast message format ~~aircraft is on the surface~~ (see 23.4.3.1.2.8.6(7)) is "surface" using one of two rates depending upon whether the high or low squitter rate has been selected (23.4.3.1.2.8.6(9)). When the high squitter rate has been selected, surface position squitters shall be emitted at random intervals that are uniformly distributed over the range from 0.4 to 0.6 seconds using a time quantization of no greater than 15 milliseconds relative to the previous surface position squitter (termed the high rate). When the low squitter rate has been selected, surface position squitters shall be emitted at random intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds using a time quantization of no greater than 15 milliseconds relative to the previous surface position squitter (termed the low rate). Exceptions to these transmission rates are specified in 23.4.3.1.2.8.6.4(g).

(d)

(e) Aircraft identification squitter rate. Aircraft identification squitter transmissions shall be emitted at random intervals that are uniformly distributed over the range of 4.8 to 5.2 seconds using a time quantization of no greater than 15 milliseconds relative to the previous identification squitter when the aircraft is reporting the airborne position squitter type, or when the aircraft is reporting the surface position squitter type and the high rate has been selected. When the surface position squitter type is being reported at the low rate, the aircraft identification squitter shall be emitted at random intervals that are uniformly distributed over the range of 9.8 to 10.2 seconds using a time quantization of no greater than 15 milliseconds relative to the previous identification squitter. Exceptions

to these transmission rates are specified in 23.4.3.1.2.8.6.4(g).

(f) Airborne velocity squitter rate. Airborne velocity squitter transmissions shall be emitted when the broadcast message format ~~aireraft is airborne~~ (see 23.4.3.1.2.8.6(7)) is "airborne" and the HVA velocity squitter is not transmitted. Airborne velocity squitter transmissions shall be emitted at random intervals that are uniformly distributed over the range from 0.4 to 0.6 seconds using a time quantization of no greater than 15 milliseconds relative to the previous airborne velocity squitter, with the exceptions as specified in 23.4.3.1.2.8.6.4(g)

(g) Other extended squitter rates. Other extended squitters shall be emitted at rates consistent with the extended squitter message type and the associated extended squitter version number.

Note. — Other extended squitter rates are specified in (Doc 9871).

(h) Delayed transmission. Extended squitter transmission shall be delayed in the following circumstances:

(i) if the transponder is in a transaction cycle (23.4.3.1.2.4.1);

(ii) if an acquisition or another type of extended squitter is in process; or

(iii) if a mutual suppression interface is active.

(iv) The delayed squitter shall be transmitted as soon as the transponder becomes available.

(5) Extended squitter antenna selection. Transponders operating with antenna diversity (23.4.3.1.2.10(4)) shall transmit extended squitter's as follows:

(a) when the broadcast message format (see 23.4.3.1.2.8.6(7)) is "airborne", ~~airborne (~~23.4.3.1.2.8.6.7 the transponder shall transmit each type of extended

squitter alternately from the two antennas; and

(b) when the broadcast message format (see 23.4.3.1.2.8.6(7)) is "on-the-ground", the transponder shall transmit extended squitters from the top antenna only.

(6) Register time-out and termination. The transponder shall clear and terminate broadcast of information in extended squitter registers as required to prevent the reporting of outdated information.

Note. — Timeout and termination of extended squitter broadcast is specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

(7) Extended squitter ADS-B message formats

Note 1.— DF = 17 message fields and formats are based on whether the aircraft is determined, by the transponder, to be on-the-ground or airborne. Level 2 and above transponders report declared air/ground status via the CA field in DF = 17 extended squitter ADS-B messages (see 23.4.3.1.2.5(2)(b)(i)).

Note 2. — Extended squitter ADS-B messages are formatted based on the effective air/ground state or the broadcast message format. Effective air/ground state is set based on the declared air/ground status (see 23.4.3.1.2.4.3(3)). Broadcast message format is set based on the declared air/ground status (see 23.4.3.1.2.4.3(3)) and in fixed-wing aircraft may also incorporate the output of a broadcast message format algorithm (see 23.4.3.1.2.8.6.7(c)).

Note 3.— The CA field reports the declared air/ground status (see 23.4.3.1.2.5(2)(b)(i)). ACAS II acquires aircraft using squitters that contain the CA field. If an aircraft reports the declared air/ground status as "on-the-ground", that aircraft will not be interrogated by ACAS II in order to reduce unnecessary interrogation activity.

Note 4.— Use of the following technique may result in surface or airborne format extended squitter ADS-B messages being transmitted when the CA field indicates the declared air/ground status is "unknown" (CA code 6).

(a) Extended squitter ADS-B message format determination for ES version numbers 0 through 2. Mode S transponders that broadcast Version 0, 1 or 2 ES messages whose formats are not determined as described

in 23.4.3.1.2.8.6(7)(b), shall determine the extended squitter ADS-B message format based on the effective air/ground state (see 23.4.3.1.2.4.3(3)).

(i) If the effective air/ground state is "on-the-ground", the extended squitter ADS-B message format shall be "surface".

(ii) If the effective air/ground state is "airborne", the extended squitter ADS-B message format shall be "airborne", except as follows:

(A) for aircraft whose emitter category (see Doc 9871) is Set "A" code 2, 3, 4, 5 or 6, or Set "B" code 7, the extended squitter ADS-B message format shall be "surface" if:

(I) if radio altitude and ground speed are available and airspeed is unavailable, and radio altitude indicates < 50 feet and ground speed indicates < 100 knots; or

(II) if radio altitude and airspeed are available and ground speed is unavailable, and radio altitude indicates < 50 feet and airspeed indicates < 100 knots; or

(III) if radio altitude, ground speed and airspeed are available and radio altitude indicates < 100 knots;

(B) for aircraft whose emitter category (see Doc 9871) is Set "A" code 2, 3, 4, 5 or 6, or Set "B" code 7, the extended squitter ADS-B message format shall be

"surface" if radio altitude is unavailable and available ground speed and airspeed both indicate < 50 knots; or

(C) for aircraft whose emitter category (see Doc 9871) is Set "C" code 1 or 2; the extended squitter ADS-B message format shall be "surface".

(b) Extended squitter ADS-B message format determination for ES version numbers 3 and greater. Mode S transponders shall use the broadcast message format to determine whether to report airborne or surface extended squitter ADS-B messages.

(i) If subsequent to the validation in (23.4.3.1.2.4.3(2) the declared air/ground status is "airborne", the broadcast message format shall be "airborne".

(ii) If subsequent to the validation in (23.4.3.1.2.4.3(2) the declared air/ground status is "on-the ground", the broadcast message format shall be "surface".

(iii) If the emitter category (see Doc 9871) is "surface vehicle – emergency vehicle" or "surface vehicle – service vehicle", the broadcast message format shall be "surface".

(iv) If subsequent to the validation in (23.4.3.1.2.4.3(2)) the declared air/ground status is "unknown" and a broadcast message format algorithm is applicable (see 23.4.3.1.2.8.6.7(c)), the broadcast message format shall be determined by the broadcast message format algorithm output.

(v) If subsequent to the validation in 23.4.3.1.2.4.3(2) the declared air/ground status is "unknown" and a broadcast message format algorithm is not applicable (see 23.4.3.1.2.8.6.7(c)), the broadcast message format shall be "airborne".

(c) Broadcast message format algorithm

Note. — Broadcast message format algorithm, if implemented, provides a means for fixed-wing aircraft, under certain conditions, to determine the broadcast message format using only sensor data available to the transponder. This is desirable to prevent aircraft without a means of automatically determining the on the-ground condition from broadcasting an incorrect extended squitter ADS-B message format.

(i) If not equipped with an automatic means of determining the on the-ground condition, aircraft whose emitter category (see Doc 9871) is Set "A" code 1, 2, 3 or 5 shall implement a broadcast message format algorithm.

(ii) If implemented, broadcast message format algorithm requirements shall apply only to aircraft whose emitter category is Set "A" code 1, 2, 3 or 5.

(iii) Reported broadcast message format. If implemented, the broadcast message format algorithm shall provide a reported broadcast message format that is limited to "airborne" or "surface".

(A) After start-up, if the broadcast message format algorithm does not update the reported broadcast message format within 300 seconds, or for more than 10 seconds after last reporting "surface" or "airborne", the reported broadcast message format shall be set to "airborne".

(B) During taxi and take-off operations, the broadcast message format algorithm shall determine and update the reported broadcast message format prior to entering or within 5 seconds of

exiting 45 the runway transition zone, including while taxiing after landing.

(C) During inflight operations, the broadcast message format algorithm shall maintain a reported broadcast message format of "airborne" while remaining outside of any runway transition zone.

Note. — For additional information regarding broadcast message format algorithm definitions, applicability and performance, refer to RTCA DO-260C/ED-102B §2.2.3.2.2.1.4.

(8) Squitter status reporting. Register 07 {HEX} shall be reserved in transponders conforming to ADS-B Version 3 and later.

Note. — Technical provisions for squitter status reporting (Register 07 {HEX}) for ADS-B Version 2 and earlier can be found in Doc 9871.

(9) Surface squitter rate ~~control.~~ Surface position messages shall be initiated using the low squitter rate. The surface squitter broadcast rate ("high" or "low" as defined in 23.4.3.1.2.8.6(4)(c) shall be determined as follows:

Note. — Transponders conforming to ADS-B Version 2 and earlier examine the transmission rate subfield (TRS) to determine whether to transmit at the "high" or "low" rate. Relevant detailed technical provisions are specified in Doc 9871.

(a) the broadcast rate shall be changed from "high" to "low" when the navigation source position data has not changed more than 10 metres in any 15-minute interval ± 10 seconds;

Note. — It is acceptable to compute the 10-metre distance using either rectangular or polar coordinates.

(b) upon selecting the "low" broadcast rate, the transmission device shall save the position data at the time that the "low" rate was selected (including at initialization); and~~the~~

~~squitter rate determined via TRS shall be subject to being overridden by commands received via RCS (23.4.3.1.2.6.1.4.1 f)). RCS code 1 shall cause the transponder to squitter at the high rate for 60 seconds. RCS code 2 shall cause the transponder to squitter at the low rate for 60 seconds. These commands shall be able to be refreshed for a new 60 second period before time-out of the prior period;~~ and

(c) the broadcast rate shall be changed from "low" to "high" when the position of the transmission device has changed by 10 metres or more since the "low" rate was selected.

(10) Latitude/longitude coding using compact position reporting (CPR). Mode S extended squitter uses compact position reporting (CPR) to encode latitude and longitude efficiently into messages.

Note. — The method used to encode/decode CPR is specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

(11) Data insertion. When the transponder determines that it is time to emit an airborne position squitter, it shall insert the current value of the barometric altitude ~~(unless inhibited by the ATS subfield,~~ and surveillance status into the appropriate fields of register 05 {HEX}. The contents of this register shall then be inserted into the ME field of DF = 17 and transmitted.

Note. — Insertion in this manner ensures that (1) the squitter contains the latest altitude and surveillance status, and (2) ground read-out of register 05 {HEX} will yield exactly the same information as the AC field of a Mode S surveillance reply.

23.4.3.1.2.8.7 EXTENDED SQUITTER/ SUPPLEMENTERY DOWNLINK FORMAT 18

10010	CF:3			PI:24

Note 1. — This format supports the broadcast of extended squitter ADS-B messages by non-transponder devices, i.e. they are not incorporated into a Mode S transponder. A separate format is used to clearly identify this non-transponder case to prevent ACAS II or

extended squitter ground stations from attempting to interrogate these devices.

Note 2. — This format is also used for ground broadcast of ADS-B related services such as traffic information broadcast (TIS-B).

Note 3.— The format of the DF = 18 transmission is defined by the value of the CF field.

(1) ES supplementary format. The format used for ES supplement shall be a 112-bit downlink format (DF = 18) containing the following fields:

Field	Reference
DF downlink format	23.4.3.1.2.3.2(1)(b)
CF control field	23.4.3.1.2.8.7(2)
PI parity/interrogator identifier	23.4.3.1.2.3.2(1)(d)

The PI field shall be encoded with II equal to zero.

(2) Control field. This 3-bit (6-8) downlink field in DF = 18 shall be used to define the format of the 112-bit transmission as follows:

Code 0 = ADS-B ES/NT devices that report the ICAO 24-bit address in the AA field (23.4.3.1.2.8.7(3))

Code 1 = Reserved for ADS-B for ES/NT devices that use other addressing techniques in the AA field (23.4.3.1.2.8.7(3)) Code 2 = Fine format TIS-B message

Code 3 = Coarse format TIS-B message

Code 4 = Reserved for TIS-B management messages

Code 5 = TIS-B messages that relay ADS-B messages that use other addressing techniques in the AA field

Code 6 = ADS-B rebroadcast using the same type codes and message formats as defined for DF = 17 ADS-B

messages

Code 7 = Reserved

Note 1.— Administrations may wish to make address assignments for ES/NT devices in addition to the 24-bit addresses allocated by ICAO (23.3) in order to increase the available number of 24-bit addresses.

Note 2.— These non-ICAO 24-bit addresses are not intended for international use.

(3) ADS-B for extended squitter/non-transponder (ES/NT) devices

10010	CF=0	AA:24	ME:56	PI:24

(a) ES/NT format.

The format used for ES/NT shall be a 112-bit downlink format (DF = 18) containing the following fields:

Field	*Reference*
DF downlink format	23.4.3.1.2.3.2(1)(b)
CF control field = 0	23.4.3.1.2.8.7(2)
AA address, announced	23.4.3.1.2.5(2)(b)(ii)
ME message, extended squitter	23.4.3.1.2.8.6(2)
PI parity/interrogator identifier	23.4.3.1.2.3.2(1)(d)

The PI field shall be encoded with II equal to zero.

(b) ES/NT squitter types

Note. — ES/NT squitter types described from 23.4.3.1.2.8.7(3)(b)(i) to 23.4.3.1.2.8.7(3)(b)(xiii) are defined in Doc 9871.

(i) Airborne position squitter. The airborne position type ES/NT shall use format DF = 18 with the format for register 05 {HEX} inserted in the ME field.

(ii) Surface position squitter. The surface position type ES/NT shall use format DF = 18 with the format for register 06 {HEX} inserted in the ME field.

(iii) Aircraft identification squitter. The aircraft identification type ES/NT shall use format DF = 18 with the format for register 08 {HEX} inserted in the ME field.

(iv) Airborne velocity squitter. The airborne velocity type ES/NT shall use format DF = 18 with the format for register 09 {HEX} inserted in the ME field.

(v) Aircraft operational status squitter. The aircraft operational status extended squitter type shall use format DF = 18 with the contents of GICB register 65 {HEX} inserted in the ME field.

(vi) Target state and status squitter. The target state and status extended squitter type shall use format DF = 18 with the contents of GICB register 62 {HEX} inserted in the ME field.

(vii) "Emergency/Priority status" squitter. The "Emergency/Priority Status" extended squitter type shall use format DF = 18 with the contents of GICB register 61 {HEX} inserted in the ME field.

(viii) HVA position squitter. The HVA position extended squitter type shall use format DF = 18 with the contents of GICB register 6E {HEX} inserted in the ME field.

(ix) HVA velocity squitter. The HVA velocity extended squitter type shall use format DF = 18 with the contents of GICB register 6F {HEX} inserted in the ME field.

(x) "UAS/RPAS Contingency" Current/Next TCP squitter. The "UAS/RPAS Contingency" Current/Next TCP extended squitter type shall use format DF = 18 with the contents of GICB register 63 {HEX} to 64 {HEX} inserted in the ME field.

(xi) ADS-B Wx AIREP squitters. The ADS-B Wx AIREP extended squitter types shall use format DF = 18 with the contents of GICB register 68

{HEX} to 6A {HEX}, as applicable, to insert the appropriate aircraft or weather state information in the ME field.

(xii) ADS-B Wx PIREP squitters. The ADS-B Wx PIREP extended squitter types shall use format DF = 18 with the contents of GICB registers 6B {HEX} to 6D {HEX}, as applicable, to insert the appropriate aircraft or weather state information in the ME field.

(xiii) Extended Squitter event-driven information. The event-driven message shall use format DF = 18 with the contents of GICB register 0A {HEX} inserted in the ME field.

Note. — Although labeled as extended squitter, prior to Version 3 this message would only be broadcast once each time the register was loaded with information. ADS-B Version 3 removed the implementation of this register.

(c) ES/NT squitter rate.

(i) Initialization. At power up initialization, the non-transponder device shall commence operation in a mode in which it does not broadcast any squitters. The non-transponder device shall initiate the broadcast of ES/NT squitters for airborne position, surface position, airborne velocity and aircraft identification when data are available for inclusion in the ME field of these squitter types. This determination shall be made individually for each squitter type. When ES/NT squitters are broadcast, transmission rates shall be as indicated in 23.4.3.1.2.8.6(4)(b) to23.4.3.1.2.8.6(4)(f)

Note 1. — This suppresses the transmission of extended squitters from aircraft that are unable to report position, velocity or identity. If input to the register for the position squitter type stops for 60 seconds, broadcast will cease until data insertion resumes, except for an ES/NT device when the broadcast message format (see

23.4.3.1.2.8.6(7)) is "surface" (as specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871)). Broadcast of airborne position squitters is not discontinued if barometric altitude data is available. Terminating broadcast of other squitter types is described in Doc 9871.

Note 2. — After timeout (3.1.2.8.7.6) this squitter type may contain an ME field of all zeros.

(ii) Delayed transmission. ES/NT squitter transmission shall be delayed if the non-transponder device is busy broadcasting one of the other squitter types.

(A) The delayed squitter shall be transmitted as soon as the non-transponder device becomes available.

(iii) ES/NT antenna selection. Non-transponder devices operating with antenna diversity (23.4.3.1.2.6.10(4)) shall transmit ES/NT squitters as follows:

(A) when the broadcast message format (see 23.4.3.1.2.8.6(7)) is "airborne",~~airborne (23.4.3.1.2.8.6.7),~~ the non-transponder device shall transmit each type of ES/NT squitter alternately from the two antennas; and

(B) when the broadcast message format (see 23.4.3.1.2.8.6(7)) is "surface", ~~on the surface (23.4.3.1.2.8.6.7),~~ the non-transponder device shall transmit ES/NT squitters from~~using~~ the top antenna.

(iv) Register timeout and termination. The non-transponder device shall clear message fields and terminate broadcast of extended squitter

messages as required to prevent the reporting of outdated information.

Note. — The timeout and termination of an extended squitter broadcast is specified in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871).*

(v) Airborne/surface message format selection ~~state determination~~. Non-transponder devices shall report airborne, or surface format extended squitter ADS-B messages as per the requirements in 23.4.3.1.2.8.6(7).~~Aircraft with an automatic means of determining on the ground condition shall use this input to select whether to report the airborne or surface message types except as specified in 23.4.3.1.2.6.10.3.1. Aircraft without such means shall report the airborne type messages.~~

(vi)

(4) THE USE OF ES BY OTHER SURVEILLANCE SYSTEMS.

(a) Surface system control

When a surface surveillance system uses DF=18 as part of a surveillance function, it shall not use the formats that have been allocated for the purpose of surveillance of aircraft, vehicles and/or obstacles.

Note 1.— The formats allocated for the purpose of surveillance of aircraft, vehicles and/or obstacles are specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

Note 2.— The transmission of any message format used for conveying position, velocity, identification, state information, etc., may result in the initiation and maintenance of false tracks in other 1090ES receivers. The use of these messages for this purpose may be prohibited in the future.

(b) Surface system status

The surface system status message type (Type Code=24) shall be the only message used to provide the status or synchronization of surface surveillance systems.

Note. — The surface system status message is specified in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871). This message will be used only by the surface surveillance system that generated it and will be ignored by other surface systems.*

23.4.3.1.2.8.8 MILITARY APPLICATION, DOWNLINK FORMAT 19

10011	AF:3	

Note. — This format supports military application. DF = 19 can be used either as a squitter or as a reply.

(1) Military format. The format used for DF = 19 shall be a 112-bit downlink format containing the following fields:

Field	Reference
DF downlink format	23.4.3.1.2.3.2(1)(b)
AF control field	23.4.3.1.2.8.8(2)

(2) Application field. This 3-bit (6-8) downlink field in DF = 19 shall be used to define the format of the 112-bit transmission.

Code 0 to 7 = Reserved for military use

23.4.3.1.2.8.9 EXTENDED SQUITTER MAXIMUM TRANSMISSION RATE

(1) The maximum total number of full power extended squitters (DF = 17, 18 and 19) emitted by any extended squitter installation shall not exceed a or b below

(a) For a transponder capable of replying to intermode Mode A/C/S all-call interrogations:

(i) 6.2 messages per second averaged over 60

seconds for nominal aircraft operation with no emergency and no ACAS RA activity, while not exceeding 11 messages being transmitted in any 1-second interval; or

(ii) 7.4 messages per second averaged over 60 seconds under an emergency and/or ACAS RA condition, while not exceeding 11 messages being transmitted in any 1-second interval.

(b) For a transponder that does not have the capability to reply to intermode Mode A/C/S all-call interrogations or an extended squitter non-transponder device (23.4.2.1.6(1)(g)):

(i) 6.7 messages per second averaged over 60 seconds for nominal aircraft operations with no temporary alert, no permanent alert, no emergency, no ACAS RA and no UAS/RPAS contingency activity, while not exceeding 15 messages being transmitted in any 1-second interval; or

(ii) 9.2 messages per second averaged over 60 seconds under a temporary/permanent alert, an emergency, an ACAS RA and/or UAS/RPAS contingency condition, while not exceeding 19 messages being transmitted in any 1-second interval.

Note 1. — It is anticipated that the transmission of any new messages required in addition to the capability specified above will be performed using the capacity provided by phase overlay.

Note 2.— The higher extended squitter rates are associated with transponders not capable of replying to intermode Mode A/C/S all-call interrogations in order to keep an equilibrium on 1 090 MHz link that is subject to overload. States are expected to ensure that this link is maintained through their transponder regulation (for example, TSO). The minimum performance of such a transponder can be

found in RTCA DO-181F or EUROCAE ED-73F or later versions.

Note 3. — A higher extended squitter rate (9.2/s) is authorized when there is an emergency, a temporary/permanent alert (Mode A code), an ACAS RA and/or a UAS contingency because such events are rare and are limited to very few platforms at the same time. Therefore, such events have a very limited effect on 1 090 MHz usage.

(2) For installations capable of emitting DF = 19 squitters and in accordance with 23.4.3.1.2.8.8, transmission rates for lower power DF = 19 squitters shall be limited to a peak of forty DF = 19 squitters per second, and thirty DF = 19 squitters per second averaged over 10 seconds, provided that the maximum total squitter power-rate product for the sum of full power DF = 17 squitters, full power DF = 18 squitters, full power DF = 19 squitters, and lower power DF = 19 squitters, is maintained at or below a level equivalent to the power sum of 6.2 full power squitters per second averaged over 10 seconds.

(3) The States shall ensure that the use of low power and higher rate DF = 19 operation (as per 23.4.3.1.2.8.9(2)) is compliant with the following requirements:

(a) it is limited to formation or element lead aircraft engaged in formation flight, directing the messages toward wing and other lead aircraft through a directional antenna with a beamwidth of no more than 90 degrees; and

(b) the type of information contained in the DF = 19 message is limited to the same type of information in the DF = 17 message, that is, information for the sole purpose of safety-of-flight.

Note. — This low-power, higher squitter rate capability is intended for limited use by State aircraft in coordination with appropriate regulatory bodies.

(4) All UF = 19 airborne interrogations shall be included in the interference control provisions of 23.4.4.3.2(2)(b)(ii).

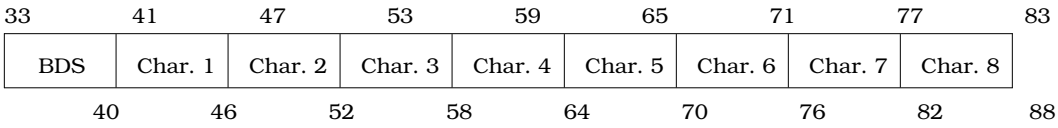
23.4.3.1.2.9 AIRCRAFT IDENTIFICATION PROTOCOL

(1) Aircraft identification reporting. A ground-initiated Comm-B request (23.4.3.1.2.6.11(2)) containing RR equals 18 and either DI does not equal 7 or DI equals 7 and RRS equals 0 shall cause the resulting reply to contain the aircraft identification in its MB field.

(a) AIS, aircraft identification subfield in MB. The transponder shall report the aircraft identification in the 48-bit (41-88) AIS subfield of MB. The aircraft identification transmitted shall be that employed in the flight plan. When no flight plan is available, the registration marking of the aircraft shall be inserted in this subfield.

Note. — When the registration marking of the aircraft is used, it is classified as "fixed direct data" (23.4.3.1.2.10.5(1)(a)). When another type of aircraft identification is used, it is classified as "variable direct data" (23.4.3.1.2.10.5(1)(c))

(b) Coding of the AIS subfield. The AIS subfield shall be coded as follows:



Note. — Aircraft identification coding provides up to eight characters.

(i) The BDS code for the aircraft identification message shall be BDS1 equals 2 (33-36) and BDS2 equals 0 (37-40).

(ii) Each character shall be coded as a 6-bit subset of the International Alphabet Number 5 (IA-5) as illustrated in Table 3-8. The character code shall be transmitted with the high order unit (b6) first and the reported aircraft identification shall be transmitted with its left-most character first. Characters shall be coded consecutively without intervening SPACE code. Any unused character

spaces at the end of the subfield shall contain a SPACE character code.

(c) Aircraft identification capability report. Transponders which respond to a ground-initiated request for aircraft identification shall report this capability in the data link capability report (23.4.3.1.2.6.10(2)(b)(ii)) by setting bit 33 of the MB subfield to 1.

(d) Change of aircraft identification. If the aircraft identification reported in the AIS subfield is changed in flight, the transponder shall report the new identification to the ground by use of the Comm-B broadcast message protocol of 23.4.3.1.2.6.11.4 for BDS1 = 2 (33 – 36) and BDS2 = 0 (37 –40). The transponder shall initiate, generate and announce the revised aircraft identification ~~even if the interface providing flight identification is lost~~. The transponder shall ensure that the BDS code is set for the aircraft identification report in all cases, including a loss of the interface. In this ~~latter case, bits 41 – 88 shall contain all ZEROs.~~

Note 1. — The setting of the BDS code by the transponder ensures that a broadcast change of aircraft identification will contain the BDS code for all cases of aircraft identification failure (for example, the loss of the interface providing aircraft identification).

Note 2.— In some transponders certified on or prior to 1 January 2030, bits 41–88 in register 20 {HEX} were set to zero upon loss of the interface providing aircraft identification. The transponder also initiated, generated and announced the change in aircraft identification upon loss of the interface.

23.4.3.1.2.10 ESSENTIAL SYSTEM CHARACTERISTICS OF THE SSR MODE S AND INTERMODE TRANSPONDER CAPABILITIES

(1) Transponder sensitivity and dynamic range. Transponder sensitivity shall be defined in terms of a given interrogation signal input level and a given percentage of corresponding replies. Only

correct replies containing the required bit pattern for the interrogation received shall be counted. Given an interrogation that requires a reply according to 23.4.3.1.2.4, the minimum triggering level, MTL, shall be defined as the minimum input power level for 90 per cent reply-to-interrogation ratio. The MTL shall be –74 dBm ±3 dB for Mode S interrogations (interrogations using P6) .The reply-to-interrogation ratio of a Mode S transponder shall be:

(a) at least 99 per cent for signal input levels between 3 dB above MTL and -21 dBm; and

(b) no more than 10 per cent at signal input levels below -81 dBm.

Note. — Transponder sensitivity and output power are described in this section in terms of signal level at the terminals of the antenna. This gives the designer freedom to arrange the installation, optimizing cable length and receiver-transmitter design, and does not exclude receiver and/or transmitter components from becoming an integral part of the antenna subassembly.

(c) Reply ratio in the presence of interference.

Note. — The following paragraphs present measures of the performance of the Mode S transponder in the presence of interfering Mode A/C interrogation pulses and low-level in-band CW interference.

(i) Reply ratio in the presence of an interfering pulse. Given a Mode S interrogation which requires a reply (23.4.3.1.2.4), the reply ratio of a transponder shall be at least 95 per cent in the presence of an interfering Mode A/C interrogation pulse if the level of the interfering pulse is 6 dB or more below the signal level for Mode S input signal levels between -68 dBm and -21 dBm and the interfering pulse overlaps the P_6 pulse of the Mode S interrogation anywhere after the sync phase reversal. Under the same conditions, the reply ratio shall be at least 50 per cent if the interference pulse level is 3 dB or more below the signal level.

(ii) Reply ratio in the presence of pulse pair interference. Given Mode S interrogation which

requires a reply (23.4.3.1.2.4), the reply ratio of a transponder shall be at least 90 percent in the presence of an interfering $P_1 - P_2$ pulse pair if the level of the interfering pulse pair is 9 dB or more below signal level for input signal levels between -68 dBm and -21 dBm and the P_1 pulse of the interfering pair occurs no earlier than the P_1 pulse of the Mode S signal.

(iii) Reply ratio in the presence of low-level asynchronous interference. For all received signals between - 65 dBm and -21 dBm and given a Mode S interrogation that requires a reply according to 23.4.3.1.2.4 and if no lockout condition is in effect, the transponder shall reply correctly with at least 95 per cent reply ratio in the presence of asynchronous interference. Asynchronous interference shall be taken to be a single Mode A/C interrogation pulse occurring at all repetition rates up to 10 000 Hz at a level 12 dB or more below the level of the Mode S signal.

Note. — Such pulses may combine with the P1 *and* P2 *pulses of the Mode S interrogation to form a valid Mode A/C-only all-call interrogation. The Mode S transponder does not respond to Mode A/C-only all-call interrogations. A preceding pulse may also combine with the* P2 *of the Mode S interrogation to form a valid Mode A or Mode C interrogation. However, the* $P_1 - P_2$ *pair of the Mode S preamble takes precedence (23.4.3.1.2.4.1(3)(d)). The Mode S decoding process is independent of the Mode A/Mode C decoding process, and the Mode S interrogation is accepted.*

(iv) Reply ratio in the presence of low-level in-band CW interference. In the presence of non-coherent CW interference at a frequency of 1 030 ±0.2 MHz at signal levels of 20 dB or more below the desired Mode S interrogation signal level, the transponder shall reply correctly to at least 90 per cent of the interrogations.

(2) Transponder peak pulse power. The peak power of each pulse of a reply shall:

(a) not be less than 18.5 dBW for aircraft not capable of operating at altitudes exceeding 4 570 m (15 000 ft);

(b) not be less than 21.0 dBW for aircraft capable of operating above 4 570 m (15 000 ft);

(c) not be less than 21.0 dBW for aircraft with maximum cruising speed exceeding 324 km/h (175 kt); and

(d) not exceed 27.0 dBW.

(e) Unwanted output power

(i) Inactive state transponder output power. When the transponder is in the inactive state the peak ~~pulse~~ power at 1 090 MHz plus or minus 3 MHz at the antenna end of the transmission line of the transponder shall not exceed -50 dBm when not installed with an ACAS unit or –70 dBm when installed with an ACAS unit. The inactive state is defined as ~~to include~~ the entire period between transmissions, less 10-microsecond transition periods preceding the first pulse and plus 10-microsecond transition periods following the last pulse of the transmission (see Figure 3-11).

(ii)

Note. — Inactive state transponder power is constrained in this way to ensure that an aircraft, when located as near as 185 m (0.1 NM) to a Mode A/C or Mode S interrogator, does not cause interference to that installation. In certain applications of Mode S, airborne collision avoidance for example, where a 1 090 MHz transmitter and receiver are in the same aircraft, it is necessary to further constrain the inactive state transponder power.

(iii) Active state transponder output power.

(A) The RF output power shall be less than or equal to the peak pulse power minus 50 dB for the interval starting 10 microseconds prior to the Mode S transmission and for the interval of 10 microseconds following a Mode S transmission (see Figure 3-11).

(B) For intervals between transmitted pulses that are greater than 0.5 microsecond, the power level at the lowest point within the interval shall be 50 dB or more below the peak pulse power.

Note 1.— These power limitations protect 1 090 MHz receivers from potential missed decodes when signals are received at close range and within desired detection range. In the absence of such limits, signal levels during non-pulse intervals can occur above receiver thresholds and can lead to unintended distortion of pulse positions or false pulse decodes preventing proper detection of transmitted signals. It also makes it more difficult for receivers to decode overlapped replies.

Note 2.— It is possible that a signal transmitted 50 dB below the peak pulse power can still affect high sensitivity receivers when transmitted in close range. More information is available in Doc 9924.

Note 3.— Information on how to verify unwanted output power can be found in RTCA DO-181F and EUROCAE ED-73F.

Note 4.— The presence of a signal at a level of 50 dB or more below the peak power may not be measurable within the first 0.5

microsecond following the transmission of a pulse because of the allowed decay time.

Note 5.— Transmitters compliant with RTCA DO-181F and EUROCAE ED-73F meet the requirements defined in 23.4.3.1.1.7(17)(b)

(3) SPECIAL CHARACTERISTICS

(a) Mode S side-lobe suppression.

Note. — Side-lobe suppression for Mode S formats occurs when a P5 pulse overlays the location of the sync phase reversal of P6, causing the transponder to fail to recognize the interrogation (23.4.3.1.2.4.1(3)(f)).

(b) Given a Mode S interrogation that requires a reply, the transponder shall:

(i) at all signal levels between MTL +3 dB and -21 dBm, have a reply ratio of less than 10 per cent if the received amplitude of P_5 exceeds the received amplitude of P_6 by 3 dB or more;

(ii) at all signal levels between MTL +3 dB and -21 dBm, have a reply ratio of at least 99 per cent if the received amplitude of P_6 exceeds the received amplitude of P_5 by 12 dB or more.

(c) Dead time.

(i) For all transponders, ~~Dead time shall be defined as~~ the time interval beginning at the end of a reply transmission and ending when the receiver ~~transponder~~ has regained sensitivity to within 3 dB of MTL

(ii) (dead time). shall not (dead time)125 microseconds'.

(iii) For transponders with improved dead time, the time interval beginning at the end of a reply transmission and ending when the receiver has regained sensitivity to within 3 dB of MTL (dead time) shall not exceed 20 microseconds.

(d) Mode S receiver desensitization. The transponder's

receiver shall be desensitized according to 23.4.3.1.1.7(7) (a) on receipt of any pulse of more than 0.7 microseconds duration.

(i) Recovery from desensitization. Recovery from desensitization shall begin at the trailing edge of each pulse of a received signal and shall occur at the rate prescribed in 23.4.3.1.1.7(7)(b) provided that no reply or data transfer is made in response to the received signal.

(e) Recovery after Mode S interrogations that do not elicit replies.

(i) Recovery after a single Mode S interrogation**.**

(A) The transponder shall recover sensitivity to within 3 dB of MTL no later than 128 microseconds after receipt of the sync phase reversal following a Mode S interrogation that is not accepted (23.4.3.1.2.4.1.2) or that is accepted but requires no reply.

(B) The transponder shall recover sensitivity to within 3 dB of MTL no later than 45 microseconds after receipt of the sync phase reversal following a Mode S interrogation that is not accepted (23.4.3.1.2.4.1.2)or that is accepted but requires no reply.

(ii) Recovery after a Mode S Comm-C interrogation. A Mode S transponder with Comm-C capability shall recover sensitivity to within 3 dB of MTL no later than 45 microseconds after receipt of the sync phase reversal following acceptance of a Comm-C interrogation for which no reply is required.

(f) Unwanted Mode S replies. Mode S transponders shall not generate unwanted Mode S replies more often than once in 10 seconds. Installation in the aircraft shall be made in

such a manner that this standard shall be achieved when all possible interfering equipments installed in the same aircraft are operating at maximum interference levels.

(i) Unwanted Mode S replies in the presence of low-level in-band CW interference. In the presence of non- coherent CW interference at a frequency of 1 030 ±0.2 MHz and at signal levels of -60 dBm or less, and in the absence of valid interrogation signals, Mode S transponders shall not generate unwanted Mode S replies more often than once per 10 seconds.

(g) Reply rate limiting

Note. — Reply rate limiting is prescribed separately for Modes A and C and for Mode S.

(i) Mode S reply rate limiting

(A) Mode S reply rate limiting . ~~Reply rate limiting is not required for the Mode S formats of a transponder. If such limiting is incorporated for circuit protection, it~~ shall permit the minimum reply rates required in 23.4.3.1.2.10(3)(h)(ii) and23.4.3.1.2.10(3)(h)(iii).

Note. — Mode S transponders certified before 1 January 2030 have no requirement for Mode S reply rate limiting function and may have a different implementation of this function.

(B) Mode S reply rate limiting type 1 3.

(I) Mode S reply rate limiting shall be separate from Modes A and C reply rate limiting.

(II) The Mode S reply rate limiting shall ensure the transponder does not cease to reply to valid Mode S interrogations for a period greater

than 100 milliseconds.

(III) The Mode S reply rate limiting shall limit the Mode S replies to a maximum reply rate of 180 Mode S replies per second or less.

Note. — The maximum reply rate limit can be less than the 180 specified here but is greater than the minimums specified in 23.4.3.1.2.10(3)(h)(iii).

(IV) The Mode S reply rate limiting shall be accomplished using methods other than sensitivity reduction.

Note. — Sensitivity-reduction rate limiting is prohibited due to the potential impact on ACAS.

(V) The Mode S reply rate limiting function shall exclude the acquisition squitter (see 23.4.3.1.2.8(5)) and extended squitter (see 23.4.3.1.2.8.6) transmissions.

(VI) The Mode S reply rate limiting function shall process received interrogations regardless of the received antenna channel.

(VII) The Mode S reply rate limiting function shall process received interrogations regardless of uplink format.

Note. — The Mode S reply rate limiting also includes replies to ACAS resolution and coordination messages.

(VIII)The Mode S reply rate limiting shall be accomplished stochastically.

(ii) Modes A and C reply rate limiting. Modes A and C prescribed sensitivity reduction (23.4.3.1.1.7(9)(b)) shall not affect the Mode S performance of the transponder.

(h) Minimum reply rate capability, Modes S.

(i) All reply rates specified in 23.4.3.1.2.10(3)(h)(iii) shall be in addition to any squitter transmissions that the transponder is required to make.

(ii) Minimum reply rate capability, Mode S. A transponder capable of transmitting only short Mode S replies shall be able to generate replies at the following rates:

50 Mode S replies in any 1-second interval 18 Mode S replies in a 100-millisecond interval 8 Mode S replies in a 25-millisecond interval 4 Mode S replies in a 1.6-millisecond interval

(A) In addition to any downlink ELM transmissions, a level 2, 3 or 4 transponders shall be able to generate as long replies at least:

16 of 50 Mode S replies in any 1-second interval
6 of 18 Mode S replies in a 100-millisecond interval
4 of 8 Mode S replies in a 25-millisecond interval 2 of 4 Mode S replies in a 1.6-millisecond interval

(B) Transponders used in conjunction with ACAS shall be able to generate as long replies at least:

60 Mode S replies in any 1-second interval 6 of 18 Mode S replies in a 100-millisecond interval 4 of 8 Mode S replies in a 25-millisecond interval 2 of 4 Mode S replies in a 1.6-millisecond interval

(C) In addition to downlink ELM transmissions, a level 5 transponder shall be able to generate as long replies at least:

24 of 50 Mode S replies in any 1-second interval
9 of 18 Mode S replies in a 100-millisecond interval 6 of 8 Mode S replies in a 25-millisecond interval
2 of 4 Mode S replies in a 1.6-millisecond interval.

(iii) Minimum Mode S ELM peak reply rate.

Note 1.— When a downlink ELM is initialized (23.4.3.1.2.7.7(1)), the Mode S transponder announces the length (in segments) of the waiting message. The transponder must be able to transmit this number of segments, plus an additional margin to make up for missed replies, during the beam dwell of the ground interrogator.

(A) At least once every second a Mode S transponder equipped for ELM downlink operation shall be capable of transmitting in a 25- millisecond interval, at least 25 per cent more segments than have been announced in the initialization (23.4.3.1.1.7.7(1)). The minimum length downlink ELM capability for level 4 and 5 transponders shall be as specified in 23.4.3.1.2.10.5(2)(b)(ii);

Note 2.— A transponder capable of processing the maximum length downlink ELM (16 segments) is therefore required to be able to transmit 20 long replies under the above conditions. Level 4 transponders may be built which process less than the maximum message length. These transponders cannot initialize a message length that exceeds their transmitter capability. For example, a transponder that can transmit at most 10 long replies under

the above conditions can never announce a message of more than 8 segments.

(i) Reply delay and jitter for Mode S

(i) For all input signal levels between MTL and –21 dBm, the leading edge of the first preamble pulse of the reply (23.4.3.1.2.2(7)(a)(i)) shall occur 128 plus or minus 0.25 microsecond after the sync phase reversal (23.4.3.1.2.2(7)(a)(ii)) of the received P6. The jitter of the reply delay shall be less than or equal to 0.08 microsecond, peak (99.9 percentile).

(j) Timers. Duration and features of timers shall be as shown in Table 3-9. All timers shall be capable of being restarted. On receipt of any start command, they shall run for their specified times. This shall occur regardless of whether they are in the running or the non-running state at the time that the start command is received. A command to reset a timer shall cause the timer to stop running and to return to its initial state in preparation for a subsequent start command.

(k) Inhibition of replies. Replies to Mode A/C/S all-call and Mode S- only all-call interrogations shall always be inhibited when the effective air/ground state is "on-the-ground" It shall not be possible to inhibit replies to discretely addressed Mode S interrogations.

Note. — Transponders certified on or after 1 January 2020 also inhibit replies to the Mode A/C/S all-call when the effective air/ground state is "on-the-ground" (see 23.4.2.1.6(4)(d)).

(i) Aircraft shall provide air/ground data~~means to determine the on-the-ground state automatically and provide that information~~ to the transponder.

(ii) Mode A/C replies from transponders with a Mode S capability shall be inhibited when the effective air/ground state is "on-the-ground" ~~shall be inhibited when the aircraft is on the ground~~ to prevent interference when in close

proximity to an interrogator or other aircraft.

(iii)

Note. — Mode S discretely addressed interrogations do not give rise to such interference and may be required for data link communications with aircraft on the airport surface. Acquisition squitter transmissions may be used for passive surveillance of aircraft on the airport surface.

Table 3-9. Timer characteristics

Timer Name	*Number*	*Reference*	*Symbol*	*Duration s*	*Tolerance s*	*Resettable*
Non-selective lock-out	1	3.1.2.6.9.2	T_D	18	±1	no
Temporary alert	1	3.1.2.6.10.1.1.2	T_C	18	±1	no
SPI	1	3.1.2.6.10.1.3	T_I	18	±1	no
Reservations B, C, D	3*	3.1.2.6.11.3.1	T_R	18	±1	yes
Multisite lockout	78	3.1.2.6.9.1	T_L	18	±1	no
* As required						

(4) Transponder antenna system and diversity operation. Mode S transponders equipped for diversity operation shall have two RF ports for operation with two antennas, one antenna on the top and the other on the bottom of the aircraft's fuselage. The received signal from one of the antennas shall be selected for acceptance and the reply shall be transmitted from the selected antenna only.

(a) Radiation pattern. The radiation pattern of antennas when installed on an aircraft shall be nominally

equivalent to that of a quarter-wave monopole on a ground plane.

Note. — Transponder antennas designed to increase gain at the expense of vertical beamwidth are undesirable because of their poor performance during turns.

(b) Antenna location. The top and bottom antennas shall be mounted as near as possible to the centre line of the fuselage. Antennas shall be located so as to minimize obstruction to their fields in the horizontal plane.

(i) The horizontal distance between the top and bottom antennas shall not be greater than 7.6 m (25 ft).

Note. —This provision is intended to support the operation of any diversity transponder (including cables) with any diversity antenna installation and still satisfy the requirement of 23.4.3.1.2.10(4)(e).

(c) Antenna selection. Mode S transponders equipped for diversity operation shall have the capability to evaluate a pulse sequence simultaneously received on both antenna channels to determine individually for each channel if the P_1 pulse and the P_2 pulse of a Mode S interrogation preamble meet the requirements for a Mode S interrogation as defined in 23.4.3.1.1

Note. — Transponders equipped for diversity operation may optionally have the capability to evaluate additional characteristics of the received pulses of the interrogations in making a diversity channel selection. The transponder may as an option evaluate a complete Mode S interrogation simultaneously received on both channels to determine individually for each channel if the interrogation meets the requirements for Mode S interrogation acceptance as defined in 23.4.3.1.2.4.1.2.1(3).

(i) If the two channels simultaneously receive at least a P_1 – P_2 pulse pair that meets the requirements for a Mode S interrogation, or if

the two channels simultaneously accept a complete interrogation, the antenna at which the signal strength is greater shall be selected for the reception of the remainder (if any) of the interrogation and for the transmission of the reply.

(ii) If only one channel receives a pulse pair that meets the requirements for an interrogation, or if only one channel accepts an interrogation, the antenna associated with that channel shall be selected regardless of received signal strength.

(iii) Selection threshold. If antenna selection is based on signal level, it shall be carried out at all signal levels between MTL and -21 dBm.

Note. — Either antenna may be selected if the difference in signal level is less than 3 dB.

(iv) Received signal delay tolerance. If an interrogation is received at one antenna 0.125 microsecond or less in advance of reception at the other antenna, the interrogations shall be considered to be simultaneous interrogations, and the above antenna selection criteria applied. If an accepted interrogation is received at either antenna 0.375 microsecond or more in advance of reception at the other antenna, the antenna selected for the reply shall be that which received the earlier interrogation. If the relative time of receipt is between 0.125 and 0.375 microsecond, the transponder shall select the antenna for reply either on the basis of the simultaneous interrogation criteria or on the basis of the earlier time of arrival.

(d) Diversity transmission channel isolation. The peak RF power transmitted from the selected antenna shall exceed the power transmitted from the non-selected antenna by at least 20 dB.

(e) Reply delay of diversity transponders. The total two-way transmission difference in mean reply delay between the two antenna channels (including the differential delay

caused by transponder-to- antenna cables and the horizontal distance along the aircraft centre line between the two antennas) shall not exceed 0.13 microsecond for interrogations of equal amplitude. This requirement shall hold for interrogation signal strengths between MTL +3 dB and -21 dBm. The jitter requirements on each individual channel shall remain as specified for non-diversity transponders.

Note. — This requirement limits apparent jitter caused by antenna switching and by cable delay differences.

23.4.3.1.2.10.5 DATA PROCESSING AND INTERFACES

(1) Direct data. Direct data shall be those which are required for the surveillance protocol of the Mode S system.

(a) Fixed direct data. Fixed direct data are data from the aircraft which do not change in flight and shall be:

(i) the aircraft address (23.4.3.1.2.4.1.2.1(5) and23.4.3.1.2.5(2)(b)(ii);

(ii) the maximum airspeed (23.4.3.1.2.8(2)(b)); and

(iii) the registration marking if used for flight identification (23.4.3.1.2.9(1)(a)).

(b) Interfaces for fixed direct data. Interfaces from the transponder to the aircraft shall be designed such that the values of the fixed direct data become a function of the aircraft installation rather than of the transponder configuration.

Note. — The intent of this provision is to encourage an interface technique which permits transponder exchange without manipulation of the transponder itself for setting the fixed direct data.

(c) Variable direct data. Variable direct data are data from the aircraft which may change in flight and shall be:

(i) the Mode C altitude code (23.4.3.1.2.6.5(4));

(ii) the Mode A identity code (23.4.3.1.2.6.7(1));

(iii) air/ground data (23.4.3.1.2.5(2)(b)(i), 23.4.3.1.2.6.5(1) and23.4.3.1.2.8(2)(a));

(iv) the aircraft identification if different from the registration marking (23.4.3.1.2.9(1)(a)); and

(v) the SPI condition (23.4.3.1.2.6.10(1)(b)).

(d) Interfaces for variable direct data.

(i) A means shall be provided, while on the ground or during flight, for the SPI condition to be inserted by the pilot, without the entry or modification of other flight data.

(ii) A means shall be provided, while on the ground or during flight, for the Mode A identity code to be displayed to the pilot and modified without the entry or modification of other flight data.

(iii) For transponders of Level 2 and above, a means shall be provided, while on the ground or during flight, for the aircraft identification to be displayed to the pilot, and, when containing variable data (23.4.3.1.2.10.5(1)(c)(iv)), to be modified without the entry or modification of other flight data.

Note. — Implementation of the pilot action for entry of data will be as simple and efficient as possible in order to minimize the time required and reduce the possibility of errors in the data entry.

(iv) Interfaces shall be included to accept the pressure-altitude and air/ground data

Note. — A specific interface design for the variable direct data is not prescribed.

(2) Indirect data

Note. — Indirect data are those which pass through the transponder in either direction, but which do not affect the surveillance function.

If origins and/or destinations of indirect data are not within the transponder's enclosure, interfaces shall be used for the necessary connections.

(a) The function of interfaces

Note. — Indirect data interfaces for standard transactions serve interrogations which require a reply and the broadcast function. Indirect data interfaces for ELM serve that system and require buffering and protocol circuitry within the transponder. Interface ports can be separate for each direction and for each service or can be combined in any manner.

(i) Uplink standard length transaction interface. The uplink standard length transaction interface shall transfer all bits of accepted interrogations, (with the possible exception of the AP field), except for UF = 0, 11 or 16.

Note. — AP can also be transferred to aid in integrity implementation.

(ii) Downlink standard length transaction interface. A transponder which transmits information originating in a peripheral device shall be able to receive bits or bit patterns for insertion at appropriate locations within the transmission. These locations shall not include those into which bit patterns generated internally by the transponder are inserted, nor the AP field of the reply. A transponder which transmits information using the Comm-B format shall have immediate access to requested data in the sense that the transponder shall respond to an interrogation with data requested by that interrogation.

Note. — This requirement may be met in two ways:

(A) the transponder may have provisions for internal data and protocol buffering;

(B) the transponder may employ a "real time" interface which operates such that uplink data leave the transponder before the corresponding reply is generated and downlink data enter the transponder in time to be incorporated in the reply.

(iii) Extended length message interface

Note. — The ELM interface extracts from, and enters into, the transponder the data exchanged between air and ground by means of the ELM protocol (23.4.3.1.2.7).

(b) Indirect data transaction rates

(i) Standard length transactions. A transponder equipped for information transfer to and from external devices shall be capable of processing the data of at least as many replies as prescribed for minimum reply rates in 23.4.3.1.2.10(3)(h)(ii) and uplink data from interrogations being delivered at a rate of at least:

50 long interrogations in any 1-second interval
18 long interrogations in a 100-millisecond interval 8 long interrogations in a 25-millisecond interval
4 long interrogations in a 1.6-millisecond interval.

Note 1.— A transponder capable of reply rates higher than the minimum of 23.4.3.1.2.10(3)(h)(ii) *need not accept long interrogations after reaching the uplink data processing limits above.*

Note 2. — The Mode S reply is the sole means of

acknowledging receipt of the data content of a Mode S interrogation. Thus, if the transponder is capable of replying to an interrogation, the Mode S installation must be capable of accepting the data contained in that interrogation regardless of the timing between it and other accepted interrogations. Overlapping Mode S beams from several interrogators could lead to the requirement for considerable data processing and buffering. The minimum described here reduces data processing to a realistic level and the non-acceptance provision provides for notification to the interrogator that data will temporarily not be accepted.

(ii) Extended length transactions. Level 3 (23.4.2.1.6(1)(c)) and level 4 (23.4.2.1.6(1)(d)) transponders shall be able to transfer data from at least four complete sixteen segment uplink ELMs (23.4.3.1.2.7(4)) in any four second interval. A level 5 transponder (23.4.2.1.6(1)(e)) shall be able to transfer the data from at least four complete sixteen segment uplink ELMs in any one second interval and shall be capable of accepting at least two complete sixteen segment uplink ELMs with the same II code in a 250-millisecond interval. A level 4 transponder shall be able to transmit at least one four-segment downlink ELM (23.4.3.1.2.7.7 and 23.4.3.1.2.10(3)(h)(ii) in any one second interval. A level 5 transponder shall be able to transmit at least one sixteen segment downlink ELM in any one second interval.

(A) Level 3 and level 4 transponders shall be able to accept at least two complete sixteen segment uplink ELMs in a 250-millisecond interval.

(c) Data formats for standard length transactions and required downlink aircraft parameters (DAPs)

(i) All level 2 and above transponders shall support the following registers:

(A) the capability reports (23.4.3.1.2.6.10(2));

(B) the aircraft identification protocol register 20 {HEX} (23.4.3.1.2.9); and

(C) for ACAS-equipped aircraft, the active resolution advisory register 30 {HEX} (23.4.4.3.8.4(2)(b)).

(ii) Where required, DAPs shall be supported by the registers listed in Table 3-10. The formats and minimum update rates of transponder registers shall be implemented consistently to ensure interoperability.

(iii) The downlink standard length transaction interface shall deliver downlink aircraft parameters (DAPs) to the transponder which makes them available to the ground. Each DAP shall be packed into the Comm-B format ('MB' field) and can be extracted using either the ground-initiated Comm-B (GICB) protocol or using MSP downlink channel 3 via the dataflash application.

Note. — The formats and update rates of each register and the dataflash application are specified in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871).*

(3) Integrity of data content transfer. A transponder which employs data interfaces shall include sufficient protection to ensure error rates of less than one error in 103 messages and less than one undetected error in 107 112-bit transmissions in both directions between the antenna and each interface port.

(4) Message cancellation. The downlink standard length transaction interface and the extended length message interface shall include the capability to cancel a message sent to the transponder for delivery to the ground, but whose delivery cycle has not been completed (i.e. a closeout has not been accomplished by a ground interrogator).

(5) Air-directed messages. The transfer of this type of message

requires all of the actions indicated in 23.4. 3.1.2.10.5(4) plus the transfer to the transponder of the interrogator identifier of the site that is to receive the message.

23.4.3.1.2.11 ESSENTIAL SYSTEM CHARACTERISTICS OF THE GROUND INTERROGATOR MODE S CAPABILITIES

(1) Interrogation repetition rates.
Mode S interrogators shall use the lowest practicable interrogation repetition rates for all interrogation modes.

Note. — Accurate azimuth data at low interrogation rates can be obtained with monopulse techniques.

(a) All-call interrogation repetition rate.

(i) The interrogation repetition rate for the paired Mode S-only and Mode A/C-only all-call interrogations used for acquisition in the multisite mode shall be less than 250 per second.

(ii) Maximum number of Mode S all-call replies triggered by an interrogator. For aircraft that are not locked out, a Mode S interrogator shall not trigger, on average, more than 6 Mode S all-call replies per period of 200 ms and no more than 26 Mode S all-call replies counted over a period of 18 seconds.

(b) Interrogation repetition rate to a single aircraft

(i) Interrogations requiring a reply. Mode S interrogations requiring a reply shall not be transmitted to a single aircraft at intervals shorter than 400 microseconds.

(ii) Uplink ELM interrogations. The minimum time between the beginning of successive Comm-C interrogations shall be 50 microseconds.

(c) Transmission rate for selective interrogations.

(i) For all Mode S interrogators, the transmission

rate for selective interrogations shall be:

(A) less than 2 400 per second averaged over a 40-millisecond interval; and

(B) less than 480 into any 3-degree sector averaged over a 1-second interval.

(ii) Additionally, for a Mode S interrogator that has overlapping coverage with the sidelobes of any other Mode S interrogator, the transmission rate for selective interrogations shall be:

(A) less than 1 200 per second averaged over a 4-second interval; and

(B) less than 1 800 per second averaged over a 1-second interval.

Note. — Typical minimum distance to ensure sidelobe separation between interrogators is 35 km.

(2) INTERROGATOR-EFFECTIVE RADIATED POWER

(a) The effective radiated power of all interrogation pulses shall be minimized as described in 23.4.3.1.1.8(3).

(3) Inactive-state interrogator output power. When the interrogator transmitter is not transmitting an interrogation, its output shall not exceed -5 dBm effective radiated power at any frequency between 960 MHz and 1 215 MHz.

Note. — This constraint ensures that aircraft flying near the interrogator (as close as 1.85 km (1 NM)) will not receive interference that would prevent them from being tracked by another interrogator. In certain instances, even smaller interrogator-to-aircraft distances are of significance, for example if Mode S surveillance on the airport surface is used. In such cases a further restraint on inactive state interrogator output power may be necessary.

(a) Spurious emission radiation

CW radiation shall not exceed 76 dB below 1 watt.

(4) SPURIOUS RESPONSE

The response to signals not within the passband shall be at least 60 dB below normal sensitivity.

(5) Lockout coordination. A Mode S interrogator shall not be operated using all-call lockout until coordination has been achieved with all other operating Mode S interrogators having any overlapping coverage volume in order to ensure that no interrogator can be denied the acquisition of Mode S-equipped aircraft. If coordination is not possible due to system designs (for example, a mobile interrogator), the interrogator shall either use passive means of acquisition or operate using lockout override (23.4.3.1.2.5(2)(a)(iv)) with supplementary acquisition (23.4.3.1.2.5(2)(a)(v).

Note 1. — This coordination may be via ground network or by the allocation of interrogator codes and will involve regional agreements where coverage overlaps international boundaries.

Note 2. — Interrogators that do not use Mode S-only all-call interrogations, all-call lockout protocol or multisite data link protocol can use any IC value in the IIS or SIS fields of their selective interrogations without a need for coordination with neighbouring systems.

(6) MOBILE INTERROGATORS

Mobile interrogators shall acquire, whenever possible, Mode S aircraft through the reception of squitters.

Note. — Passive squitter acquisition reduces channel loading and can be accomplished without the need for coordination.

TABLES ~~Table 3-11. Transmitted signal tolerances~~

Table 3-1. Pulse shapes Interrogation pulse durations

Pulse Duration Duration tolerance (Rise time) (Decay time) Min. Max. Min. Max.

Reference	*Function*	*Tolerance*
3.1.2.1.4.1	Pulse duration P_1, P_2, P_3, P_4, P_5	±0.09 microsecond
	Pulse duration P_6	±0.20 microsecond
3.1.1.4	Pulse duration $P_1 - P_3$	±0.18 microsecond
	Pulse duration $P_1 - P_2$	±0.10 microsecond
3.1.2.1.5.1.3	Pulse duration $P_3 - P_4$	±0.04 microsecond
3.1.2.1.5.2.4	Pulse duration $P_1 - P_2$	±0.04 microsecond
	Pulse duration P_2 — sync phase reversal	±0.04 microsecond
	Pulse duration P_6 — sync phase reversal	±0.04 microsecond
	Pulse duration P_5 — sync phase reversal	±0.05 microsecond
3.1.1.5	Pulse amplitude P_3	P_1 ±0.5 dB
3.1.2.1.5.1.4	Pulse amplitude P_4	P_3 ±0.5 dB
3.1.2.1.5.2.5	Pulse amplitude P_6	Equal to or greater than $P_2 - 0.25$ dB
3.1.2.1.4.1	Pulse rise times	0.05 microsecond minimum, 0.1 microsecond maximum
3.1.2.1.4.1	Pulse decay times	0.05 microsecond minimum, 0.2 microsecond maximum

23.4.4 AIRBORNE COLLISION AVOIDANCE SYSTEM

23.4.4.1 DEFINITIONS RELATING TO AIRBORNE COLLISION AVOIDANCE SYSTEM

23.4.4.2 ACAS I GENERAL PROVISIONS AND CHARACTERISTICS

(1) Functional requirements. ACAS I shall perform the following functions:

(a) surveillance of nearby SSR transponder-equipped aircraft; and

(b) provide indications to the flight crew identifying the approximate position of nearby aircraft as an aid to visual acquisition.

Note. — ACAS I is intended to operate using Mode A/C interrogations only. Furthermore, it does not coordinate with other ACAS. Therefore, a Mode S transponder is not required as a part of an ACAS I installation.

(2) Signal format. The RF characteristics of all ACAS I signals shall conform to the provisions of 23.4.3.1.1.1 through 23.4.3.1.1.6 and 23.4.3.1.2.1 through 23.4.3.1.2.4.

(3) Interference control.

(a) Maximum radiated RF power. The effective radiated power of an ACAS I transmission at 0-degree elevation relative to the longitudinal axis of the aircraft shall not exceed 24 dBW.

(b) Unwanted radiated power. When ACAS I is not transmitting an interrogation, the effective radiated power in any direction shall not exceed -70 dBm.

Note. — This requirement is to ensure that, when not transmitting an interrogation, ACAS I does not radiate RF energy that could interfere with, or reduce the sensitivity of, the SSR transponder or radio equipment in other nearby aircraft or ground facilities.

(c) Interference limiting**.** Each ACAS I interrogator shall control its interrogation rate or power or both in all SSR modes to minimize interference effects (23.4.4.2(3)(c)(iii)) and 23.4.4.2(3)(c)(iv)).

(i) Determination of own transponder reply rate. ACAS I shall monitor the rate that own transponder replies to

interrogations to ensure that the provisions in 23.4.4.2(3)(c)(iii)) are met.

(ii) Determination of the number of ACAS II and ACAS III interrogators. ACAS I shall count the number of ACAS II and ACAS III interrogators in the vicinity to ensure that the provisions in 23.4.4.2(3)(c)(iii)) or 23.4.4.2(3)(c)(iv)) are

met. This count shall be obtained by monitoring ACAS broadcasts (UF = 16), (23.4.4.3.7(1)(b)(iv) and shall be updated as the number of distinct ACAS aircraft addresses received within the previous 20-s period at a nominal frequency of at least 1 Hz.

(iii) Mode A/C ACAS I interference limits. The interrogator power shall not exceed the following limits:

n_a	*Upper limit for* $\{\sum_{k=1}^{k_1} P_a(k)\}$	
	If $f_r \leq 240$	*If* $f_r > 240$
0	250	118
1	250	113
2	250	108
3	250	103
4	250	98
5	250	94
6	250	89
7	250	84
8	250	79
9	250	74
10	245	70
11	228	65
12	210	60
13	193	55
14	175	50
15	158	45
16	144	41
17	126	36
18	109	31
19	91	26
20	74	21
21	60	17
≥22	42	12

where:

n_a = number of operating ACAS II and ACAS III equipped aircraft near own (based on ACAS broadcasts received with a transponder

receiver threshold of -74 dBm);

{ } = average value of the expression within the brackets over last interrogation cycles;

$P_a(k)$ = peak power radiated from the antenna in all directions of the pulse having the largest amplitude in the group of pulses comprising a single interrogation during the kth Mode A/C interrogation in a 1 s interrogation cycle, W;

K = index number for Mode A/C interrogations, k = 1, 2,..., kt;

K_t = number of Mode A/C interrogations transmitted in a 1 s interrogation cycle;

f_r = Mode A/C reply rate of own transponder.

(iv) Mode S ACAS I interference limits. An ACAS I that uses Mode S interrogations shall not cause greater interference effects than an ACAS I using Mode A/C interrogations only

23.4.4.3 GENERAL PROVISIONS RELATING TO ACAS II AND ACAS III

23.4.4.3.1 FUNCTIONAL REQUIREMENTS

(1) ACAS functions. ACAS shall perform the following functions:

(a) surveillance;

(b) generation of TAs;

(c) threat detection;

(d) generation of RAs;

(e) coordination; and

(f) communication with ground stations

The equipment shall execute functions (ii) through (v) on each cycle of operation.

Note. — Certain features of these functions must be standardized to ensure

that ACAS units cooperate satisfactorily with other ACAS units, with Mode S ground stations and with the ATC system. Each of the features that are standardized is discussed below. Certain other features are given herein as provisions.

Note 1. — The acronym ACAS is used in this section to indicate either ACAS II or ACAS III.

Note 2.— Carriage requirements for ACAS equipment are addressed in Part 7 of the Ghana Civil Aviation (Flight Standards) Directives.

Note 3. — The term "equipped threat" is used in this section to indicate a threat fitted with ACAS II or ACAS III.

(i) The duration of a cycle shall not exceed 1.2 s.

23.4.4.3.2 SURVEILLANCE PERFORMANCE REQUIREMENTS

(1) General surveillance requirements. ACAS shall interrogate SSR Mode A/C and Mode S transponders in other aircraft and detect the transponder replies. ACAS shall measure the range and relative bearing of responding aircraft. For ACAS X compliant systems, in addition to information from other sources described above, ACAS shall be able to receive other aircraft's ADS-B position, velocity and status information. Using these measurements and information conveyed by transponder replies and for ACAS X compliant systems also by ADS-B messages, ACAS shall estimate the relative positions of each responding aircraft. ACAS shall include provisions for achieving such position determination in the presence of ground reflections, interference and variations in signal strength.

(a) Track establishment probability. ACAS shall generate an established track, with at least a 0.90 probability that the track is established 30 s before closest approach, on aircraft equipped with transponders when all of the following conditions are satisfied:

(i) the elevation angles of these aircraft are within ±10 degrees relative to the ACAS aircraft pitch plane;

(ii) the magnitudes of these aircraft's rates of change of altitude are less than or equal to 51 m/s (10 000 ft/min);

(iii) the transponders and antennas of these aircraft meet the Standards of 23.4.3.1.1 and 23.4.3.1.2;

(iv) the closing speeds and directions of these aircraft, the

local density of SSR transponder-equipped aircraft and the number of other ACAS interrogators in the vicinity (as determined by monitoring ACAS broadcasts, 23.4.4.3.7(1)(b)(iv) satisfy the conditions specified in Table 4-1; and

(v) the minimum slant range is equal to or greater than 300 m (1 000 ft).

Table 4-1. ACAS design assumptions

Conditions									*Performance*
Quadrant									
Forward		*Side*		*Back*		*Maximum traffic density*		*Maximum number of other ACAS within 56 km (30 NM)*	
Maximum closing speed									
m/s	*kt*	*m/s*	*kt*	*m/s*	*kt*	*aircraft/ km2*	*aircraft/ NM2*		*Probability of success*
260	500	150	300	93	180	0.087	0.30	30	0.90
620	1 200	390	750	220	430	0.017	0.06	30	0.90

Note.— Table 4-1 shows the design assumption upon which the development of ACAS was based. Operational experience and simulation show that ACAS provides adequate surveillance for collision avoidance even when the maximum number of other ACAS within 56 km (30 NM) is somewhat higher than that shown in Table 4-1. Future ACAS designs will take account of current and expected ACAS densities.

(b) ACAS shall continue to provide surveillance with no abrupt degradation in track establishment probability as any one of the condition bounds defined in 23.4.4.3.2(1)(a) is exceeded.

(c) ACAS shall not track Mode S aircraft that report that they are on the ground.

Note. — A Mode S aircraft may report that it is on the ground by coding in the capability (CA) field in a DF = 11 or DF = 17 transmission (23.4.3.1.2.5(2)(b)(i)) or by coding in the vertical status (VS) field in a DF = 0 transmission (23.4.3.1.2.8(2)(a)). Alternatively, if the aircraft is under Mode S ground surveillance, ground status may be determined by monitoring the flight status (FS) field in downlink formats DF = 4, 5, 20 or 21 (Section 23.4.3.1.2.6.5(1)).

(d) ACAS shall achieve the required tracking performance when the average SSR Mode A/C asynchronous reply rate from transponders in the vicinity of the ACAS aircraft is 240 replies per second and when the peak interrogation rate received by the individual transponders under surveillance is 500 per second.

Note. — The peak interrogation rate mentioned above includes interrogations from all sources.

(e) False track probability. The probability that an established Mode A/C track does not correspond in range and altitude, if reported, to an actual aircraft shall be less than 1.2 per cent. For an established Mode S track this probability shall be less than 0.1 percent. These limits shall not be exceeded in any traffic environment.

(f) RANGE AND BEARING ACCURACY

(i) Range shall be measured with a resolution of 14.5 m (1/128 NM) or better.

(ii) The errors in the relative bearings of the estimated positions of intruders shall not exceed 10 degrees rms.

Note. — This accuracy in the relative bearing of intruders is practicable and sufficient as an aid to the visual acquisition of potential threats. In addition, such relative bearing information has been found useful in threat detection, where it can indicate that an intruder is a threat. However, this accuracy is not sufficient as a basis for horizontal RAs, nor is it sufficient for reliable predictions of horizontal miss distance.

(2) INTERFERENCE CONTROL

(a) Maximum radiated RF power. The effective radiated power of an ACAS transmission at 0-degree elevation relative to the longitudinal axis of the aircraft shall not exceed 27 dBW.

(i) Unwanted radiated power. When ACAS is not transmitting an interrogation, the effective radiated power in any direction shall not exceed -70 dBm.

(b) Interference limiting. Each ACAS interrogator operating below a pressure altitude of 5 490 m (18 000 ft) shall control its interrogation rate or power or both so as to conform with specific inequalities (23.4.4.3.2(2)(b)(ii).

(i) Determination of the number of other ACAS. ACAS shall count the number of other ACAS II and III interrogators in the vicinity to ensure that the interference limits are met. This count shall be obtained by monitoring ACAS broadcasts (UF = 16), (23.4.4.3.7(1)(b)(iv) Each ACAS shall monitor such broadcast interrogations to determine the number of other ACAS within detection range.

(ii) ACAS interference limiting inequalities. ACAS shall adjust its interrogation rate and interrogation power such that the following three inequalities remain true, except as provided in 23.4.4.3.2(2)(b)(ii)(A)

$$\{ \sum_{i=1}^{i_1} \left[\frac{p(i)}{250}\right]^{\alpha} \} < minimum \left[\frac{280}{1+n_a}, \frac{11}{\alpha^2}\right] \quad (1)$$

$$\{ \sum_{i=1}^{i_1} m(i) \} < 0.01 \quad (2)$$

$$\{ \frac{1}{B} \sum_{k=1}^{k_1} \frac{P_a(k)}{250} \} < minimum \left[\frac{80}{1+n_a}, 3\right] \quad (3)$$

The variables in these inequalities shall be defined as follows:

i = number of interrogations (Mode A/C and Mode S) transmitted in a 1 s interrogation cycle. This shall include all Mode S interrogations used by the ACAS functions, including those in addition to UF = 0 and UF = 16 interrogations, except as provided in 23.4.4.3.2(2)(b)(ii)(A);

Note. — UF = 19 interrogations are included in it as specified in 23.4.3.1.2.8.9(4).

i = index number for Mode A/C and Mode S interrogations, i = 1, 2... i_t;

= the minimum of α_1 calculated as 1/4 $[n_b/n_c]$ subject to the special conditions given below and α_2 calculated as $\text{Log}_{10}[n_a/n_b] / \text{Log}_{10} 25$, where n_b and n_c are defined as the number of operating ACAS II and ACAS III equipped aircraft (airborne or on the ground) within 11.2 km (6 NM) and 5.6 km (3 NM) respectively, of own ACAS (based on ACAS surveillance). ACAS aircraft operating on the ground or at or below a radio altitude of 610 m (2 000 ft) AGL shall include both airborne and on-ground ACAS II and ACAS III aircraft in the value for n_b and n_c. Otherwise, ACAS shall include only airborne ACAS II and ACAS III aircraft in the value for n_b and n_c. The values of α, α_1 and α_2 are further constrained to a minimum of 0.5 and a maximum of 1.0.

IF $[(n_b \leq 1)$ OR $(n_b \leq 4$ AND $n_c \leq 2$ AND $n_a > 25)]$ THEN $\alpha_1 = 1.0$,

IF $[(n_c > 2)$ AND $(n_b > 2\, n_c)$ AND $(n_a < 40)]$ THEN $\alpha_1 = 0.5$;

p(i) = peak power radiated from the antenna in all directions of the pulse having the largest amplitude in the group of pulses comprising a single interrogation during the *i*th interrogation in a 1 s interrogation cycle, W;

m(i) = duration of the mutual suppression interval for own transponder associated with the *i*th interrogation in a 1 s interrogation cycle, s;

B = beam sharpening factor (ratio of 3 dB beam width to beamwidth resulting from interrogation side-lobe suppression). For ACAS interrogators that employ transmitter side-lobe suppression (SLS), the appropriate beamwidth shall be the extent in azimuth angle of the Mode A/C replies from one transponder as limited by SLS, averaged over the transponder population;

{} see 23.4.4.2(3)(c)(iii)

$P_a(k)$	"
k	"
k_f	"
n_a	"

Note. — RA and ACAS broadcasts (23.4.4.3.6(2)(a)and 23.4.4.3.7(1)(b)(iv)) are interrogations.

(A) Transmissions during RAs. All air-to-air coordination interrogations and RA and ACAS broadcasts shall be transmitted at full power, and these interrogations shall be excluded from the summations of Mode S interrogations in the left-hand terms of inequalities (1) and (2) in 23.4.4.3.2(2)(b)(ii) for the duration of the RA.

(B) Transmissions from ACAS units on the ground. Whenever the ACAS aircraft indicates that it is on the ground, ACAS interrogations shall be limited by setting the number of other ACAS II and III aircraft (na) count in the interference limiting inequalities to a value that is three times the value obtained based on ACAS broadcasts received with a transponder receiver threshold of -74 dBm. Whenever Mode A/C interrogation power is reduced because of interference limiting, the Mode A/C interrogation power in

the forward beam shall be reduced first until the forward sequence matches the right and left sequences. The forward, right and left interrogation powers shall then sequentially be

reduced until they match the rear interrogation power. Further reduction of Mode A/C power shall be accomplished by sequentially reducing the forward, side and rear interrogation powers.

(C) Transmissions from ACAS units above 5 490 m (18 000 ft) altitude. Each ACAS interrogator operating above a pressure altitude of 5 490 m (18 000 ft) shall control its interrogation rate or power or both such that inequalities (1) and (3) in 23.4.4.3.2(2)(b)(ii) remain true when na and a are equal to 1, except as provided in 23.4.4.3.2(2)(b)(ii)(A)

23.4.4.3.3 TRAFFIC ADVISORIES (TAS)

(1) TA function. ACAS shall provide TAs to alert the flight crew to potential threats. Such TAs shall be accompanied by an indication of the approximate relative position of potential threats to facilitate visual acquisition.

(a) Display of potential threats. If potential threats are shown on a traffic display, they shall be displayed in amber or yellow.

Note 1. — These colours are generally considered suitable for indicating a cautionary condition.

Note 2. —Additional information assisting in the visual acquisition such as vertical trend and relative altitude may be displayed as well.

Note 3. — Traffic situational awareness is improved when tracks can be supplemented by display of heading information (e.g. as extracted from received ADS-B messages).

(2) PROXIMATE TRAFFIC DISPLAY

(a) While any RA and/or TA are displayed, proximate traffic within 11 km (6 NM) range and, if altitude reporting, ±370 m (1 200 ft) altitude

~~should shall~~ be displayed. This proximate traffic shall be distinguished (e.g. by colour or symbol type) from threats and potential threats, which ~~should~~ shall be more prominently displayed.

(b) While any RA and/or TA are displayed, visual acquisition of the threats and/or potential threat shall not be adversely affected by the display of proximate traffic or other data unrelated to collision avoidance.

(3) TAs as RA precursors. The criteria for TAs shall be such that they are satisfied before those for an RA.

Note. — Ideally, RAs would always be preceded by a TA but this is not always possible, e.g. the RA criteria might be already satisfied when a track is first established, or a sudden and sharp manoeuvre by the intruder could cause the TA lead time to be less than a cycle.

(a) TA warning time.

(i) For TCAS Version 7.1 compliant systems ~~intruders reporting altitude~~, the nominal TA warning time for intruders reporting altitude shall not be greater than (T+20 s) where T is the nominal warning time for the generation of the resolution advisory.

(ii) For ACAS X compliant systems, the TA warning time shall be sufficient to allow the flight crew to take actions described in PANS-OPS, Volume III and prepare for a potential resolution advisory.

Note. — The nominal TA warning time is 20 s or less before the generation of the resolution advisory.

23.4.4.3.4 THREAT DETECTION

(1) **Declaration of threat.** ACAS shall evaluate appropriate characteristics of each intruder to determine whether or not it is a threat.

(a) Intruder characteristics. As a minimum, the characteristics of an intruder that are used to identify a threat shall include:

(i) tracked altitude;

(ii) tracked rate of change of altitude;

(iii) tracked slant range;

(iv) tracked rate of change of slant range; and

(v) for TCAS Version 7.1 compliant systems: sensitivity level of intruder's ACAS, Si.

(vi) For an intruder not equipped with ACAS II or ACAS III, S_i. shall be set to 1.

(b) Own aircraft characteristics. As a minimum, the characteristics of own aircraft that are used to identify a threat shall include:

(i) altitude;

(ii) rate of change of altitude; and

(iii) sensitivity level of own ACAS (23.4.4.3.4(3)).

(2) Sensitivity levels. ACAS shall be capable of operating at any of a number of sensitivity levels. These shall include:

(a) S = 1, a "standby" mode in which the interrogation of other aircraft and all advisories are inhibited;

(b) S = 2, a "TA only" mode in which Ras are inhibited;

(c) for TCAS Version 7.1 compliant systems: S = 3-7, further levels that enable the issue of RAs that provide the warning times indicated in Table 4-2 as well as TAs; and

(d) for ACAS X compliant systems: S = 3, a "TA/RA" mode in which RAs and TAs can be issued.

(3) Selection of own sensitivity level (So).The selection of own ACAS sensitivity level shall be determined by sensitivity level control (SLC) commands which shall be accepted from a number of sources as follows:

(a) SLC command generated automatically by ACAS based on altitude band or other external factors;

(b) SLC command from pilot input; and

(c) for TCAS Version 7.1 compliant systems: SLC command from Mode S ground stations.

Note. — ACAS X compliant systems acknowledge SLC commands from ground stations so that the ground stations do not need to be modified for these commands. However, the sensitivity level value is not used in ACAS X compliant systems.

Table 4-2

For TCAS Version 7.1 compliant systems:

Sensitivity level	*2*	*3*	*4*	*5*	*6*	*7*
Nominal warning time	no RAs	15s	20s	25s	30s	35s

(i) Permitted SLC command codes. As a minimum, the acceptable SLC command codes shall include:

		Coding
for SLC based on altitude band	2-7	(for TCAS Version 7.1-complaint systems)
	2-3	(for ACAS X-compliant systems)
for SLC from pilot input	0,1,2	
for SLC from Mode S ground stations	0,2-6	(for TCAS Version 7.1-compliant systems

(ii) Altitude-band SLC command. Where ACAS selects an SLC

command based on altitude, hysteresis shall be applied to the nominal altitude thresholds at which SLC command value changes are required as follows: for a climbing ACAS aircraft the SLC command shall be increased at the appropriate altitude threshold plus the hysteresis value; for a descending ACAS aircraft the SLC command shall be decreased at the appropriate altitude threshold minus the hysteresis value.

(iii) Pilot SLC command. For the SLC command set by the pilot the value 0 shall indicate the selection of the "automatic" mode for which the sensitivity level selection shall be based on the other commands.

(iv) Mode S ground station SLC command.

(A) For TCAS Version 7.1 compliant systems: For SLC commands transmitted via Mode S ground stations (23.4.4.3.8.4(2)(a)(i), the value 0 shall indicate that the station concerned is not issuing an SLC command and that sensitivity level selection shall be based on the other commands, including non-0 commands from other Mode S ground stations. ACAS shall not process an uplinked SLC value of 1.

(B) For ACAS X compliant systems: ACAS shall receive any SLC commands from Mode S ground stations but shall not use their sensitivity level values.

(C) ATS selection of SLC command code. ATS authorities shall ensure that procedures are in place to inform pilots of any ATS selected SLC command code other than 0 (23.4.4.3.4(3)(c)(i)

(v) Selection rule. Own ACAS sensitivity level shall be set to the smallest non-0 SLC command received from any of the sources listed in 23.4.4.3.4(3)

(4) Selection of parameter values for RA generation. For TCAS Version 7.1 compliant systems: When the sensitivity level of own ACAS is 3 or greater, the parameter values used for RA generation that depend on sensitivity level shall

be based on the greater of the sensitivity level of own ACAS, S_o, and the sensitivity level of the intruder's ACAS, S_i.

(5) Selection of parameter values for TA generation. For TCAS Version 7.1 compliant systems: The parameter values used for TA generation that depend on sensitivity level shall be selected on the same basis as those for RAs (23.4.4.3.4(4)) except when an SLC command with a value of 2 ("TA only" mode) has been received from either the pilot or a Mode S ground station. In this case, the parameter values for TA generation shall retain the values they would have had in the absence of the SLC command from the pilot or Mode S ground station.

(6) Validation of ADS-B tracks for RA generation. For ACAS X compliant systems: If ADS-B tracks fail validation via active interrogation and reply, ACAS shall revert back to using active surveillance for threat resolution logic.

Note. — Only validated ADS-B is used in the generation of RAs.

(7) Designation of aircraft for do not alert (DNA). For ACAS X compliant systems with Xo functionality: If an intruder aircraft is designated as do not alert (DNA), no alerts for the intruder aircraft shall be issued to the flight crew of the own aircraft.

Note. — ACAS Xo provides additional modes with modified threat detection criteria in respect of designated intruders. For more details on ACAS Xo, refer to RTCA/DO-385 or EUROCAE/ED-256.

23.4.4.3.5 RESOLUTION ADVISORIES (RAS)

(1) RA generation. For all threats, ACAS shall generate an RA except where it is not possible to select an RA that can be predicted to provide adequate separation either because of uncertainty in the diagnosis of the intruder's flight path or because there is a high risk that a manoeuvre by the threat will negate the RA.

(a) Display of threats. If threats are shown on a traffic display, they shall be displayed in red.

Note. — This colour is generally considered suitable for indicating a warning condition.

(b) RA cancellation.

(i) For TCAS 7.1 compliant systems: Once an RA has been generated against a threat or threats it shall be maintained or modified until tests that are less stringent than those for threat detection indicate on two consecutive cycles that the RA may be cancelled, at which time it shall be cancelled.

(ii) For ACAS X compliant systems: Once an RA has been generated against a threat or threats it shall be maintained until the intruder or intruders of the RA cease to be a threat.

(2) RA selection. ACAS shall generate the RA that is predicted to provide adequate separation from all threats and that has the least effect on the current flight path of the ACAS aircraft consistent with the other provisions in this section.

(3) RA effectiveness. The RA shall not recommend or continue to recommend a manoeuvre or manoeuvre restriction that, considering the range of probable threat trajectories, is more likely to reduce separation than increase it, subject to the provisions in 23.4.4.3.5(5)(a)(i)and 23.4.4.3.5(6)

*Note. — See also 23.4.4.*3.5(8).

(a) New ACAS installations after 1 January 2014 shall monitor own aircraft's vertical rate to verify compliance with the RA sense. If non-compliance is detected, ACAS shall stop assuming compliance and instead shall assume the observed vertical rate.

Note 1. — This overcomes the retention of an RA sense that would work only if followed. The revised vertical rate assumption is more likely to allow the logic to select the opposite sense when it is consistent with the non-complying aircraft's vertical rate.

Note 2.— Equipment complying with RTCA/DO-185 or DO-185A standards (also known as TCAS Version 6.04A or TCAS Version 7.0) do not comply with this requirement.

Note 3.— Compliance with this requirement can be achieved through the implementation of traffic alert and collision avoidance system (TCAS) Version 7.1 as specified in RTCA/DO-185B EUROCAE/ED-143 or airborne collision avoidance system X (ACAS Xa and Xo) as specified in RTCA/DO-385 or EUROCAE/ED-256.

(b) All ACAS shall be compliant with the requirement in 23.4.4.3.5(3)(a) .

(c) After 1 January 2017, all ACAS units shall comply with the requirements stated in 23.4.4.3.5(3)(a).

(4) Aircraft capability. The RA generated by ACAS shall be consistent with the performance capability of the aircraft.

(a) Proximity to the ground. Descend RAs shall not be generated or maintained when own aircraft is below 300 m (1 000 ft) AGL.

(b) ACAS shall ~~not~~ operate in TA only mode ~~sensitivity levels 3-7~~ when own aircraft is below 300 m (1 000 ft) AGL nominal value with hysteresis applied.

(5) Reversals of sense. ACAS shall not reverse the sense of an RA from one cycle to the next, except as permitted in 23.4.4.3.5(5)(a) to ensure coordination or when the predicted separation at closest approach for the existing sense is inadequate.

(a) Sense reversals against equipped threats. If an RAC received from an equipped threat is incompatible with the current RA sense, ACAS shall modify the RA sense to conform with the received RAC if own aircraft address is higher in value than that of the threat.

Note. — 23.4.4.3.6(1)(c) requires that the own ACAS RAC for the threat is also reversed.

(i) ACAS shall not modify an RA sense in a way that makes it incompatible with an RAC received from an equipped threat if own aircraft address is higher in value than that of the threat.

(b) Sense reversals due to inadequate predicted separation. ACAS shall initiate not more than one reversal per threat per encounter due to inadequate predicted separation.

Note 1.— For TCAS Version 7.1 compliant systems: The aircraft with the lower 24-bit aircraft address can initiate this type of reversal at any time during the encounter; the aircraft with the higher 24-bit aircraft address performs this type of reversal only to comply with an RAC received from the aircraft with a lower 24-bit aircraft address.

Note 2.— For ACAS X compliant systems: In a coordinated encounter

as described in section 23.4.4.3.6(1), , the aircraft with the lower 24-bit aircraft address can initiate this type of reversal at any time during the encounter; the aircraft with the higher 24-bit aircraft address can initiate this type of reversal only before it has received an RAC from the threat or after receiving cancellation of any remaining RAC from the threat.

(6) RA strength retention**.** Subject to the requirement that a descend RA is not generated at low altitude (23.4.4.3.5(4)(a))an RA shall not be modified if the time to closest approach is too short to achieve a significant response or if the threat is diverging in range.

(7) Weakening an RA. An RA shall not be weakened if it is likely that it would subsequently need to be strengthened.

(8) ACAS-equipped threats. The RA shall be compatible with all the RACs transmitted to threats (23.4.4.3.6(1)(c)). If an RAC is received from a threat before own ACAS generates an RAC for that threat, the RA generated shall be compatible with the RAC received unless such an RA is more likely to reduce separation than increase it and own aircraft address is lower in value than that of the threat.

Note. — In encounters with more than one threat where it is necessary to pass above some threats and below other threats, this standard can be interpreted as referring to the whole duration of the RA. Specifically, it is permissible to retain an RA to climb (descend) towards a threat that is above (below) own aircraft provided there is a calculated intention to provide adequate separation from all threats by subsequently levelling-off.

(9) Encoding of ARA subfield. On each cycle of an RA, the RA sense, strength and attributes shall be encoded in the active RA (ARA) subfield (23.4.4.3.8.4(2)(b)(i)(A)). ~~If the ARA subfield has not been refreshed for an interval of 6 s, it shall be set to 0, along with the MTE subfield in the same message~~ (23.4.4.3.8.4.2.2.1.3).

(10) System response time. The system delay from receipt of the relevant SSR reply to presentation of an RA sense and strength to the pilot shall be as short as possible and shall not exceed 1.5 s.

23.4.4.3.6 COORDINATION AND COMMUNICATION

(1) PROVISIONS FOR COORDINATION WITH ACAS-EQUIPPED THREATS

Note 1.— The provisions in this section apply to aircraft that coordinate with

ACAS equipped aircraft via 1 030/1 090 MHz discrete Mode S interrogations/replies.

Note 2.— ACAS equipment not capable of utilizing 1 030/1 090 MHz discrete Mode S interrogations/replies and that will use ADS-B to convey the applicable coordination scheme is under development. ACAS X-compliant systems incorporate the ability to coordinate with threats using cachaca's equipment. For more details, refer to Section 2.2.3.9.3.1 of RTCA/DO-385 or EUROCAE/ED-256.

(a) Multi-aircraft coordination. In a multi-aircraft situation, ACAS shall coordinate with each equipped threat individually.

(b) Data protection during coordination. ACAS shall prevent simultaneous access to stored data by concurrent processes, in particular, during resolution message processing.

(c) Coordination interrogation. Each cycle ACAS shall transmit a coordination interrogation to each equipped threat, unless generation of an RA is delayed because it is not possible to select an RA that can be predicted to provide adequate separation (23.4.4.3.5(1)). The resolution message transmitted to a threat shall include an RAC selected for that threat. If an RAC has been received from the threat before ACAS selects an RAC for that threat, the selected RAC shall be compatible with the received RAC unless no more than three cycles have elapsed since the RAC was received, the RAC is altitude-crossing, and own aircraft address is lower in value than that of the threat in which case ACAS shall select its RA independently. If an RAC received from an equipped threat is incompatible with the RAC own ACAS has selected for that threat, ACAS shall modify the selected RAC to be compatible with the received RAC if own aircraft address is higher in value than that of the threat.

Note. — The RAC included in the resolution message is in the form of a vertical RAC (VRC) for ACAS II (23.4.4.3.8.4.2.3(3)(b)) and a vertical RAC (VRC) and/or horizontal RAC (HRC) for ACAS III.

(i) Coordination termination. Within the cycle during which an intruder ceases to be a reason for maintaining the RA, ACAS shall send are solution message to that intruder by means of a coordination interrogation. The resolution message shall include the cancellation code for the last RAC sent to that intruder while it was a reason for maintaining the RA.

Note. — During an encounter with a single threat, the threat

ceases to be a reason for the RA when the conditions for cancelling the RA are met. During an encounter with multiple threats, a threat ceases to be a reason for the RA when the conditions for cancelling the RA are met in respect of that threat, even though the RA may have to be maintained because of other threats.

(ii) ACAS coordination interrogations shall be transmitted until a coordination reply is received from the threat, up to a maximum of not less than six and not more than twelve attempts. The successive interrogations shall be nominally equally spaced over a period of 100 ±5 ms. If the maximum number of attempts is made and no reply is received, ACAS shall continue its regular processing sequence.

(iii) ACAS shall provide parity protection (23.4.4.3.8.4.2.3(3)(f) And 23.4.4.3.8.4.2.3(3)(g) for all fields in the coordination interrogation that convey RAC information.

Note. — This includes the vertical RAC (VRC), the cancel vertical RAC (CVC), the horizontal RAC (HRC) and the cancel horizontal RAC (CHC).

(iv) Whenever own ACAS reverses its sense against an equipped threat, the resolution message that is sent on the current and subsequent cycles to that threat shall contain both the newly selected RAC and the cancellation code for the RAC sent before the reversal.

(v) When a vertical RA is selected, the vertical RAC (VRC) (23.4.4.3.8.4.2.3(3)(b)) that own ACAS includes in a resolution message to the threat shall be as follows:

(A) “do not pass above” when the RA is intended to provide separation above the threat;

(B) “do not pass below” when the RA is intended to provide separation below the threat.

(d) Resolution message processing. Resolution messages shall be processed in the order in which they are received and with delay limited to that required to prevent possible concurrent access to stored data and delays due to the processing of previously received resolution messages. Resolution messages that are being delayed shall be temporarily queued to prevent possible loss of messages. Processing a resolution message shall include decoding the message

and updating the appropriate data structures with the information extracted from the message.

Note 1.— For TCAS Version 7.1 compliant systems: According to 23.4.4.3.6(1)(b)), resolution message processing must not access any data whose usage is not protected by the coordination lock state.

Note 2. — For ACAS X compliant systems: Simultaneous data access may exist because incoming resolution messages are received asynchronously to ACAS X processing, effectively interrupting this processing. Simultaneous reading and writing by concurrent processes are to be prevented.

(i) An RAC or an RAC cancellation received from another ACAS shall be rejected if the encoded sense bits indicate the existence of a parity error or if undefined value(s) are detected in the resolution message. An RAC or an RAC cancellation received without parity errors and without undefined resolution message values shall be considered valid.

(ii) RAC storage. A valid RAC received from another ACAS shall be stored or shall be used to update the previously stored RAC corresponding to that ACAS. A valid RAC cancellation shall cause the previously stored RAC to be deleted. A stored RAC that has not been updated for an interval of 6 s shall be deleted.

RAC record update. A valid RAC or RAC cancellation received from another ACAS shall be used to update the RAC record. If a bit in the RAC record has not been refreshed for an interval of 6 s by any threat, that bit shall be set to 0.

(2) PROVISIONS FOR ACAS COMMUNICATION WITH GROUND STATIONS

(a) Air-initiated downlink of ACAS RAs. When an ACAS RA exists, ACAS shall:

(i) transfer to its Mode S transponder an RA report for transmission to the ground in a Comm-B reply (23.4.4.3.11(4)(a)); and

(ii) transmit periodic RA broadcasts (23.4.4.3.7(3)(b)).

(b) Sensitivity level control (SLC) command. For TCAS Version 7.1 compliant systems: ACAS shall store SLC commands from Mode S ground stations. An SLC command received from a Mode S ground station shall remain effective until replaced by an SLC command from the same ground station as indicated by the site number contained in the IIS subfield of the interrogation. If an existing stored command from a Mode S ground station is not refreshed within 4 minutes, or if the SLC command received has the value 15 (23.4.4.3.8.4(2)(a)(i)the stored SLC command for that Mode S ground station shall be set to 0.

Note. — ACAS X compliant systems do not use the sensitivity level value obtained from an SLC command to modify the sensitivity level value of own aircraft.

(3) PROVISIONS FOR DATA TRANSFER BETWEEN ACAS AND ITS MODE S TRANSPONDER

(a) Data transfer from ACAS to its Mode S transponder**:**

(i) ACAS shall transfer RA information to its Mode S transponder for transmission in an RA report (23.4.4.3.8.4(2)(b)(ii)) and in a coordination reply (23.4.4.3.8.4.2.4(3));

(ii) ACAS shall transfer current sensitivity level to its Mode S transponder for transmission in a sensitivity level report (23.4.4.3.8.4.2.5); and

(iii) ACAS shall transfer capability information to its Mode S transponder for transmission in a data link capability report (23.4.4.3.8.4(2)(c)).

Note. — For ACAS X compliant systems: ACAS will not transfer a sensitivity level value greater than 3 as part of the capability information to its Mode S transponder.

(b) Data transfer from Mode S transponder to its ACAS:

(i) ACAS shall receive from its Mode S transponder sensitivity level control commands (23.4.4.3.8.4(2)(a)(i)) transmitted

by Mode S ground stations;

Note. — For ACAS X compliant systems: It is necessary to receive SLC commands from the transponder to be compliant with the interface protocols between the Mode S transponder and the ACAS unit; however, the sensitivity level values are not used (refer to 23.4.4.3.4(3)(c)(iv)).

(ii) ACAS shall receive from its Mode S transponder ACAS broadcast messages (23.4.4.3.8.4.2.3(4)) transmitted by other ACAS; and

(iii) ACAS shall receive from its Mode S transponder resolution messages (23.4.4.3.8.4.2.3(3)) transmitted by other ACAS for air-air coordination purposes.

23.4.4.3.7 ACAS PROTOCOLS

(1) SURVEILLANCE PROTOCOLS

(a) Surveillance of Mode A/C transponders.

(i) ACAS shall use the Mode C-only all-call interrogation (23.4.3.1.2.1.5(1)(b)) for surveillance of aircraft equipped with Mode A/C transponders.

(ii) Using a sequence of interrogations with increasing power, surveillance interrogations shall be preceded by an S1-pulse (Section23.4.3.1.1.7(4)(d)) to reduce interference and improve Mode A/C target detection.

(b) SURVEILLANCE OF MODE S TRANSPONDERS

(i) Detection. ACAS shall monitor 1 090 MHz for Mode S acquisition squitters (DF = 11). ACAS shall detect the presence and determine the address of Mode S-equipped aircraft using their Mode S acquisition squitters (DF = 11) or extended squitters (DF = 17).

Note 1.— It is acceptable to acquire individual aircraft using either acquisition or extended squitters (DF = 11

or DF = 17), and to monitor for both squitters. However, ACAS must monitor for acquisition squitters because, at any time, not all aircraft will transmit the extended squitter.

Note 2. — If, in the future, it becomes permitted for aircraft not to transmit the acquisition squitter, relying instead on continual transmission of the extended squitter, it would become essential for all ACAS units to monitor for both the acquisition and the extended squitters.

(ii) Surveillance interrogations. On first receipt of a 24-bit aircraft address from an aircraft that is determined to be within the reliable surveillance range of ACAS based on reception reliability and that is within an altitude band 3 050 m (10 000 ft) above and below own aircraft, ACAS shall transmit a short air-air interrogation (UF = 0) for range acquisition. Surveillance interrogations shall be transmitted at least once every five cycles when this altitude condition is satisfied. Surveillance interrogations shall be transmitted each cycle if the range of the detected aircraft is less than 5.6 km (3 NM) or the calculated time to closest approach is less than 60 s, assuming that both the detected and own aircraft proceed from their current positions with unaccelerated motion and that the range at closest approach equals 5.6 km (3 NM). Surveillance interrogations shall be suspended for a period of five cycles if:

(A) a reply was successfully received; and

(B) own aircraft and intruder aircraft are operating below a pressure altitude of 5 490 m (18 000 ft); and

(C) the range of the detected aircraft is greater than 5.6 km (3 NM) and the calculated time to closest approach exceeds 60 seconds, assuming that both the detected and own aircraft proceed from their current positions with unaccelerated motion and that the range at closest approach equals 5.6 km (3 NM).

(D) Range acquisition interrogations. ACAS shall use

the short air-air surveillance format (UF = 0) for range acquisition. ACAS shall set AQ = 1 (23.4.3.1.2.8(1)(a)) and RL = 0 (23.4.3.1.2.8(1)(b)) in an acquisition interrogation.

Note 1.— Setting AQ = 1 results in a reply with bit 14 of the RI field equal to 1 and serves as an aid in distinguishing the reply to own interrogation from replies elicited from other ACAS units (23.4.4.3.7(1)(b)(ii)(E))

Note 2.— In the acquisition interrogation RL is set to 0 to command a short acquisition reply (DF = 0).

(E) Tracking interrogations. ACAS shall use the short air-air surveillance format (UF = 0) with RL = 0 and AQ = 0 for tracking interrogations.

(iii) Surveillance replies. These protocols are described in 23.4.4.3.11(3)(a).

(iv) ACAS broadcast. An ACAS broadcast shall be made nominally every 8 to 10 s at full power from the top antenna. Installations using directional antennas shall operate such that complete circular coverage is provided nominally every 8 to 10 s.

Note. — A broadcast causes other Mode S transponders to accept the interrogation without replying and to present the interrogation content containing the MU field at the transponder output data interface. The UDS1 = 3, UDS2 = 2 combination identifies the data as an ACAS broadcast containing the 24-bit address of the interrogating ACAS aircraft. This provides each ACAS with a means of determining the number of other ACAS within its detection range for limiting interference. The format of the MU field is described in 23.4.4.3.8.4.2.3.

(c) SURVEILLANCE OF ADS-B MESSAGES FROM INTRUDER AIRCRAFT FOR ACAS X COMPLIANT SYSTEMS:

(i) Detection. ACAS shall monitor 1 090 MHz extended squitter.

(ii) ACAS shall receive and use 1 090 MHz extended squitter messages which include information on ADS-B airborne and surface position, airborne velocity, target state and status, and aircraft operational status.

(2) AIR-AIR COORDINATION PROTOCOLS

Note 1.— The provisions in this section apply to aircraft that coordinate with ACAS equipped aircraft via 1 030/1 090 MHz discrete Mode S interrogations/replies.

Note 2.— ACAS equipment not capable of utilizing 1 030/1 090 MHz discrete Mode S interrogations/replies and that will use ADS-B to convey the applicable coordination scheme is under development. ACAS X compliant systems incorporate the ability to coordinate with threats using such ACAS equipment. For more details, refer to Section 2.2.3.9.3.1 of RTCA/DO-385 or EUROCAE/ED-256.

(a) Coordination interrogations. ACAS shall transmit UF = 16 interrogations (23.4.3.1.2.3.2, Figure 3-7) with AQ = 0 and RL = 1 when another aircraft reporting RI = 3 or 4 is declared a threat (23.4.4.3.4). The MU field shall contain the resolution message in the subfields specified in 23.4.4.3.8.4.2.3(3).

Note 1.— A UF = 16 interrogation with AQ = 0 and RL = 1 is intended to cause a DF = 16 reply from the other aircraft.

Note 2.— An aircraft reporting RI = 3 or RI = 4 is an aircraft equipped with an operating ACAS which has vertical only or vertical and horizontal resolution capability, respectively.

(b) Coordination reply. These protocols are described in 23.4.4.3.11(3)(b).

(3) PROTOCOLS FOR ACAS COMMUNICATION WITH GROUND STATIONS

(a) RA reports to Mode S ground stations. These protocols are described in 23.4.4.3.11(4)(a).

(b) RA broadcasts. RA broadcasts shall be transmitted at full power from the bottom antenna at jittered ~~nominally 8 s intervals for the period that the RA is indicated~~ intervals. The RA broadcast shall include the MU field as specified in 23.4.4.3.8.4.2.3(5). The RA

broadcast shall describe the ~~most recent~~ current RA ~~that existed during the preceding 8 s period~~. Installations using directional antennas shall operate such that complete circular coverage is provided. ~~nominally every 8 s and the same RA sense and strength is broadcast in each direction.~~

Note. — The nominal jittered interval of RA broadcasts is every 8 s for the majority of ACAS legacy systems and 1 s for ACAS X compliant systems.

(c) Data link capability report. These protocols are described in 23.4.4.3.11(4)(b).

(d) ACAS sensitivity level control.

(i) For TCAS Version 7.1 compliant systems: ACAS shall act upon an SLC command if and only if TMS (23.4.3.1.2.6.1(4)(a) has the value 0 and DI is either 1 or 7 in the same interrogation.

(ii) For ACAS X compliant systems: ACAS shall receive any SLC commands from Mode S ground stations but shall not use their sensitivity level values.

23.4.4.3.8 SIGNAL FORMATS

(1) The RF characteristics of all ACAS signals shall conform to the Standards of 23.4.3.1.1.1 through 23.4.3.1.1.6, 23.4.3.1.2.1 through 23.4.3.1.2.3, 23.4.3.1.2.5 and 23.4.3.1.2.8.

(2) Relationship between acas and mode s signal formats

Note. — ACAS uses Mode S transmissions for surveillance and communications. ACAS air-air communication functions permit RA decisions to be coordinated with ACAS-equipped threats. ACAS air-ground communication functions permit the reporting of RAs to ground stations.

(3) Signal format conventions. The data encoding of all ACAS signals shall conform to the requirements of 23.4.3.1.2.3.

Note. — In air-air transmissions used by ACAS, interrogations transmitted at 1 030 MHz are designated as uplink transmissions and contain uplink format

(UF) codes. Replies received at 1 090 MHz are designated as downlink transmissions and contain downlink format (DF) codes.

23.4.4.3.8.4 FIELD DESCRIPTION

Note 1. — The air-air surveillance and communication formats which are used by ACAS but not fully described in 23.4.3.1.2.1 are given in Figure 4-1.

Note 2. — This section defines the Mode S fields (and their subfields) that are processed by ACAS to accomplish ACAS functions. Some of the ACAS fields (those also used for other SSR Mode S functions) are described with unassigned ACAS codes in Section 23.4.3.1.2.6. Such codes are assigned in 23.4.4.3.8.4(1).. Fields and subfields used only by ACAS equipment are assigned in 23.4.4.3.8.4(2).

Note 3.— The bit numbering convention used in 23.4.4.3.8.4 reflects the bit numbering within the entire uplink or downlink format rather than the bits within individual fields or subfields.

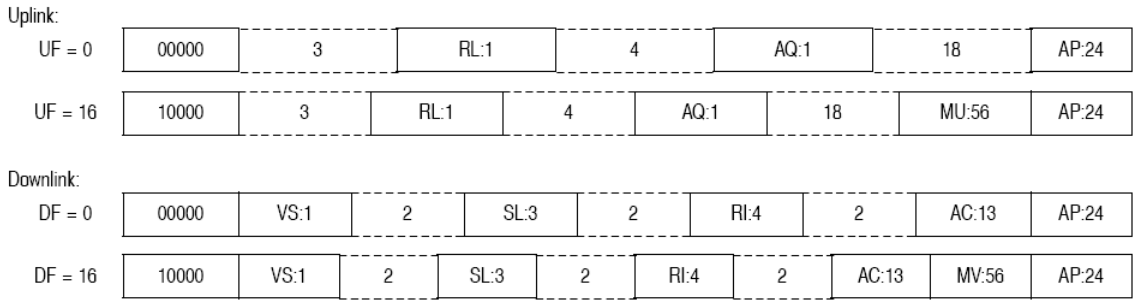


Figure 4-1. Surveillance and communication formats used by ACAS

(1) FIELDS AND SUBFIELDS INTRODUCED IN 23.4.3.1.2

Note. — Codes for mission fields and subfields that are designated "reserved for ACAS" in 23.4.3.1.2, are specified in this section.

(a) DR (downlink request). The significance of the coding of the downlink request field shall be as follows:

Coding
0-1 See 23.4.3.1.2.6.5(2)
0 ACAS message available
1 Comm-B message available and ACAS message available 4-5

See 23.4.3.1.2.6.5(2)

6 Comm-B broadcast message 1 available and ACAS message available

7 Comm-B broadcast message 2 available and ACAS message available

8-31 See 23.4.3.1.2.6.5(2)

(b) RI (air-air reply information). The significance of the coding in the RI field shall be as follows:

Coding

0 No operating ACAS

1 Not assigned

2 ACAS with resolution capability inhibited

3 ACAS with vertical-only resolution capability and capability to utilize 1 030/1 090 MHz discrete Mode S interrogations/replies for coordination

4 ACAS with vertical and horizontal resolution capability and capability to utilize 1 030/1 090 MHz discrete Mode S interrogations/replies for coordination

5-6 Reserved for passive ACAS

7 Not assigned

8-15 See 23.4.3.1.2.8(2)(b)

(i) Bit 14 of the reply format containing this field shall replicate the AQ bit of the interrogation. The RI field shall report "no operating ACAS" (RI = 0) if the ACAS unit has failed or is in standby. The RI field shall report "ACAS with resolution capability inhibited" (RI = 2) if sensitivity level is 2 or TA only mode has been selected.

Note. — Codes 0-7 in the RI field indicate that the reply is a tracking reply and also give the ACAS capability of the interrogated aircraft. Codes 8-15 indicate that the reply is an acquisition reply and also give the maximum true airspeed capability of the interrogated aircraft.

(c) RR (reply request). The significance of the coding in the reply request field shall be as follows:

Coding

0-18 See 23.4.3.1.2.6.1(2)

19 Transmit a resolution advisory report

20-31 See 23.4.3.1.2.6.1(2)

(2) ACAS FIELDS AND SUBFIELDS

Note. — The following paragraphs describe the location and coding of those fields and subfields that are not defined in Section 23.4.3.1.2 but are used by aircraft equipped with ACAS.

(a) For TCAS Version 7.1 compliant systems: Subfield in MA

(i) ADS (A-definition subfield). This 8-bit (33-40) subfield shall define the remainder of MA.

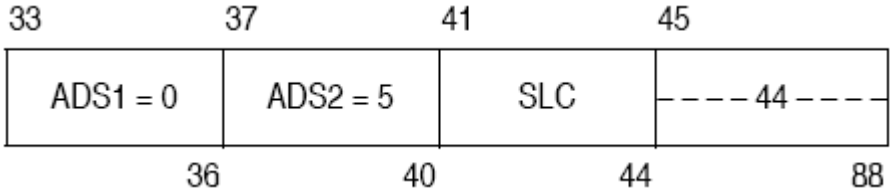
Note. — For convenience of coding, ADS is expressed in two groups of four bits each, ADS1 and ADS2.

(ii) When ADS1 = 0 and ADS2 = 5, the following subfield shall be contained in MA:

(iii) SLC (ACAS sensitivity level control (SLC) command). This 4-bit (41-44) subfield shall denote a sensitivity level command for own ACAS.

	Coding
0	No command issued
1	Not assigned
2	Set ACAS sensitivity level to 2
3	Set ACAS sensitivity level to 3
4	Set ACAS sensitivity level to 4
5	Set ACAS sensitivity level to 5
6	Set ACAS sensitivity level to 6
7-14	Not assigned
15	Cancel previous SLC command from this ground station

Note. 1— Structure of MA for a sensitivity level control command:



Note 2. — ACAS X compliant systems receive SLC

commands, but their sensitivity level values are not used.

(b) Subfields in MB

Note. — 23.4.4.3.8.4(2)(b)(i) is applicable to TCAS Version 7.1 compliant systems, while 23.4.4.3.8.4(2)(b)(ii) is applicable to ACAS X compliant systems. 23.4.4.3.8.4(2)(b)(iii) is applicable to both TCAS Version 7.1 and ACAS X compliant systems.

(i) For TCAS Version 7.1 compliant systems: Subfields in MB for an RA report. When BDS1 = 3 and BDS2 = 0, the subfields indicated below shall be contained in MB

Note. — The requirements for communication of information relating to the current or recent RAs is described in23.4.4.3.11(4)(a).).

(A) ARA (active RAs). This 14-bit (41-54) subfield shall indicate the characteristics of the RA, if any, generated by the ACAS associated with the transponder transmitting the subfield (23.4.4.3.6(2)(a)(i))The bits in ARA shall have meanings determined by the value of the MTE subfield (23.4.4.3.8.4(2)(b)(i)(D)) and, for vertical RAs, the value of bit 41 of ARA. The meaning of bit 41 of ARA shall be as follows:

	Coding
0	There is more than one threat and the RA is intended to provide separation below some threat(s) and above some other threat(s) or no RA has been generated (when MTE = 0)
1	Either there is only one threat or the RA is intended to provide separation in the same direction for all threats

When ARA bit 41 = 1 and MTE = 0 or 1, bits 42-47 shall have the following meanings:

Bit	*Coding*	
42	0	RA is preventive
	1	RA is corrective

43	0	Upward sense RA has
	1	Downward sense RA has
44	0	RA is not increased rate
	1	RA is increased rate
45	0	RA is not a sense reversal
	1	RA is a sense reversal
46	0	RA is not altitude
	1	RA is altitude crossing
47	0	RA is vertical speed limit
	1	RA is positive
48-54		Reserved for ACAS III

When ARA bit 41 = 0 and MTE = 1, bits 42-47 shall have the following meanings:

Bit	*Coding*	
42	0	RA does not require a correction in the
	1	RA requires a correction in the upward
43	0	RA does not require a positive climb
	1	RA requires a positive climb
44	0	RA does not require a correction in the
	1	RA requires a correction in the
45	0	RA does not require a positive descend
	1	RA requires a positive descend
46	0	RA does not require a crossing
	1	RA requires a crossing
47	0	RA is not a sense reversal
	1	RA is a sense reversal
48-54		Reserved for ACAS III

Note.1— When ARA bit 41 = 0 and MTE = 0, no vertical RA has been generated.

Note 2.— An RA is considered crossing if own aircraft is expected to cross the altitude of the intruder before closest approach, e.g. pass above a threat currently above own aircraft. An RA is considered crossing regardless of whether the word "crossing" is included in the aural annunciation.

(B) RAC (RACs record). This 4-bit (55-58) subfield shall indicate all the currently active RACs, if any, received from other ACAS aircraft. The bits in RAC shall have the following meanings:

Bit	Resolution advisory complement
55	Do not pass below
56	Do not pass above
57	Do not turn left
58	Do not turn right

A bit set to 1 shall indicate that the associated RAC is active. A bit set to 0 shall indicate that the associated RAC is inactive.

(C) RAT (RA terminated indicator). This 1-bit (59) subfield shall indicate when an RA previously generated by ACAS has ceased being generated.

Coding	
0	ACAS is currently generating the RA indicated in the ARA subfield
1	The RA indicated by the ARA subfield has been terminated (23.4.4.3.11(4)(a)

*Note 1. — After an RA has been terminated by ACAS, it is still required to be reported by the Mode S transponder for 18±1 s (*23.4.4.3.11(4)(a)*). The RA terminated indicator may be used, for example, to permit timely removal of an RA indication from an air traffic controllers display, or for assessments of RA duration within a particular airspace.*

Note 2. — RAs may terminate for a number of reasons: normally, when the conflict has been resolved and the threat is diverging in range; or when the threat's Mode S transponder for some reason ceases to report altitude during the conflict. The RA terminated indicator is used to show that the RA has been removed in each of these cases.

(D) MTE (multiple threat encounter). This 1-bit (60) subfield shall indicate whether two or more simultaneous threats are currently being processed by the ACAS threat resolution logic.

Coding	
0	One threat is being processed by the resolution logic (when ARA bit 41 = 1); or no threat is being processed by the resolution log (when ARA bit 41 = 0)
1	Two or more simultaneous threats are being

processed by the resolution logic

(E) TTI (threat type indicator subfield). This 2-bit subfield (61-62) shall define the type of identity data contained in the TID subfield.

Coding	
0	No identify data in TID
1	TID contains a Mode S transponder address
2	TID contains altitude, range and bearing data
3	Not assigned

(F) TID (threat identity data subfield). This 26-bit subfield (63-88) shall contain the Mode S address of the threat or the altitude, range, and bearing if the threat is not Mode S equipped. If two or more threats are simultaneously processed by the ACAS resolution logic, TID shall contain the identity or position data for the most recently declared threat. If TTI = 1, TID shall contain in bits 6386 the aircraft address of the threat, and bits 87 and 88 shall be set to 0. If TTI = 2, TID shall contain the following three subfields.

(I) TIDA (threat identity data altitude subfield). This 13-bit subfield (63-75) shall contain the most recently reported Mode C altitude code of the threat.

Coding													
Bit	63	64	65	66	67	68	69	70	71	72	73	74	75
Mode C code bit	C_1	A_1	C_2	A_2	C_4	A_4	0	B_1	D_1	B_2	D_2	B_4	D_4

(II) TIDR (threat identity data range subfield). This 7-bit subfield (76-82) shall contain the most recent threat range estimated by ACAS.

Coding (n)

n	*Estimated range (NM)*
0	No range estimate available
1	Less than 0.05

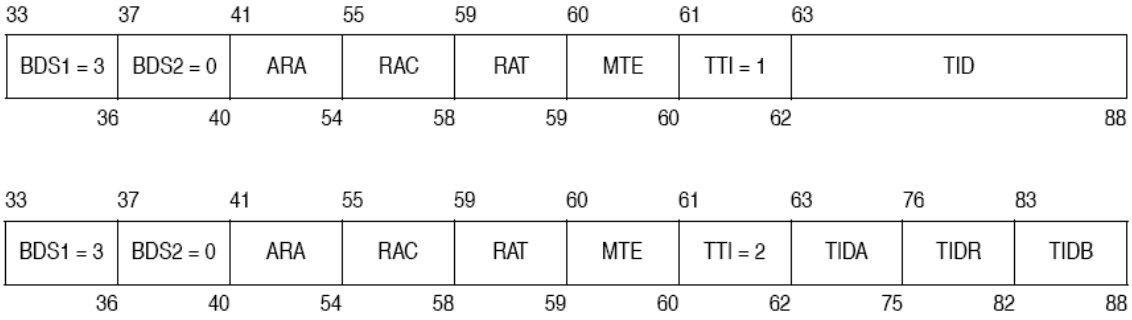
2-126	(n-1)/10 ±0.05
127	Greater than 12.55

(III) TIDB (threat identity data bearing subfield). This 6-bit subfield (83-88) shall contain the most recent estimated bearing of the threat aircraft, relative to the ACAS aircraft heading.

Coding (n)

n	*Estimated bearing (degrees)*
0	No bearing estimate available
1-60	Between 6(n-1) and 6n
61-63	*Not assigned*

Note. — Structure of MB for an RA report:



(ii) For ACAS X compliant systems: Subfields in MB for an RA report. When BDS1=3 and BDS2=0, the subfields indicated below shall be contained in MB.

(A) ARA (active RAs). This 10-bit (41-50) subfield shall indicate the currently active RA if any generated by own ACAS X unit against one or more threat aircraft. The ARA subfield is further divided into:

(I) AVRA (vertical RA). This 7-bit (41-47) subfield contains the vertical component of the ARA as defined below; and

(II) AHRA (horizontal RA). This 3-bit (48-50) subfield contains the horizontal component of the ARA. For ACAS X compliant systems, AHRA=0.

Bits 41-50 shall have the following meanings:

Bit	*Coding*	
41	0	Different vertical senses have been generated in a multi-threat encounter (when MTE = 1); or no RA has been generated (when MTE=0)
	1	The same vertical sense has been generated in a single or multi-threat encounter
42	0	RA is not crossing
	1	RA is crossing
43	0	Upward sense RA has been generated (i.e. own aircraft intent is to pass above the threat)
	1	Downward sense RA has been generated (i.e. own aircraft intent is to pass below the threat)
44		Strength bit 1
45		Strength bit 2
46		Strength bit 3
47		Strength bit 4
48-50	0	AHRA

Note. —An RA is considered crossing if own aircraft is expected to cross the altitude of the intruder before closest approach, e.g., pass above a threat currently above own aircraft. An RA is considered crossing regardless of whether the word "crossing" is included in the aural annunciation.

The strength bits indicated in bits 44 - 47 shall have the following meaning:

Strength bits 1 2 3 4		
0 0 0 0	0	Clear of conflict
0 0 0 1	1	Monitor vertical speed
0 0 1 0	2	Level-off; weakening of positive RA
0 0 1 1	3	Level-off; corrective when climbing/descending
0 1 0 0	4	Climb/descend at 1500 ft/min
0 1 0 1	5	Reversal to climb/descend
0 1 1 0	6	Increase climb/descend
0 1 1 1	7	Maintain rate; at current rate > 1500 ft/min
1 0 0 0	8	Reversal to maintain
1 0 0 1	9	Level-off; reversal to corrective negative RA
1 0 1 0	10	Monitor vertical speed; following descend RA, descend inhibited
1 0 1 1	11	Monitor vertical speed; reversal to preventive negative RA
1 1 0 0	12	Unallocated
1 1 0 1	13	Unallocated
1 1 1 0	14	Preventive multi-threat level off (MTLO) while level
1 1 1 1	15	Corrective MTLO while climbing/descending

Note. — For MTLO own aircraft with -500 ft/min to +500 ft/min is "level"; own aircraft with vertical rate > 500 ft/min is "climbing" and own aircraft with vertical rate < -500 ft/min is "descending"

(B) LDI (low-level descend inhibit). This 2-bit (51-52) subfield is derived from the own aircraft radar altimeter value and shall indicate whether own aircraft is in a region where low level descend inhibits may be applied. The coding shall have the following meanings:

Bits 51-52 Coding	
0	No descend inhibit
1	Increase descend RAs inhibited
2	Both increase descend RAs and descend RAs inhibited
3	All RAs are inhibited

(C) RMF (RA message format). This 2-bit (53-54) subfield indicates the collision avoidance (CA) system used to generate bits 41-88 of the RF message. The coding shall have the following meanings:

Bits 53-54 *Coding*	
0	All TCAS II versions
1	ACAS X compliant system
2	Reserved for ACAS III
3	Unallocated

(D) RAC (RACs record). This 4-bit (55-58) subfield shall indicate all the currently active RACs, if any, received from other ACAS aircraft. The bits in RAC shall have the following meanings:

Bit	*Resolution advisory complement*
55	Do not pass below
56	Do not pass above
57	Reserved for horizontal coordination
58	Reserved for horizontal coordination

A bit set to 1 shall indicate that the associated RAC is active. A bit set to 0 shall indicate that the associated RAC is inactive.

(E) RAT (RA terminated indicator). This 1-bit (59) subfield shall indicate when an RA previously generated by ACAS has ceased being generated.

Coding

0 ACAS is currently generating the RA indicated in the ARA subfield

1 The RA indicated by the ARA subfield has been terminated (23.4.4.3.11(4)(a))

Note 1. — After an RA has been terminated by ACAS, it is still required to be reported by the Mode S transponder for 18±1 s (23.4.4.3.11(4)(a)). The RA terminated indicator may be used, for example, to permit timely removal of an RA indication from an air traffic controllers display, or for assessments of RA duration within a particular airspace.

Note 2. — RAs may terminate for a number of reasons: normally, when the conflict has been resolved and the threat is diverging in range; or when the threat's Mode S transponder for any reason ceases to report altitude during the conflict. The RA terminated indicator is used to show that the RA has been removed in each of these cases.

(F) MTE (multiple threat encounter). This 1-bit (60)

subfield shall indicate whether two or more simultaneous threats are currently being processed by the ACAS threat resolution logic.

Coding

0 One threat is being processed by the resolution logic (when ARA bit 41 = 1); or no threat is being processed by the resolution logic (when ARA bit 41 = 0)

1 Two or more simultaneous threats are being processed by the resolution logic

(G) CNT (continuation bit). This 1-bit subfield (61) shall indicate whether a follow-on RF message is being generated to report additional information.

Coding

0 No follow-on RF message exists

1 A follow-on RF message exists

(H) TTI (threat type indicator subfield). This 1-bit subfield (62) shall define the type of identity data contained in the TID subfield.

Coding

0 TID contains altitude, range and bearing data

1 TID contains a 24-bit aircraft address

(I) TID (threat identity data subfield). This 24-bit subfield (63-86) shall contain the 24bit aircraft address of the threat or the altitude, range, and bearing if the threat is not Mode S equipped. If two or more threats are simultaneously processed by the ACAS resolution logic, TID shall contain the identity or position data for the most recently declared threat. If TTI = 1, TID shall contain in bits 63-86 the aircraft address of the threat. If TTI = 0, TID shall contain the following three subfields (refer to 23.4.4.3.8.4(2)(b)(ii)(H))

(I) TIDA (threat identity data altitude subfield). This 11-bit subfield (63-73) shall contain the most recent threat altitude estimated by ACAS, expressed in binary to a resolution of 100 ft as follows.

Coding

0	No data
1	Alt < -950 ft
2	-950 ft ≤ Alt < -850 ft
3	-850 ft ≤ Alt < -750 ft
4….	

(II) TIDR (threat identity data range subfield). This 7-bit subfield (74-80) shall contain the most recent threat range estimated by ACAS.

Coding (n)

n	Estimated range (NM)
0	No range estimate available
1	Less than 0.05
2-126	(n-1)/10 ±0.05
127	Greater than 12.55

(III) TIDB (threat identity data bearing subfield).

This 6-bit subfield (81-86) shall contain the most recent estimated bearing of the threat aircraft, relative to the ACAS aircraft heading.

Coding (n)

n	Estimated bearing (degrees)
0	No bearing estimate available

1-60	Between 6(n-1) and 6n
61-63	Not assigned

(J) DSI (designation indicator). This 1-bit subfield (87) shall be coded as follows:

Coding	
0	The threat defined in TID is not designated for Xo or the designation is not applied
1	The threat defined in TID is designated for Xo, and the designation is applied

(K) SPI (suppression indicator). This 1-bit subfield (88) shall be coded as follows:

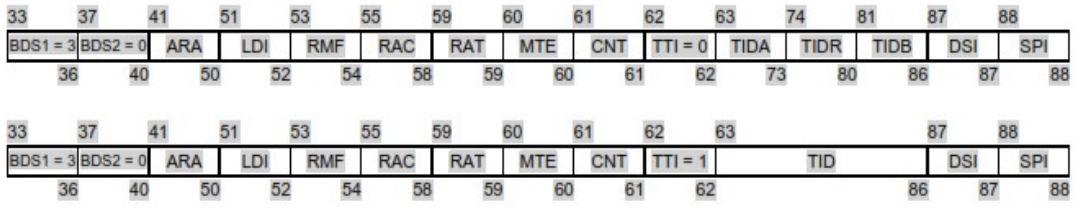
For single-threat encounters:

Coding	
0	The RA is not suppressed
1	The RA is suppressed (not announced to the flight crew)

For multi-threat encounters, suppression does not apply, so the SPI subfield shall indicate the following designations:

Coding	
0	No threat other than the one defined in TID is designated for Xo
1	Another threat is designated for Xo, and the designation is applied

Note. — For ACAS X compliant systems: Subfields in MB for an RA report.



(iii) Subfields in MB for the data link capability report. When BDS1 = 1 and BDS2 = 0, the following bit patterns shall be

provided to the transponder for its data link capability report:

Bit	*Coding*	
43-46	0000	TCAS Version 7.1 compliant and other systems defined by bits 71 and 72
	0001	ACAS Xa (RTCA/DO-385 and EUROCAE/ED-256)
	0010 to 1111	Reserved for ACAS II
48	0	ACAS failed or on standby
	1	ACAS operating
69	0	Hybrid surveillance not operational
	1	Hybrid surveillance fitted and operational
70	0	ACAS generating TAs only
	1	ACAS generating TAs and RAs

Bit 72	Bit	ACAS version
0	0	RTCA/DO-185 (pre-ACAS)
0	1	RTCA/DO-185A
1	0	RTCA/DO-185B & EUROCAE
1	1	All later systems (see Note 3 and 23.4.4.3.8.4.2.8)~~Reserved~~

Note 1.— A summary of the MB subfields for the data link capability report structure is described in Section 23.4.3.1.2.6.10(2)(b).

Note 2. — The use of hybrid surveillance to limit ACAS active interrogations is described in 23.4.4.5.1. The ability only to support decoding of DF = 17 extended squitter messages is not sufficient to set bit 72.

Note 3.— Future versions of ACAS will be identified using part numbers and software version numbers specified in registers E516 and E616.

23.4.4.3.8.4.2.3 MU FIELD.

(1) This 56-bit (33-88) field of long air-air surveillance interrogations (Figure 4-1) shall be used to transmit resolution messages, ACAS broadcasts and RA broadcasts.

(2) UDS (U-definition subfield). This 8-bit (33-40) subfield shall define the remainder of MU.

Note. — For convenience in coding, UDS is expressed in two groups of four bits each, UDS1 and UDS2.

(3) Subfields in MU for a resolution message. When UDS1 = 3 and UDS2 = 0 the following subfields shall be contained in MU:

(a) MTB (multiple threat bit). This 1-bit (42) subfield shall indicate the presence or absence of multiple threats.

Coding
0 Interrogating ACAS has one threat
1 Interrogating ACAS has more than one threat

(b) VRC (vertical RAC). This 2-bit (45-46) subfield shall denote a vertical RAC relating to the addressed aircraft.

Coding
0 No vertical RAC sent
1 Do not pass below
2 Do not pass above
3 Not assigned

(c) CVC (cancel vertical RAC). This 2-bit (43-44) subfield shall denote the cancellation of a vertical RAC previously sent to the addressed aircraft. This subfield shall be set to 0 for a new threat.

Coding
0 No cancellation
1 Cancel previously sent "Do not pass below"
2 Cancel previously sent "Do not pass above"
3 Not assigned

(d) HRC (horizontal RAC). This 3-bit (50-52) subfield shall denote a horizontal RAC relating to the addressed aircraft.

Coding
0 No horizontal RAC or no horizontal resolution capability
1 Other ACAS sense is turn left; do not turn left
2 Other ACAS sense is turn left; do not turn right
3 Not assigned
4 Not assigned
5 Other ACAS sense is turn right; do not turn left

6 Other ACAS sense is turn right; do not turn right
7 Not assigned

(e) CHC (cancel horizontal RAC). This 3-bit (47-49) subfield shall denote the cancellation of a horizontal RAC previously sent to the addressed aircraft. This subfield shall be set to 0 for a new threat.

Coding

0 No cancellation or no horizontal resolution capability
1 Cancel previously sent "Do not turn left"
2 Cancel previously sent "Do not turn right"
3-7 Not assigned

(f) VSB (vertical sense bits subfield). This 4-bit (61-64) subfield shall be used to protect the data in the CVC and VRC subfields. For each of the 16 possible combinations of bits 43-46 the following VSB code shall be transmitted:

	CVC		VRC		VSB			
Coding	43	44	45	46	61	62	63	64
0	0	0	0	0	0	0	0	0
1	0	0	0	1	1	1	1	0
2	0	0	1	0	0	1	1	1
3	0	0	1	1	1	0	0	1
4	0	1	0	0	1	0	1	1
5	0	1	0	1	0	1	0	1
6	0	1	1	0	1	1	0	0
7	0	1	1	1	0	0	1	0
8	1	0	0	0	1	1	0	1
9	1	0	0	1	0	0	1	1
10	1	0	1	0	1	0	1	0
11	1	0	1	1	0	1	0	0
12	1	1	0	0	0	1	1	0
13	1	1	0	1	1	0	0	0
14	1	1	1	0	0	0	0	1
15	1	1	1	1	1	1	1	1

Note. — The rule used to generate the VSB subfield bit setting is a distance 3 Hamming code augmented with a parity bit, producing the ability to detect up to three errors in the eight transmitted bits.

(g) HSB (horizontal sense bits subfield). This 5-bit (56-60) subfield shall be used to protect the data in the CHC and HRC subfields. For each of the 64 possible combinations of bits 47-52 the following HSB code shall be transmitted:

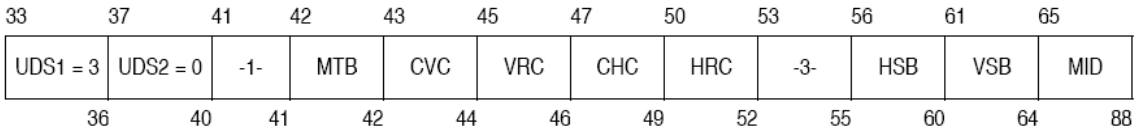
	CHC				HRC		HSB				
Coding	47	48	49	50	51	52	56	57	58	59	60
0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	0	1	0	1	1
2	0	0	0	0	1	0	1	0	0	1	1
3	0	0	0	0	1	1	1	1	0	0	0
4	0	0	0	1	0	0	1	1	1	0	0
5	0	0	0	1	0	1	1	0	1	1	1
6	0	0	0	1	1	0	0	1	1	1	1
7	0	0	0	1	1	1	0	0	1	0	0
8	0	0	1	0	0	0	0	1	1	0	1
9	0	0	1	0	0	1	0	0	1	1	0
10	0	0	1	0	1	0	1	1	1	1	0
11	0	0	1	0	1	1	1	0	1	0	1
12	0	0	1	1	0	0	1	0	0	0	1
13	0	0	1	1	0	1	1	1	0	1	0
14	0	0	1	1	1	0	0	0	0	1	0
15	0	0	1	1	1	1	0	1	0	0	1
16	0	1	0	0	0	0	1	0	1	0	1
17	0	1	0	0	0	1	1	1	1	1	0
18	0	1	0	0	1	0	0	0	1	1	0
19	0	1	0	0	1	1	0	1	1	0	1
20	0	1	0	1	0	0	0	1	0	0	1
21	0	1	0	1	0	1	0	0	0	1	0
22	0	1	0	1	1	0	1	1	0	1	0
23	0	1	0	1	1	1	1	0	0	0	1
24	0	1	1	0	0	0	1	1	0	0	0
25	0	1	1	0	0	1	1	0	0	1	1
26	0	1	1	0	1	0	0	1	0	1	1
27	0	1	1	0	1	1	0	0	0	0	0
28	0	1	1	1	0	0	0	0	1	0	0
29	0	1	1	1	0	1	0	1	1	1	1
30	0	1	1	1	1	0	1	0	1	1	1
31	0	1	1	1	1	1	1	1	1	0	0
32	1	0	0	0	0	0	1	1	0	0	1
33	1	0	0	0	0	1	1	0	0	1	0
34	1	0	0	0	1	0	0	1	0	1	0
35	1	0	0	0	1	1	0	0	0	0	1
36	1	0	0	1	0	0	0	0	1	0	1
37	1	0	0	1	0	1	0	1	1	1	0
38	1	0	0	1	1	0	1	0	1	1	0
39	1	0	0	1	1	1	1	1	1	0	1
40	1	0	1	0	0	0	1	0	1	0	0
41	1	0	1	0	0	1	1	1	1	1	1
42	1	0	1	0	1	0	0	0	1	1	1
43	1	0	1	0	1	1	0	1	1	0	0
44	1	0	1	1	0	0	0	1	0	0	0

	CHC			HRC			HSB				
Coding	47	48	49	50	51	52	56	57	58	59	60
45	1	0	1	1	0	1	0	0	0	1	1
46	1	0	1	1	1	0	1	1	0	1	1
47	1	0	1	1	1	1	1	0	0	0	0
48	1	1	0	0	0	0	0	1	1	0	0
49	1	1	0	0	0	1	0	0	1	1	1
50	1	1	0	0	1	0	1	1	1	1	1
51	1	1	0	0	1	1	1	0	1	0	0
52	1	1	0	1	0	0	1	0	0	0	0
53	1	1	0	1	0	1	1	1	0	1	1
54	1	1	0	1	1	0	0	0	0	1	1
55	1	1	0	1	1	1	0	1	0	0	0
56	1	1	1	0	0	0	0	0	0	0	1
57	1	1	1	0	0	1	0	1	0	1	0
58	1	1	1	0	1	0	1	0	0	1	0
59	1	1	1	0	1	1	1	1	0	0	1
60	1	1	1	1	0	0	1	1	1	0	1
61	1	1	1	1	0	1	1	0	1	1	0
62	1	1	1	1	1	0	0	1	1	1	0
63	1	1	1	1	1	1	0	0	1	0	1

Note. — The rule used to generate the HSB subfield bit setting is a distance 3 Hamming code augmented with a parity bit, producing the ability to detect up to three errors in the eleven transmitted bits.

(h) MID (Aircraft address). This 24-bit (65-88) subfield shall contain the 24-bit aircraft address of the interrogating ACAS aircraft.

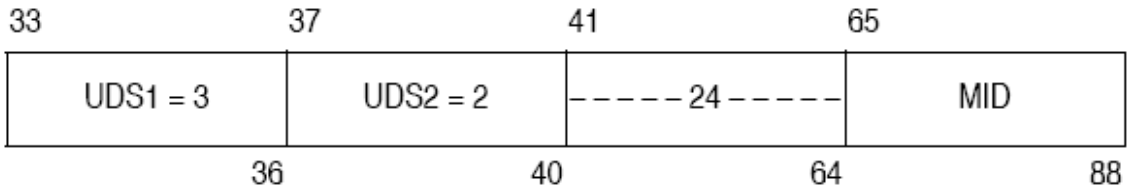
Note. — Structure of MU for a resolution message:



(4) Subfield in MU for an ACAS broadcast. When UDS1 = 3 and UDS2 = 2, the following subfield shall be contained in MU:

(a) MID (Aircraft address). This 24-bit (65-88) subfield shall contain the 24-bit aircraft address of the interrogating ACAS aircraft.

Note. — Structure of MU for an ACAS broadcast:



(5) Subfields in MU for an RA broadcast (RA broadcast interrogation message)

Note. — 23.4.4.3.8.4.2.3(5)(a) is only applicable to TCAS Version 7.1 compliant systems, while 23.4.4.3.8.4.2.3(5)(b) is only applicable to ACAS X compliant systems.

(a) For TCAS Version 7.1 compliant systems: Subfields in MU for an RA broadcast (RA broadcast interrogation message). When UDS1 = 3 and UDS2 = 1, the following subfields shall be contained in MU:

(i) ARA (active RAs). This 14-bit (41-54) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(i)(A).

(ii) RAC (RACs record). This 4-bit (55-58) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(i)(B).

(iii) RAT (RA terminated indicator). This 1-bit (59) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(i)(C)).

(iv) MTE (multiple threat encounter). This 1-bit (60) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(i)(D).

(v) AID (Mode A identity code). This 13-bit (63-75) subfield shall denote the Mode A identity code of the reporting aircraft.

Coding

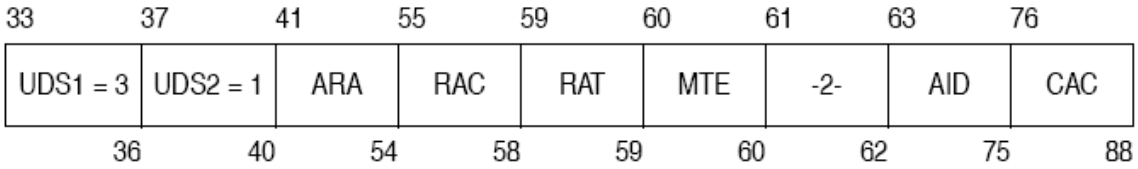
Bit	63	64	65	66	67	68	69	70	71	72	73	74	75
Mode A code bit	A_4	A_2	A_1	B_4	B_2	B_1	0	C_4	C_2	C_1	D_4	D_2	D_1

(vi) CAC (Mode C altitude code). This 13-bit (76-88) subfield shall denote the Mode C altitude code of the reporting aircraft.

Coding

Bit	76	77	78	79	80	81	82	83	84	85	86		88
Mode C code bit	C_1	A_1	C_2	A_2	C_4	A_4	0	B_1	D_1	B_2	D_2	B_4	D_4

Note. — Structure of MU for an RA broadcast:



(b) For ACAS X compliant systems: Subfields in MU for an RA broadcast (RA broadcast interrogation message). When UDS1 = 3 and UDS2 =1, the following subfields shall be contained in MU:

(i) ARA (active RAs). This 10-bit (41-50) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(ii)(A).

(ii) LDI (low-level descend inhibit). This 2-bit (51-52) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(ii)(B).

(iii) RMF (RA message format). This 2-bit (53-54) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(ii)(C).

(iv) RAC (RACs record). This 4-bit (55-58) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(ii)(D).

(v) RAT (RA terminated indicator). This 1-bit (59) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(ii)(E).

(vi) MTE (multiple threat encounter). This 1-bit (60) subfield shall be coded as define 23.4.4.3.8.4(2)(b)(ii)(F).

(vii) SPI (Suppression indicator). This 1-bit (61) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(ii)(K).

(viii) AID (Mode A identity code). This 13-bit (63-75) subfield shall denote the Mode A identity code of the reporting aircraft.

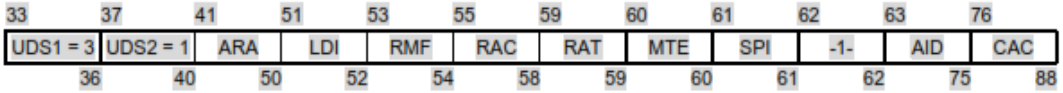
Coding													
Bit	63	64	65	66	67	68	69	70	71	72	73	74	75
Mode A code bit	A_4	A_2	A_1	B_4	B_2	B_1	0	C_4	C_2	C_1	D_4	D_2	D_1

(ix) CAC (Mode C altitude code). This 13-bit (76-88) subfield

shall denote the Mode C altitude code of the reporting aircraft.

Coding													
Bit	76	77	78	79	80	81	82	83	84	85	86	87	88
Mode C code bit	C_1	A_1	C_2	A_2	C_4	A_4	0	B_1	D_1	B_2	D_2	B_4	D_4

Note. — Structure of MU for an RA broadcast:



23.4.4.3.8.4.2.4 MV FIELD.

(1) This 56-bit (33-88) field of long air-air surveillance replies (Figure 4-1) shall be used to transmit air-air coordination reply messages.

(2) VDS (V-definition subfield). This 8-bit (33-40) subfield shall define the remainder of MV.

Note. — For convenience in coding, VDS is expressed in two groups of four bits each, VDS1 and VDS2.

(3) Subfields in MV for a coordination reply

Note. — 23.4.4.3.8.4.2.4(3)(a) is only applicable to TCAS Version 7.1 compliant systems, while 23.4.4.3.8.4.2.4(3)(b) is only applicable to ACAS X compliant systems.

(a) For TCAS Version 7.1 compliant systems: Subfields in MV for a coordination reply. When VDS1 = 3 and VDS2 = 0, the following subfields shall be contained in MV:

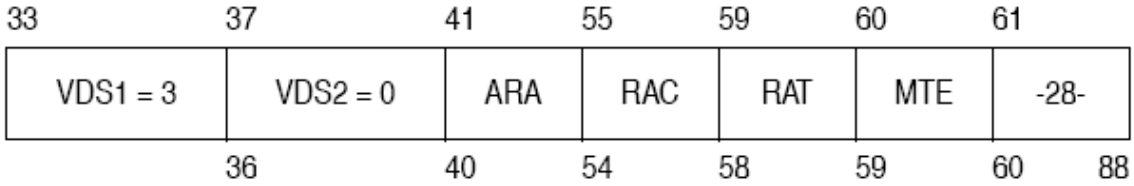
(i) ARA (active RAs). This 14-bit (41-54) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(i)(A)

(ii) RAC (RACs record). This 4-bit (55-58) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(i)(B)

(iii) RAT (RA terminated indicator). This 1-bit (59) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(i)(C)

(iv) MTE (multiple threat encounter). This 1-bit (60) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(i)(D)

Note. — For convenience in coding, VDS is expressed in two groups of four bits each, VDS1 and VDS2.



(b) For ACAS X compliant systems: Subfields in MV for a coordination reply. When VDS1 = 3 and VDS2 = 0, the following subfields shall be contained in MV:

(i) ARA (active RAs). This 10-bit (41-50) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(ii)(A)).

(ii) LDI (low-level descend inhibit). This 2-bit (51-52) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(ii)(B)).

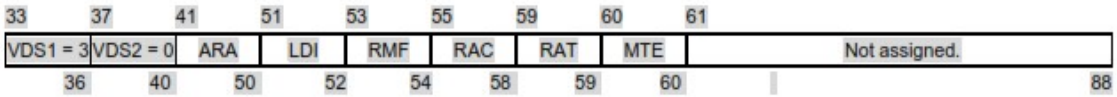
(iii) RMF (RA message format). This 2-bit (53-54) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(ii)(C)).

(iv) RAC (RACs record). This 4-bit (55-58) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(ii)(D)).

(v) RAT (RA terminated indicator). This 1-bit (59) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(ii)(E)).

(vi) MTE (multiple threat encounter). This 1-bit (60) subfield shall be coded as defined in 23.4.4.3.8.4(2)(b)(ii)(F)).

Note. — Structure of MV for a coordination reply:



23.4.4.3.8.4.2.5 SL (SENSITIVITY LEVEL REPORT).

(1) This 3-bit (9-11) downlink field shall be included in both short and long air-air reply formats (DF = 0 and 16). This field shall denote the sensitivity level at which ACAS is currently operating.

Coding

0 ACAS inoperative

1 ACAS is operating at sensitivity level 1

2 ACAS is operating at sensitivity level 2

3 ACAS is operating at sensitivity level 3

4 ACAS is operating at sensitivity level 4

5 ACAS is operating at sensitivity level 5

6 ACAS is operating at sensitivity level 6

7 ACAS is operating at sensitivity level 7

Note. — For ACAS X compliant systems: ACAS will not transmit an SL code greater than 3.

23.4.4.3.8.4.2.6 CC: CROSS-LINK CAPABILITY.

This 1-bit (7) downlink field shall indicate the ability of the transponder to support the cross-link capability, i.e. decode the contents of the DS field in an interrogation with UF equals 0 and respond with the contents of the specified GICB register in the corresponding reply with DF equals 16.

Coding

0 signifies that the transponder cannot support the cross- link capability.

1 signifies that the transponder supports the cross-link capability.

23.4.4.3.8.4.2.7 FOR ACAS X COMPLIANT SYSTEMS

(1) Extended squitter ME field for use in air-to-air coordination. This 56-bit (33-88) field shall be used for air-to-air coordination involving ADS-B only equipped intruders (intruders that cannot receive a discrete 1 030 MHz resolution message).

Note. — ADS-B messages with TYPE code = 28 (ADS-B operational coordination message, refer to 23.4.4.3.8.4.2.7(2)) and TYPE code = 31 (ADS-B aircraft operational status message, refer to 23.4.4.3.8.4.2.7(3) are used in air-to-air coordination.

(2) Subfields in ME for ADS-B operational coordination message (OCM).

Note. — In the subfields defined below, the bit number is relative to the start of the extended squitter, where bit 33 is the start of the ME message field.

(a) TYPE. This 5-bit (33-37) subfield that defines the type of extended squitter shall be set to 28 for the ADS-B OCM.

(b) Subtype. This 3-bit (38-40) subfield that further defines TYPE shall be set to 3 for the ADS-B OCM.

(c) MTB (multiple threat bit). This 1-bit (42) subfield shall indicate a multiple threat according to the codes as defined in 23.4.4.3.8.4.2.3.

(d) CVC (cancel vertical RAC). This 2-bit (43-44) subfield shall be used by airborne ACAS X equipment to cancel a vertical resolution advisory complement sent to an ACAS equipped threat aircraft with codes as defined in 23.4.4.3.8.4.2.3.

(e) VRC (vertical RAC). This 2-bit (45-46) subfield shall be used by airborne ACAS X equipment to send a vertical resolution advisory complement (“do not pass above” or “do not pass below”) to an ACAS equipped threat aircraft with codes as defined in 23.4.4.3.8.4.2.3.

(f) CHC (cancel horizontal RAC). This 3-bit (47-49) subfield shall be used by ACAS X with horizontal on-board resolution equipment to cancel a horizontal resolution advisory complement sent to an ACAS equipped threat aircraft with codes as defined in 23.4.4.3.8.4.2.3. The CHC shall be set to 0 in TCAS resolution messages transmitted by ACAS X without horizontal resolution capability.

(g) HRC (horizontal RAC). This 3-bit (50-52) subfield shall be used by ACAS X with horizontal on-board resolution equipment to send a horizontal resolution advisory complement to manoeuvre (“do not

turn left" or "do not turn right") to the ACAS equipped threat aircraft with codes as defined in 23.4.4.3.8.4.2.3. The HRC shall be set to 0 in ADS-B OCMs transmitted by ACAS X without horizontal resolution capability.

(h) HSB (horizontal sense bits subfield). This 5-bit (53-57) subfield shall be used as a parity coding field to protect the six horizontal sense bits (47-52). The originating aircraft equipped with ACAS which is capable of 1 030/1 090 MHz transmission and that sends a coordination message shall include bits 53-57 with code as defined in 23.4.4.3.8.4.2.3. in all ADS-B OCMs sent. The receiving ACAS X aircraft shall examine HSB (bits 53-57) in the ADS-B OCMs. If the six vertical sense bits (47-52) are not in agreement with the HSB (bits 53-57), the receiving ACAS X aircraft detects there is an error in the message and shall not use the message contents.

(i) VSB (vertical sense bits subfield). This 4-bit (58-61) subfield shall be used as a parity coding field to protect the four vertical sense bits (43-46). The originating active ACAS shall include VSB (bits 58-61) with codes as defined in 23.4.4.3.8.4.2.3 in all operational coordination messages sent. The receiving ACAS X shall examine VSB (bits 58-61) in operational coordination messages received. If four vertical sense bits (43-46) are not in agreement with VSB (bits 58-61), the receiving ACAS X aircraft detects there is an error in the message and shall not use the message contents.

(j) TAA (threat identity aircraft address). This 24-bit (65-88) subfield shall contain the 24-bit aircraft address of the threat with codes as defined in 23.4.4.3.8.4.2.3.

Note. —The structure of ME for an operational coordination message is:

Position	# of bits	Subfield	Remarks
33-37	5	TYPE	= 28
38-40	3	Subtype	= 3
41	1	-	Not assigned
42	1	MTB	-
43-44	2	CVC	-
45-46	2	VRC	-
47-49	3	CHC	-
50-52	3	HRC	-
53-57	5	HSB	-
58-61	4	VSB	-
62-64	3	-	Not assigned
65-88	24	TAA	-

(3) Subfields in ME for aircraft operational status message.

Note. — In the subfields defined below, the bit number is relative to the start of the extended squitter, where bit 33 is the start of the ME message field.

(a) TYPE. This 5-bit (33-37) subfield that defines the type of extended squitter shall be set to 31 for the Aircraft operational status message.

(b) (Subtype. This 3-bit (38-40) subfield that further defines TYPE shall be set to 0 for airborne aircraft and 1 for surface aircraft. For ACAS X air-to-air coordination purposes, Subtype shall always be set to 0.

(c) CC (airborne capability class code). This 16-bit (41-56) subfield which is part of Subtype=0 messages shall be coded as defined in 23.4.4.3.8.4.2.7(3)(c)(i) to 23.4.4.3.8.4.2.7(3)(c)(iv)

(i) Bit (41-42). This 2-bit (41-42) subfield shall be set to 0 for ACAS air-to-air coordination purposes.

(ii) CA Operational (collision avoidance operational). This 1-bit (43) subfield shall be set to 1 to indicate that a collision avoidance system is available and operational and capable of issuing resolution advisories. When this bit is set to 1, the collision avoidance coordination capability bits shall be examined to provide detailed coordination information.

Note. — For all TCAS II versions and ACAS X compliant systems, the associated Mode S transponder sets the CA Operational bit=1 when RI=3 or 4.

(iii) Bits (44-54) shall not be used by the ACAS X air-to-air coordination process but are reserved for future use.

(iv) DAA (detect and avoid). This 2-bit (55-56) subfield shall be used as defined below:

00	No DAA capability or no capability of DAA system to receive CA coordination information
01	Aircraft has a DAA system capable of receiving TCAS resolution messages and ADS-B OCMs
10	Aircraft has a DAA system capable of receiving only ADS-B OCMs
11	Not defined

Note 1. — The DAA bits indicate whether and what type of coordination information needs to be provided to the aircraft so that the DAA system of the threat aircraft can listen and provide guidance that is interoperable with ACAS. These bits are independent of the CA Coordination capability bits, as aircraft with a DAA system may or may not have an ACAS. For more details of DAA bits, refer to RTCA/DO-365.

Note 2. — The type of coordination message transmitted, resolution message or ADS-B OCM, depends both on the receive capability of the DAA system and on the transmit capability of the ACAS. If the DAA system can receive both the resolution message and the OCM, an ACAS with 1 030 MHz transmit capability is required to transmit the resolution message.

(d) OM (airborne operational mode). This 16-bit (57-72) subfield which is part of Subtype=0 messages shall be coded as defined in 23.4.4.3.8.4.2.7(3)(d)(i) to 23.4.4.3.8.4.2.7(3)(d)(iii)

(i) Bits (57-58). This 2-bit (57-58) subfield shall be set to 0 for ACAS X air-to-air coordination purposes.

(ii) Bits (59-64) and Bit 72. The bits (59-64) and bit 72 shall not be used by the ACAS X air-to-air coordination process.

(iii) CCCB (collision avoidance coordination capability bits). This 7-bit (65-71) subfield shall be used as defined below:

Vertical and horizontal (2 bits (65-66))	
00	Vertical
01	Horizontal
10	Blended
11	Reserved
Aircraft CAS Type / Capability (3 bits (67-69))	
000	Active ACAS (TCAS II)
001	Active ACAS (except all TCAS II)
010	Active ACAS (except all TCAS II) with OCM transmit capability
011	Responsive ACAS
100	Passive ACAS with 1 030 MHz resolution message receive capability
101	Passive ACAS with only OCM receive capability
110 to 111	Reserved
Reserved (2 bits (70-71))	
00 to 11	Intended for unmanned aircraft systems use

Note. — The two reserved bits marked 'Intended for unmanned aircraft systems use' are envisioned asa priority field to distinguish among users with different levels of capability or as directed by regulatory authorities.

23.4.4.3.8.4.2.8 ACAS UNIT PART NUMBER AND ACAS SOFTWARE PART NUMBER.

If the ACAS and associated transponder have the necessary capacity, ACAS shall transmit its unit part number to transponder register $E5_{16}$ and shall transmit its software part number to transponder register $E6_{16}$.

Note. — The data formats for transponder registers $E5_{16}$ and $E6_{16}$ are specified in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

23.4.4.3.9 ACAS EQUIPMENT CHARACTERISTICS.

(1) Interfaces. As a minimum, the following input data shall be provided to the ACAS:

(a) aircraft address code;

(b) air-air and ground-air Mode S transmissions received by the Mode S transponder for use by ACAS (23.4.4.3.6(3)(b));

(c) own aircraft's maximum cruising true airspeed capability (23.4.3.1.2.8(2)(b));

(d) pressure altitude;

(e) radio altitude;

(f) operating mode control (standby, TA only and TA/RA Mode);

(g) for ACAS X compliant systems: heading;

(h) for ACAS X compliant systems: GNSS own aircraft's position and velocity;

(i) for ACAS X compliant systems: ADS-B airborne and surface position, airborne velocity, target state and status, and aircraft operational status messages from other aircraft for use by ACAS; and

(j) For ACAS X-compliant systems with Xo special modes available: Designation information for special operation mode.

Note. — Specific requirements for additional inputs for ACAS II and III are listed in the appropriate sections below.

(2) Aircraft antenna system. ACAS shall transmit interrogations and receive replies via two antennas, one mounted on the top of the aircraft and the other on the bottom of the aircraft. The top-mounted antenna shall be directional and capable of being used for direction finding.

(a) Polarization. Polarization of ACAS transmissions shall be nominally vertical.

(b) Radiation pattern. The radiation pattern in elevation of each antenna when installed on an aircraft shall be nominally equivalent to that of a quarter-wave monopole on a ground plane.

(c) ANTENNA SELECTION

(i) Squitter reception. ACAS shall be capable of receiving squitters via the top and bottom antennas.

(ii) Interrogations. ACAS interrogations shall not be transmitted simultaneously on both antennas.

(3) Pressure altitude source. The altitude data for own aircraft provided to ACAS shall be obtained from the source that provides the basis for own Mode C or Mode S reports, and they shall be provided at the finest quantization available.

(a) A source providing a resolution finer than 7.62 m (25 ft) shall be used.

(b) Where a source providing a resolution finer than 7.62 m (25 ft) is not available, and the only altitude data available for own aircraft is Gilham encoded, at least two independent sources shall be used and compared continuously in order to detect encoding errors.

(c) Two altitude data sources shall be used and compared in order to detect errors before provision to ACAS.

(d) The provisions of 23.4.4.3.10(3)) shall apply when the comparison of the two altitude data sources indicates that one of the sources is in error.

23.4.4.3.10 MONITORING

(1) Monitoring function. ACAS shall continuously perform a monitoring function in order to provide a warning if any of the following conditions at least are satisfied:

(a) there is no interrogation power limiting due to interference control (23.4.4.2(3)(c) and the maximum radiated power is reduced to less than that necessary to satisfy the surveillance requirements specified in 23.4.4.3.2; or

(b) any other failure in the equipment is detected which results in a reduced capability of providing TAs or RAs; or

(c) data from external sources indispensable for ACAS operation are not provided, or the data provided are not credible.

(2) Effect on ACAS operation. The ACAS monitoring function shall not adversely

affect other ACAS functions.

(3) Monitoring response. When the monitoring function detects a failure (23.4.4.3.10(1))ACAS shall:

(a) indicate to the flight crew that an abnormal condition exists;

(b) prevent any further ACAS interrogations; and

(c) cause any Mode S transmission containing own aircraft's resolution capability to indicate that ACAS is not operating.

23.4.4.3.11 REQUIREMENTS FOR A MODE S TRANSPONDER USED IN CONJUNCTION WITH ACAS

(1) Transponder capabilities. In addition to the minimum transponder capabilities defined in 23.4.3.1, the Mode S transponder used in conjunction with ACAS shall have the following capabilities:

(a) ability to handle the following formats:

Format No.	Format name
UF = 16	Long air-air surveillance interrogation
DF = 16	Long air-air surveillance reply

(b) ability to receive long Mode S interrogations (UF = 16) and generate long Mode S replies (DF = 16) at a continuous rate of 16.6 ms (60 per second);

(c) means for delivering the ACAS data content of all accepted interrogations addressed to the ACAS equipment;

(d) antenna diversity (as specified in 23.4.3.1.2.10(4);

(e) mutual suppression capability; and

(f) inactive state transponder output power restriction.

When the Mode S transponder transmitter is in the inactive state, the peak pulse power at 1 090 MHz ±3 MHz at the terminals of the Mode S transponder antenna shall not exceed -70 dBm.

(2) DATA TRANSFER BETWEEN ACAS AND ITS MODE S TRANSPONDER

(a) Data transfer from ACAS to its Mode S transponder:

(i) The Mode S transponder shall receive from its ACAS RA information for transmission in an RA report (23.4.4.3.8.4(2)(b)(i)) and in a coordination reply (23.4.4.3.8.4.2.4(3))

(ii) the Mode S transponder shall receive from its ACAS current sensitivity level for transmission in a sensitivity level report (23.4.4.3.8.4.2.5)

(iii) the Mode S transponder shall receive from its ACAS capability information for transmission in a data link capability report (23.4.4.3.8.4(2)(b)(iii)) and for transmission in the RI field of air-air downlink formats DF = 0 and DF = 16 (23.4.4.3.8.4(1)(b)); and

(iv) the Mode S transponder shall receive from its ACAS an indication that RAs are enabled or inhibited for transmission in the RI field of downlink formats 0 and 16.

(b) Data transfer from Mode S transponder to its ACAS:

(i) For TCAS Version 7.1 compliant systems: The Mode S transponder shall transfer to its ACAS received sensitivity level control commands (23.4.4.3.8.4(2)(a)(i) transmitted by Mode S stations;

(ii) the Mode S transponder shall transfer to its ACAS received ACAS broadcast messages (23.4.4.3.8.4.2.3(4)) transmitted by other ACASs;

(iii) the Mode S transponder shall transfer to its ACAS received resolution messages (23.4.4.3.8.4.2.3(3)) transmitted by other ACASs for air-air coordination purposes; and

(iv) the Mode S transponder shall transfer to its ACAS own aircraft's Mode A identity data for transmission in an RA broadcast (23.4.4.3.8.4.2.3(5)).

(3) COMMUNICATION OF ACAS INFORMATION TO OTHER ACAS

(a) Surveillance reply. The ACAS Mode S transponder shall use the short (DF = 0) or long (DF = 16) surveillance formats for replies to ACAS surveillance interrogations. The surveillance reply shall include the VS field as specified in 23.4.3.1.2.8(1), the RI field as specified in 23.4.3.1.2.8(1) and in 23.4.4.3.8.4(1)(b), and the SL field as specified in 23.4.4.3.8.4.2.5

(b) Coordination reply. The ACAS Mode S transponder shall transmit a coordination reply upon receipt of a coordination interrogation from an equipped threat subject to the conditions of 23.4.4.3.11(3)(b)(i). The coordination reply shall use the long air-air surveillance reply format, DF= 16, with the VS field as specified in 23.4.3.1.2.8(2), the RI field as specified in 23.4.3.1.2.8(2 and in 23.4.4.3.8.4(1)(b), the SL field as specified in 23.4.4.3.8.4.2.5 and the MV field as specified in 23.4.4.3.8.4.2.4. ~~Coordination replies shall be transmitted even if the minimum reply rate limits of the transponder (23.4.3.1.2.10.3.7.2) are exceeded.~~

(i) The ACAS Mode S transponder shall reply with a coordination reply to a coordination interrogation received from another ACAS if and only if the transponder is able to deliver the ACAS data content of the interrogation to its associated ACAS.

(4) COMMUNICATION OF ACAS INFORMATION TO GROUND STATIONS

(a) RA reports to Mode S ground stations. During the period of an RA and for 18±1 s following the end of the RA, the ACAS Mode S transponder shall indicate that it has an RA report by setting the appropriate DR field code in replies to a Mode S sensor as specified in 23.4.4.3.8.4(1)(a). The RA report shall include the MB field as specified in 23.4.4.3.8.4(2)(b)(i). The RA report shall describe the most recent RA that existed during the preceding 18±1 s period.

Note 1.— The last sentence of 23.4.4.3.11(4)(a) means that for 18±1 s following the end of an RA, all MB subfields in the RA report with the exception of bit 59 (RA terminated indicator) will retain the information reported at the time the RA was last active.

Note 2.— Upon receipt of a reply with DR = 2, 3, 6 or 7, a Mode S ground station may request downlink of the RA report by setting RR = 19 and either DI = 7, or DI = 7 and RRS = 0 in a surveillance or Comm-A interrogation to the ACAS aircraft. When this interrogation is received, the transponder replies with a Comm-B reply whose MB field contains

the RA report.

(b) Data link capability report. The presence of an ACAS shall be indicated by its Mode S transponder to a ground station in the Mode S data link capability report.

Note. — This indication causes the transponder to set codes in a data link capability report as specified in 23.4.4.3.8.4(2)(b)(iii). .

23.4.4.3.12 INDICATIONS TO THE FLIGHT CREW

(1) CORRECTIVE AND PREVENTIVE RAS

(a) Indications to the flight crew shall distinguish between preventive and corrective RAs.

(2) ALTITUDE CROSSING RAS

(a) If ACAS generates an altitude crossing RA, a specific indication shall be given to the flight crew that it is crossing.

23.4.4.4 PERFORMANCE OF THE ACAS II COLLISION AVOIDANCE LOGIC

Note 1. — Caution is to be observed when considering potential improvements to ACAS since changes may affect more than one aspect of the system performance. It is essential that alternative designs would not degrade the performance of other designs and that such compatibility is demonstrated with a high degree of confidence. The performance specified in Section 5 is based on the performance achieved by TCAS Version 7.1 compliant systems.

Note 2. — The performance of ACAS X compliant systems is improved compared to the performance of TCAS Version 7.1 compliant systems. For more information, refer to the Airborne Collision Avoidance System (ACAS) Manual (Doc 9863).

(1) Definitions relating to the performance of the collision avoidance logic.

Note. — The notation $[t_1, t_2]$ is used to indicate the interval between t_1 and t_2.

Altitude layer means each encounter is attributed to one of six altitude

layers as follows:

Layer	*1*	*2*	*3*	*4*	*5*	*6*
from		2 300 ft	5 000 ft	10 000 ft	20 000 ft	41 000 ft
to	2 300 ft	5 000 ft	10 000 ft	20 000 ft	41 000 ft	

The altitude layer of an encounter is determined by the average altitude of the two aircraft at closest approach.

Note. — For the purposes of defining the performance of the collision avoidance logic, there is no need to specify the physical basis of the altitude measurement or the relationship between altitude and ground level.

Approach angle means the differences in the ground headings of the two aircraft at closest approach, with 180 degrees defined as head on and 0 degrees defined as parallel.

Crossing encounter means an encounter in which the altitude separation of the two aircraft exceeds 100 ft at the beginning and at the end of the encounter window, and the relative vertical position of two aircraft at the end of the encounter window is reversed from that at the beginning of the encounter window.

Encounter means for the purposes of defining the performance of the collision avoidance logic, an encounter consists of two simulated aircraft trajectories. The horizontal coordinates of the aircraft represent the actual position of the aircraft, but the vertical coordinate represents an altimeter measurement of altitude.

Encounter class means encounters are classified according to whether or not the aircraft are transitioning at the beginning and end of the encounter window, and whether or not the encounter is crossing.

Encounter window means the time interval [tca - 40 s, tca + 10 s].

Horizontal miss distance (hmd) means the minimum horizontal separation observed in an encounter.

Level aircraft means an aircraft that is not transitioning.

Original trajectory means the original trajectory of an ACAS-equipped aircraft is that followed by the aircraft in the same encounter when it was not ACAS equipped.

Original rate means the original rate of an ACAS-equipped aircraft at any time is its altitude rate at the same time when it followed the original trajectory.

Required rate means for the standard pilot model, the required rate is that closest to the original rate consistent with the RA.

TCA means nominally, the time of closest approach. For encounters in the standard encounter model (23.4.4.4.2.6)), a reference time for the construction of the encounter at which various parameters, including the vertical and horizontal separation (vmd and hmd), are specified.

Note. — Encounters in the standard encounter model (23.4.4.4.2.6) are constructed by building the trajectories of the two aircraft outwards starting at tca. When the process is complete, tca may not be the precise time of closest approach and differences of a few seconds are acceptable.

Transitioning aircraft means an aircraft having an average vertical rate with a magnitude exceeding 400 feet per minute (ft/min), measured over some period of interest.

Turn extent means a heading difference defined as an aircraft's ground heading at the end of a turn minus its ground heading at the beginning of the turn.

Vertical miss distance (vmd) means notionally, the vertical separation at closest approach. For encounters in the standard encounter model (23.4.4.4.2.6), by construction the vertical separation at the time tca.

(2) Conditions under which the requirements apply. The following assumed conditions shall apply to the performance requirements specified in 23.4.4.4.3and 23.4.4.4.4:

(a) range and bearing measurements and an altitude report are available for the intruder each cycle as long as it is within 14 NM, but not when the range exceeds 14 NM;

(b) the errors in the range and bearing measurements conform to

standard range and bearing error models (23.4.4.4(2)(l) and 23.4.4.4(3));

(c) the intruder's altitude reports, which are its Mode C replies, are expressed in 100 ft quanta;

(d) an altitude measurement that has not been quantized and is expressed with a precision of 1 ft or better is available for own aircraft;

(e) errors in the altitude measurements for both aircraft are constant throughout any particular encounter;

(f) the errors in the altitude measurements for both aircraft conform to a standard altimetry error model (23.4.4.4(4));

(g) the pilot responses to RAs conform to a standard pilot model (23.4.4.4(5));

(h) the aircraft operate in an airspace in which close encounters, including those in which ACAS generates an RA, conform to a standard encounter model (23.4.4.4.2(6));

(i) ACAS-equipped aircraft are not limited in their ability to perform the manoeuvres required by their RAs; and

(j) as specified in 23.4.4.4.2.7:

(i) the intruder involved in each encounter is not equipped (23.4.4.4.2.7(1)(a)); or

(ii) the intruder is ACAS-equipped but follows a trajectory identical to that in the unequipped encounter (23.4.4.4.2.7(1)(b)); or

(iii) the intruder is equipped with an ACAS having a collision avoidance logic identical to that of own ACAS (23.4.4.4.2.7(1)(c));

Note. — The phrase "altitude measurement" refers to a measurement by an altimeter prior to any quantization.

(k) The performance of the collision avoidance logic shall not degrade abruptly as the statistical distribution of the altitude errors or the statistical distributions of the various parameters that characterize the standard encounter model or the response of pilots to the advisories are varied, when surveillance reports are not available on every cycle or when the quantization of the altitude measurements for the intruder is varied or the altitude measurements for own aircraft are quantized.

(l) STANDARD RANGE ERROR MODEL

The errors in the simulated range measurements shall be taken from a Normal distribution with mean 0 ft and standard deviation 50 ft.

(3) STANDARD BEARING ERROR MODEL

The errors in the simulated bearing measurements shall be taken from a Normal distribution with mean 0.0 degrees and standard deviation 10.0 degrees.

(4) STANDARD ALTIMETRY ERROR MODEL

(a) The errors in the simulated altitude measurements shall be assumed to be distributed as a Laplacian distribution with zero mean having probability density

$$p(e) = 1/2\,\lambda \exp(-e/\lambda)$$

(b) The parameter λ required for the definition of the statistical distribution of altimeter error for each aircraft shall have one of two values, λ_1 and λ_2, which depend on the altitude layer of the encounter as follows:

Layer	*1*		*2*		*3*		*4*		*5*		*6*	
	m	*ft*	*m*	*ft*	*m*	*ft*	*m*	*ft*	*m*	*ft*	*m*	*ft*
λ_1	10	35	11	38	13	43	17	58	22	72	28	94
λ_2	18	60	18	60	21	69	26	87	30	101	30	101

(c) For an aircraft equipped with ACAS the value of λ shall be λ1.

(d) For aircraft not equipped with ACAS, the value of shall be selected randomly using the following probabilities:

Layer	*1*	*2*	*3*	*4*	*5*	*6*
prob(λ_1)	0.391	0.320	0.345	0.610	0.610	0.610
prob(λ_2)	0.609	0.680	0.655	0.390	0.390	0.390

(5) Standard pilot model. The standard pilot model used in the assessment of the performance of the collision avoidance logic shall be that:

(a) any RA is complied with by accelerating to the required rate (if necessary) after an appropriate delay;

(b) when the aircraft's current rate is the same as its original rate and the original rate complies with the RA, the aircraft continues at its original rate, which is not necessarily constant due to the possibility of acceleration in the original trajectory;

(c) when the aircraft is complying with the RA, its current rate is the same as the original rate and the original rate changes and consequently becomes inconsistent with the RA, the aircraft continues to comply with the RA;

(d) when an initial RA requires a change in altitude rate, the aircraft responds with an acceleration of 0.25 g after a delay of 5 s from the display of the RA;

(e) when an RA is modified and the original rate complies with the modified RA, the aircraft returns to its original rate (if necessary) with the acceleration specified in g) after the delay specified in h);

(f) when an RA is modified and the original rate does not comply with the modified RA, the aircraft responds to comply with the RA with the acceleration specified in g) after the delay specified in h);

(g) the acceleration used when an RA is modified is 0.25 g unless the modified RA is a reversed sense RA or an increased rate RA in which case the acceleration is 0.35 g;

(h) the delay used when an RA is modified is 2.5 s unless this results in the acceleration starting earlier than 5 s from the initial RA in which case the acceleration starts 5 s from the initial RA; and

(i) when an RA is cancelled, the aircraft returns to its original rate (if necessary) with an acceleration of 0.25 g after a delay of 2.5 s.

23.4.4.4.2.6 STANDARD ENCOUNTER MODEL.

23.4.4.4.2.6.1 ELEMENTS OF THE STANDARD ENCOUNTER MODEL

(1) In order to calculate the effect of ACAS on the risk of collision (23.4.4.4.3) and the compatibility of ACAS with air traffic management (ATM) (23.4.4.4.4), sets of encounters shall be created for each of:

(a) the two aircraft address orderings;

(b) the six altitude layers;

(c) nineteen encounter classes; and

(d) nine or ten vmd bins as specified in 23.4.4.4.2.6.2(4).

The results for these sets shall be combined using the relative weightings given in 23.4.4.4.2.6.2.

(2) Each set of encounters shall contain at least 500 independent, randomly generated encounters.

(3) The two aircraft trajectories in each encounter shall be constructed with the following randomly selected characteristics:

(a) in the vertical plane:

(i) a vmd from within the appropriate vmd bin;

(ii) a vertical rate for each aircraft at the beginning of the encounter window, $\dot{z}_1$ and at the end of the encounter window, $\dot{z}_2$;

(iii) a vertical acceleration; and

(iv) a start time for the vertical acceleration; and

(b) and in the horizontal plane:

(i) an hmd;

(ii) an approach angle;

(iii) a speed for each aircraft at closest approach;

(iv) a decision for each aircraft whether or not it turns;

(v) the turn extent; the bank angle; and the turn end time;

(vi) a decision for each aircraft whether or not its speed changes; and

(vii) the magnitude of the speed change.

Note. — It is possible for the selections made for the various characteristics of an encounter to be irreconcilable. When this occurs, the problem can be resolved by discarding either the selection for a particular characteristic or the whole encounter, as most appropriate.

(c) Two models shall be used for the statistical distribution of hmd (23.4.4.4.2.6.4(1) . For calculations of the effect of ACAS on the risk of collision (23.4.4.4.3), hmd shall be constrained to be less than 500 ft. For calculations of the compatibility of ACAS with ATM (23.4.4.4.4), hmd shall be selected from a larger range of values (23.4.4.4.2.6.4(1)(b)).

Note. — 23.4.4.4.2.6.2 and 23.4.4.4.2.6.3 specify vertical characteristics for the aircraft trajectories in the standard encounter model that depend on whether the hmd *is constrained to be small ("for calculating risk ratio") or can take larger values ("for ATM compatibility"). Otherwise, the characteristics of the encounters in the vertical and horizontal planes are independent.*

23.4.4.4.2.6.2 ENCOUNTER CLASSES AND WEIGHTS

(1) Aircraft address. Each aircraft shall be equally likely to have the higher aircraft address.

(2) Altitude layers. The relative weights of the altitude layers shall be as follows:

Laye	*1*	*2*	*3*	*4*	*5*	*6*
prob(layer)	0.13	0.25	0.32	0.22	0.07	0.01

(3) Encounter classes

(a) The encounters shall be classified according to whether the aircraft are level (L) or transitioning (T) at the beginning (before tca) and end (after tca) of the encounter window and whether or not the encounter is crossing, as follows:

Class	*before* tca	*after* tca	*before* tca	*after* tca	*Crossing*
1	L	L	T	T	yes
2	L	L	L	T	yes
3	L	L	T	L	yes
4	T	T	T	T	yes
5	L	T	T	T	yes
6	T	T	T	L	yes
7	L	T	L	T	yes
8	L	T	T	L	yes
9	T	L	T	L	yes
10	L	L	L	L	no
11	L	L	T	T	no
12	L	L	L	T	no
13	L	L	T	L	no
14	T	T	T	T	no
15	L	T	T	T	no
16	T	T	T	L	no
17	L	T	L	T	no
18	L	T	T	L	no
19	T	L	T	L	no

(b) The relative weights of the encounter classes shall depend on layer as follows:

	for calculating risk ratio		*for ATM compatibility*	
Class	*Layers 1-3*	*Layers 4-6*	*Layers 1-3*	*Layers 4-6*
1	0.00502	0.00319	0.06789	0.07802
2	0.00030	0.00018	0.00408	0.00440
3	0.00049	0.00009	0.00664	0.00220
4	0.00355	0.00270	0.04798	0.06593
5	0.00059	0.00022	0.00791	0.00549
6	0.00074	0.00018	0.00995	0.00440
7	0.00002	0.00003	0.00026	0.00082
8	0.00006	0.00003	0.00077	0.00082
9	0.00006	0.00003	0.00077	0.00082
10	0.36846	0.10693	0.31801	0.09011
11	0.26939	0.41990	0.23252	0.35386
12	0.06476	0.02217	0.05590	0.01868
13	0.07127	0.22038	0.06151	0.18571
14	0.13219	0.08476	0.11409	0.07143
15	0.02750	0.02869	0.02374	0.02418
16	0.03578	0.06781	0.03088	0.05714
17	0.00296	0.00098	0.00255	0.00082
18	0.00503	0.00522	0.00434	0.00440
19	0.01183	0.03651	0.01021	0.03077

(4) vmd bins

(a) The *vmd* of each encounter shall be taken from one of ten *vmd* bins for the non-crossing encounter classes, and from one of nine or ten vmd bins for the crossing encounter classes. Each vmd bin shall have an extent of 100 ft for calculating risk ratio, or an extent of 200 ft for calculating compatibility with ATM. The maximum vmd shall be 1 000 ft for calculating risk ratio, and 2 000 ft otherwise.

(b) For non-crossing encounter classes, the relative weights of the vmd bins shall be as follows:

vmd *bin*	*for calculating risk ratio*	*for ATM compatibility*
1	0.013	0.128
2	0.026	0.135
3	0.035	0.209
4	0.065	0.171
5	0.100	0.160
6	0.161	0.092
7	0.113	0.043
8	0.091	0.025
9	0.104	0.014
10	0.091	0.009

Note. — The weights for the vmd bins do not sum to 1.0. The weights specified are based on an analysis of encounters captured in ATC ground radar data. The missing proportion reflects the fact that the encounters captured included some with vmd exceeding the maximum vmd in the model.

(c) For the crossing classes, the relative weights of the vmd bins shall be as follows:

vmd *bin*	*for calculating risk ratio*	*for ATM compatibility*
1	0.0	0.064
2	0.026	0.144
3	0.036	0.224
4	0.066	0.183
5	0.102	0.171
6	0.164	0.098
7	0.115	0.046
8	0.093	0.027
9	0.106	0.015
10	0.093	0.010

Note. — For the crossing classes, vmd *must exceed 100 ft so that the encounter qualifies as a crossing encounter. Thus, for the calculation of risk*

ratio there is no vmd *bin 1, and for calculations of the compatibility with ATM* vmd *bin 1 is limited to [100 ft, 200 ft].*

23.4.4.4.2.6.3 CHARACTERISTICS OF THE AIRCRAFT TRAJECTORIES IN THE VERTICAL PLANE

(1) vmd. The vmd for each encounter shall be selected randomly from a distribution that is uniform in the interval covered by the appropriate vmd bin.

(2) Vertical rate

(a) For each aircraft in each encounter, either the vertical rate shall be constant $\dot{Z}$ or the vertical trajectory shall be constructed so that the vertical rate at tca - 35 s is $\dot{Z}_1$, and the vertical rate at tca + 5 s is $\dot{Z}_2$. Each vertical rate, $\dot{Z}$, $\dot{Z}_1$ or $\dot{Z}_2$ shall be determined by first selecting randomly an interval within which it lies and then selecting the precise value from a distribution that is uniform over the interval selected.

(b) The intervals within which the vertical rates lie shall depend on whether the aircraft is level, i.e. marked "L" in 23.4.4.4.2.6.2(3)(a), or transitioning, i.e. marked "T" in 23.4.4.4.2.6.2(3)(a), and shall be as follows:

L	T
[240 ft/min, 400 ft/min]	[3 200 ft/min, 6 000 ft/min]
[80 ft/min, 240 ft/min]	[400 ft/min, 3 200 ft/min]
[-80 ft/min, 80 ft/min]	[-400 ft/min, 400 ft/min]
[-240 ft/min, -80 ft/min]	[-3 200 ft/min, -400 ft/min]
[-400 ft/min, -240 ft/min]	[-6 000 ft/min, -3 200 ft/min]

(c) For aircraft that are level over the entire encounter window, the vertical rate $\dot{Z}$ shall be constant. The probabilities for the intervals within which $\dot{Z}$ lies shall be as follows:

$\dot{z}$ *(ft/min)*	*prob*($\dot{z}$)
[240 ft/min, 400 ft/min]	0.0382
[80 ft/min, 240 ft/min]	0.0989
[–80 ft/min, 80 ft/min]	0.7040
[–240 ft/min, –80 ft/min]	0.1198
[–400 ft/min, –240 ft/min]	0.0391

(d) For aircraft that are not level over the entire encounter window, the intervals for Ż1 and Ż2 shall be determined jointly by random selection using joint probabilities that depend on altitude layer and on whether the aircraft is transitioning at the beginning of the encounter window (Rate-to-Level), at the end of the encounter window (Level-to-Rate) or at both the beginning and the end(Rate-to-Rate). The joint probabilities for the vertical rate intervals shall be as follows: IS: 23.4.4

for aircraft with Rate-to-Level trajectories in layers 1 to 3,

$\dot{z}_2$ interval	joint probability of $\dot{z}_1$ and $\dot{z}_2$ interval				
[240 ft/min, 400 ft/min]	0.0019	0.0169	0.0131	0.1554	0.0000
[80 ft/min, 240 ft/min]	0.0000	0.0187	0.0019	0.1086	0.0000
[–80 ft/min, 80 ft/min]	0.0037	0.1684	0.0094	0.1124	0.0075
[–240 ft/min, –80 ft/min]	0.0037	0.1461	0.0094	0.0243	0.0037
[–400 ft/min, –240 ft/min]	0.0000	0.1742	0.0094	0.0094	0.0019
	–6 000 ft/min	–3 200 ft/min	–400 ft/min	400 ft/min	3 200 ft/min	6 000 ft/min $\dot{z}_1$

for aircraft with Rate-to-Level trajectories in layers 4 to 6,

$\dot{z}_2$ interval	joint probability of $\dot{z}_1$ and $\dot{z}_2$ interval				
[240 ft/min, 400 ft/min]	0.0105	0.0035	0.0000	0.1010	0.0105
[80 ft/min, 240 ft/min]	0.0035	0.0418	0.0035	0.1776	0.0279
[–80 ft/min, 80 ft/min]	0.0279	0.1219	0.0000	0.2403	0.0139
[–240 ft/min, –80 ft/min]	0.0035	0.0767	0.0000	0.0488	0.0105
[–400 ft/min, –240 ft/min]	0.0105	0.0453	0.0035	0.0174	0.0000
	–6 000 ft/min	–3 200 ft/min	–400 ft/min	400 ft/min	3 200 ft/min	6 000 ft/min $\dot{z}_1$

for aircraft with Level-to-Rate trajectories in layers 1 to 3,

$\dot{z}_2$ interval	joint probability of $\dot{z}_1$ and $\dot{z}_2$ interval				
[3 200 ft/min, 6000 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[400 ft/min, 3200 ft/min]	0.0074	0.0273	0.0645	0.0720	0.1538
[–400 ft/min, 400 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[–3 200 ft/min, –400 ft/min]	0.2978	0.2084	0.1365	0.0273	0.0050
[–6 000ft/min, –3 200ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
	–400 ft/min	–240 ft/min	–80 ft/min	80 ft/min	240 ft/min	400 ft/min $\dot{z}_1$

for aircraft with Level-to-Rate trajectories in layers 4 to 6,

$\dot{z}_2$ interval	joint probability of $\dot{z}_1$ and $\dot{z}_2$ interval				
[3 200 ft/min, 6 000 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0192
[400 ft/min, 3 200 ft/min]	0.0000	0.0000	0.0962	0.0577	0.1154
[–400 ft/min, 400 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[–3 200 ft/min, –400 ft/min]	0.1346	0.2692	0.2308	0.0577	0.0192
[–6 000 ft/min, –3 200 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
	–400 ft/min	–240 ft/min	–80 ft/min	80 ft/min	240 ft/min	400 ft/min $\dot{z}_1$

for aircraft with Rate-to-Rate trajectories in layers 1 to 3,

$\dot{z}_2$ interval	joint probability of $\dot{z}_1$ and $\dot{z}_2$ interval				
[3 200 ft/min, 6 000 ft/ min]	0.0000	0.0000	0.0007	0.0095	0.0018
[400 ft/min, 3 200 ft/min]	0.0000	0.0018	0.0249	0.2882	0.0066
[–400 ft/min, 400 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[–3 200 ft/min, –400 ft/min]	0.0048	0.5970	0.0600	0.0029	0.0011
[–6 000 ft/min, –3 200 ft/min]	0.0000	0.0007	0.0000	0.0000	0.0000
	–6 000 ft/min	–3 200 ft/min	–400 ft/min	400 ft/min	3 200 ft/min	6 000 ft/min $\dot{z}_1$

for aircraft with Rate-to-Rate trajectories in layers 4 to 6,

$\dot{z}_2$ interval	joint probability of $\dot{z}_1$ and $\dot{z}_2$ interval				
[3 200 ft/min, 6 000 ft/ min]	0.0014	0.0000	0.0028	0.0110	0.0069
[400 ft/min, 3 200 ft/min]	0.0028	0.0028	0.0179	0.4889	0.0523
[–400 ft/min, 400 ft/min]	0.0000	0.0000	0.0000	0.0000	0.0000
[–3 200 ft/min, –400 ft/min]	0.0317	0.3029	0.0262	0.0152	0.0028
[–6 000 ft/min, –3 200 ft/min]	0.0110	0.0220	0.0014	0.0000	0.0000
	–6 000 ft/min	–3 200 ft/min	–400 ft/min	400 ft/min	3 200 ft/min	6 000 ft/min $\dot{z}_1$

(e) For a Rate-to-Rate track, if line $| \dot{Z}2 - \dot{Z}1 | < 566$ ft/min then the track shall be constructed with a constant rate equal to $\dot{Z}1$.

(3) Vertical acceleration

(a) Subject to 23.4.4.4.2.6.3(2)(e) for aircraft that are not level over the entire encounter window, the rate shall be constant and equal to$\dot{Z}1$ over at least the interval [tca - 40 s, tca - 35 s] at the beginning of the encounter window and shall be constant and equal to $\dot{Z}2$ over at least the interval [tca + 5 s, tca + 10 s] at the end of the encounter window. The vertical acceleration shall be constant in the

intervening period.

(b) The vertical acceleration shall be modelled as follows:

$$\ddot{z} = (A\dot{z}_2 - \dot{z}_1) + \varepsilon \quad (\ddot{z})$$

where the parameter A is case-dependent as follows:

and the error ε is selected randomly using the following probability density:
$p(\varepsilon) = 1/2\mu \exp(-|\varepsilon|/\mu)$

where $\mu = 0.3$ ft s-2.

Note. — The sign of the acceleration z is determined by ż1 and ż2 . An error ε that reverses this sign must be rejected and the error reselected.

(4) Acceleration start time. The acceleration start time shall be distributed uniformly in the time interval [tca - 35 s, tca - 5 s] and shall be such that $\dot{Z}_2$ is achieved no later than tca + 5 s.

23.4.4.4.2.6.4 CHARACTERISTICS OF THE AIRCRAFT TRAJECTORIES IN THE HORIZONTAL PLANE

(1) Horizontal miss distance

(a) For calculations of the effect of ACAS on the risk of collision (23.4.4.4.3), hmd shall be uniformly distributed in the range [0, 500 ft].

(b) For calculations concerning the compatibility of ACAS with ATM (23.4.4.4.4), hmd shall be distributed so that the values of hmd have the following cumulative probabilities:

hmd *(ft)*	*cumulative probability* Layers 1-3	Layers 4-6	hmd *(ft)*	*cumulative probability* Layers 1-3	Layers 4-6
0	0.000	0.000	17 013	0.999	0.868
1 215	0.152	0.125	18 228	1.000	0.897
2 430	0.306	0.195	19 443		0.916
3 646	0.482	0.260	20 659		0.927
4 860	0.631	0.322	21 874		0.939
6 076	0.754	0.398	23 089		0.946
7 921	0.859	0.469	24 304		0.952
8 506	0.919	0.558	25 520		0.965
9 722	0.954	0.624	26 735		0.983
10 937	0.972	0.692	27 950		0.993
12 152	0.982	0.753	29 165		0.996
13 367	0.993	0.801	30 381		0.999
14 582	0.998	0.821	31 596		1.000
15 798	0.999	0.848			

(2) Approach angle. The cumulative distribution for the horizontal approach angle shall be as follows:

approach angle (deg.)	*cumulative probability* Layers 1-3	Layers 4-6	*approach angle (deg.)*	*cumulative probability* Layers 1-3	Layers 4-6
0	0.00	0.00	100	0.38	0.28
10	0.14	0.05	110	0.43	0.31
20	0.17	0.06	120	0.49	0.35
30	0.18	0.08	130	0.55	0.43
40	0.19	0.08	140	0.62	0.50
50	0.21	0.10	150	0.71	0.59
60	0.23	0.13	160	0.79	0.66
70	0.25	0.14	170	0.88	0.79
80	0.28	0.19	180	1.00	1.00
90	0.32	0.22			

(3) Aircraft speed. The cumulative distribution for each aircraft's horizontal ground speed at closest approach shall be as follows:

(4)

Ground speed (kt)	cumulative probability Layers 1-3	Layers 4-6	ground speed(kt)	cumulative probability Layers 1-3	Layers 4-6
45	0.000		325	0.977	0.528
50	0.005		350	0.988	0.602
75	0.024	0.000	375	0.997	0.692
100	0.139	0.005	400	0.998	0.813
125	0.314	0.034	425	0.999	0.883
150	0.486	0.064	450	1.000	0.940
175	0.616	0.116	475		0.972
200	0.700	0.171	500		0.987
225	0.758	0.211	525		0.993
250	0.821	0.294	550		0.998
275	0.895	0.361	575		0.999
300	0.949	0.427	600		1.000

Horizontal manoeuvre probabilities. For each aircraft in each encounter, the probability of a turn, the probability of a speed change given a turn, and the probability of a speed change given no turn shall be as follows:

Layer	*Prob(turn)*	*Prob(speed change) given a turn*	*Prob(speed change) given no turn*
1	0.31	0.20	0.5
2	0.29	0.20	0.25
3	0.22	0.10	0.15
4, 5, 6	0.16	0.05	0.10

(a) Given a speed change, the probability of a speed increase shall be0.5 and the probability of a speed decrease shall be 0.5.

(5) Turn extent. The cumulative distribution for the extent of any turn shall be as follows:

	cumulative probability	
Turn extent (deg.)	*Layers 1-3*	*Layers 4-6*
15	0.00	0.00
30	0.43	0.58
60	0.75	0.90
90	0.88	0.97
120	0.95	0.99
150	0.98	1.00
180	0.99	
210	1.00	

(a) The direction of the turn shall be random, with the probability of a left turn being 0.5 and the probability of a right turn being 0.5.

(6) Bank angle. An aircraft's bank angle during a turn shall not be less than 15 degrees. The probability that it equals 15 degrees shall be 0.79 in layers 1-3 and 0.54 in layers 4-5. The cumulative distribution for larger bank angles shall be as follows:

	cumulative probability	
Bank angle (deg.)	*Layers 1-3*	*Layers 4-6*
15	0.79	0.54
25	0.96	0.82
35	0.99	0.98
50	1.00	1.00

(7) Turn end time. The cumulative distribution for each aircraft's turn end time shall be as follows:

Turn end time (seconds before tca*)*	*cumulative probability* *Layers 1-3*	*Layers 4-6*
0	0.42	0.28
5	0.64	0.65
10	0.77	0.76
15	0.86	0.85
20	0.92	0.94
25	0.98	0.99
30	1.00	1.00

(8) Speed change. A constant acceleration or deceleration shall be randomly selected for each aircraft performing a speed change in a given encounter and shall be applied for the duration of the encounter. Accelerations shall be uniformly distributed between 2 kt/s and 6 kt/s. Decelerations shall be uniformly distributed between 1 kt/s and 3 kt/s.

23.4.4.4.2.7 ACAS EQUIPAGE OF THE INTRUDER

(1) The performance requirements specified in 23.4.4.4.3 and 23.4.4.4.4 each apply to three distinct situations in which the following conditions concerning the intruder's ACAS and trajectory shall apply:

(a) where the intruder involved in each encounter is not equipped (23.4.4.3.6(1)(c)), it follows a trajectory identical to that which it follows when own aircraft is not equipped;

(b) where the intruder is ACAS-equipped but follows a trajectory identical to that in the unequipped encounter 23.4.4.4(2)(j)(ii)).

(i) it follows the identical trajectory regardless of whether or not there is an RA;

(ii) the intruder ACAS generates an RA and transmits an RAC that is received immediately after any RA is first announced to the pilot of own aircraft;

(iii) the sense of the RAC generated by the intruder ACAS and transmitted to own aircraft is opposite to the sense of the first RAC selected and transmitted to the intruder by own aircraft (23.4.4.4(2)(j)(ii));

(iv) the RAC transmitted by the intruder is received by own

aircraft; and

(v) the requirements apply both when own aircraft has the lower aircraft address and when the intruder aircraft has the lower aircraft address; and

(c) where the intruder is equipped with an ACAS having a collision avoidance logic identical to that of own ACAS ((23.4.4.4(2)(j)(ii)),

(i) the conditions relating to the performance of own aircraft, ACAS and pilot apply equally to the intruder aircraft, ACAS and pilot;

(ii) RACs transmitted by one aircraft are received by the other; and

(iii) the requirements apply both when own aircraft has the lower aircraft address and when the intruder aircraft has the lower aircraft address.

23.4.4.4.2.8 COMPATIBILITY BETWEEN DIFFERENT COLLISION AVOIDANCE LOGIC DESIGNS

(1) When considering alternative collision avoidance logic designs, certification authorities ~~should~~ shall verify that:

(a) the performances of the alternative design are acceptable in encounters involving ACAS units that use existing designs; and

(b) the performances of the existing designs are not degraded by the use of the alternative design.

Note. — To address the compatibility between different collision avoidance logic designs, the conditions described in 23.4.4.4.2.7(1)(b) are the most severe that can be anticipated in this respect.

23.4.4.4.3 REDUCTION IN THE RISK OF COLLISION

(1) Under the conditions of 23.4.4.4(2), the collision avoidance logic shall be such that the expected number of collisions is reduced to the following proportions of the number expected in the absence of ACAS:

(a) when the intruder is not ACAS equipped 0.18;

(b) when the intruder is equipped but does not respond 0.32; and

(c) when the intruder is equipped and responds 0.04.

23.4.4.4.4 COMPATIBILITY WITH AIR TRAFFIC MANAGEMENT (ATM)

(1) NUISANCE ALERT RATE

(a) Under the conditions of 23.4.4.4(2), the collision avoidance logic shall be such that the proportion of RAs which are a "nuisance" (23.4.4.4.4(1)(b)) shall not exceed:

(i) .06 when own aircraft's vertical rate at the time the RA is first issued is less than 400 ft/min; or

(ii) .08 when own aircraft's vertical rate at the time the RA is first issued exceeds 400 ft/min.

Note. — This requirement is not qualified by the ACAS equipage of the intruder (4.4.2.7) since it has negligible effect on the occurrence and frequency of nuisance RAs.

(b) An RA shall be considered a "nuisance" for the purposes of 23.4.4.4.4(1)(a) unless, at some point in the encounter in the absence of ACAS, the horizontal separation and the vertical separation are simultaneously less than the following values:

	horizontal separation	*vertical separation*
above FL100	2.0 NM	750 ft
below FL100	1.2 NM	750 ft

(2) COMPATIBLE SENSE SELECTION

(a) Under the conditions of 23.4.4.4(2), the collision avoidance logic shall be such that the proportion of encounters in which following the RA results in an altitude separation at closest approach with

the opposite sign to that occurring in the absence of ACAS shall not exceed the following values:

(i) when the intruder is not ACAS equipped .08;

(ii) when the intruder is equipped but does not respond .08; and

(iii) when the intruder is equipped and responds .12.

(3) DEVIATIONS CAUSED BY ACAS

(a) Under the conditions of 23.4.4.4(2), the collision avoidance logic shall be such that the number of RAs resulting in "deviations" (23.4.4.4.4(3)(b)) greater than the values indicated shall not exceed the following proportions of the total number of RAs:

	when own aircraft's vertical rate at the time the RA is first issued	
	is less than 400 ft/min	*exceeds 400 ft/min*
when the intruder is not ACAS equipped,		
for deviations ≥300ft	.15	.23
for deviations ≥600ft	.04	.13
for deviations ≥1 000ft	.01	.07
when the intruder is equipped but does not respond,		
for deviations ≥300ft	.23	.35
for deviations ≥600ft	.06	.16
for deviations ≥1 000ft	.02	.07
when the intruder is equipped and responds,		
for deviations ≥300ft	.11	.23
for deviations ≥600ft	.02	.12
for deviations ≥1 000ft	.01	.06

(b) For the purposes of 23.4.4.4.4(3)(a), the "deviation" of the equipped aircraft from the original trajectory shall be measured in the interval from the time at which the RA is first issued until the time at which, following cancellation of the RA, the equipped aircraft has recovered its original altitude rate. The deviation shall be calculated as the largest altitude difference at any time in this interval between the trajectory followed by the equipped aircraft when responding to its RA and its original trajectory.

23.4.4.4.5 RELATIVE VALUE OF CONFLICTING OBJECTIVES

The collision avoidance logic ~~should~~ shall be such as to reduce as much as practicable the risk of collision (measured as defined in 23.4.4.4.3) and limit as much as practicable the disruption to ATM (measured as defined in 23.4.4.4.4).

23.4.4.5 ACAS USE OF EXTENDED SQUITTER REPORTS

23.4.4.5.1 ACAS HYBRID SURVEILLANCE USING EXTENDED SQUITTER POSITION DATA

Note.— Surveillance protocols defined in this section are for ACAS hybrid surveillance, and surveillance protocols for ACAS not equipped for hybrid surveillance are defined in 23.4.4.3.7(1).

(1) DEFINITIONS

Active surveillance means the process of tracking an intruder by using the information gained from the replies to own aircraft's interrogations.

Hybrid surveillance means the process of using active surveillance to validate and monitor other aircraft being tracked principally using passive surveillance in order to preserve ACAS independence.

Initial acquisition means the process of starting the formation of a new track upon receipt of a squitter from a Mode S aircraft for which there is no track by making an active interrogation.

Passive surveillance means the process of tracking another aircraft without interrogating it, by using the other aircraft's extended squitters. ACAS uses the information contained in passive tracks to

monitor the need for active surveillance, but not for any other purpose.

Validation means the process of verifying the relative position of an intruder using passive information by comparing it to the relative position obtained by active interrogation.

(2) An ACAS equipped to receive extended squitter position reports for passive surveillance of non-threatening intruders shall utilize this passive position information in the following manner.

(3) PASSIVE SURVEILLANCE

(a) EXTENDED HYBRID SURVEILLANCE

(i) Systems using extended hybrid surveillance mode shall establish a track in such a way that no interrogations are performed, i.e. acquiring the track through exclusive use of ADS-B extended squitter, when the following conditions are met:

(A) own aircraft position data meets the following minimum level of quality:

(I) own aircraft horizontal position uncertainty (95 per cent) is < 0.1 NM; and

(II) own aircraft horizontal position integrity shall be such that the probability of an undetected position error, which is greater than 0.6 NM radius, is less than 1 × 10-7.

(B) the received signal strength is equal or less than –68 dBm ±2 dB (extended hybrid surveillance minimum triggering level), or own aircraft is operating on the surface; and

(C) the intruder data quality meets the following minimum requirements:

(I) the ADS-B version number ≥ 2;

(II) the reported NIC ≥ 6 (< 0.6 NM);

(III) the reported NACp ≥ 7 (< 0.1 NM);

(IV) the reported SIL = 3;

(V) the reported SDA = 2 or 3; and

(VI) the barometric altitude is valid.

(ii) The system shall not use ADS-rebroadcast (ADS-R) and TIS-B data to passively acquire an aircraft.

Note 1.— ADS-R is described in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

Note 2. — The signal level strength cannot be applied to ADS-R and TIS-B data.

(iii) A track maintained under extended hybrid surveillance mode shall transition to a track maintained under active surveillance mode if range and altitude of hybrid threat criteria are met.

Note. — Information concerning range and altitude hybrid threat criteria can be found in RTCA DO-300A Change 1/EUROCAE ED-221A – Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance.

(iv) A track under extended hybrid surveillance mode shall transition to a track under hybrid surveillance mode, if:

(A) the signal indicates a high probability to be in close proximity, i.e. signal > extended hybrid surveillance MTL, except when operating on the airport surface; or

(B) intruder data or own data quality does not meet minimum requirements.

(b) Validation. To validate the position of an intruder reported by extended squitter, ACAS shall determine the relative range and relative bearing as computed from the position and geographical heading of own aircraft and the intruder's position as reported in the extended squitter. This derived range and relative bearing, and the altitude reported in the squitter shall be compared to the range, relative bearing and altitude determined by active ACAS interrogation of the aircraft. Differences between the derived and

measured range and relative bearing and the squitter and reply altitude shall be computed and used in tests to determine whether the extended squitter data is valid. If these tests are satisfied the passive position shall be considered to be validated and the track shall be maintained on passive data unless it is a near threat as described in 23.4.4.5.1(4). If any of these validation tests fail, active surveillance shall be used to track the intruder.

Note. — Suitable tests for validating extended squitter data information for the purposes of ACAS hybrid surveillance can be found in RTCA DO-300A Change 1/EUROCAE ED-221A – Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance.

(c) Supplementary active interrogations. In order to ensure that an intruder's track is updated at least as frequently as required in the absence of extended squitter data (23.4.4.3.7(1)(b)(ii)), each time a track is updated using squitter information the time at which an

active interrogation would next be required shall be calculated. An active interrogation shall be made at that time if a further squitter has not been received before the interrogation is due.

(4) Near threat. An intruder shall be tracked under active surveillance if it is a near threat, as determined by separate tests on the range and altitude of the aircraft. These tests shall be such that an intruder is considered a near threat before it becomes a potential threat and thus triggers a traffic advisory as described in 23.4.4.3.3 These tests shall be performed once per second. All near threats, potential threats and threats shall be tracked using active surveillance.

Note. — Suitable tests for determining that an intruder is a near threat can be found in RTCA/DO-300.

(5) Revalidation and monitoring. If an aircraft is being tracked using passive surveillance, periodic active interrogations shall be performed to validate and monitor the extended squitter data as required in 23.4.4.5.1(3)(b). The default rates of revalidation shall be once per minute for a non-threat and once per 10 seconds for a near threat. The tests required in 23.4.4.5.1(3)(b) shall be performed for each interrogation, and active surveillance shall be used to track the intruder if these revalidation tests fail.

Note. — More information about criteria of revalidation rate can be found in RTCA DO-300A Change 1/EUROCAE ED-221A – Minimum Operational Performance Standards (MOPS) for Traffic Alert and

(6) Full active surveillance. If the following condition is met for a track being updated via passive surveillance data:

(a) $|a| \leq 10\,000$ ft and both;

(b) $|a| \leq 3\,000$ ft or $|a - 3\,000 \text{ ft}| / |\dot{a}| \leq 60$ s; and

(c) $r \leq 3$ NM or $(r - 3 \text{ NM}) / |\dot{r}| \leq 60$ s;

where: a = intruder altitude separation in ft

$\dot{a}$ = altitude rate estimate in ft/s

r = intruder slant range in NM

$\dot{r}$ = range rate estimate in NM/s

the aircraft shall be declared an active track and shall be updated on active range measurements once per second for as long as the above condition is met.

(7) All near threats, potential threats and threats shall be tracked using active surveillance.

(8) Adequate protection against residual ADS-B position data shall be provided in track state computation when transitioning from passive to active surveillance, in order to avoid unnecessary advisories during such transitions.

Note. — A suitable means of protection can be found in RTCA DO-300 Change 2 and RTCA DO-300A Change 1/EUROCAE ED-221A – Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance, Section 2.2.6.2.

(9) A track under active surveillance shall transition to passive surveillance if it is neither a near threat, potential threat nor a threat. The tests used to determine it is no longer a near threat shall be similar to those used in 23.4.4.5.1(4) but with larger thresholds in order to have hysteresis which prevents the possibility of frequent transitions between active and passive surveillance.

Note. — Suitable tests for determining that an intruder is no longer a near threat can be found in RTCA DO-300A Change 1/EUROCAE ED-221A – Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System II (TCAS II) Hybrid Surveillance

23.4.4.5.2 ACAS OPERATION WITH AN IMPROVED RECEIVER MTL

Note. — Applications of extended squitter that are independent of ACAS might be implemented (for convenience) using the ACAS receiver. The use of an improved receiver minimum triggering level (MTL) will make it possible to receive extended squitters from ranges of up to 60 NM and beyond in support of such applications.

(1) An ACAS operating with a receiver having a MTL more sensitive than -74 dBm shall implement the capabilities specified in the following paragraphs.

(2) Dual minimum triggering levels. The ACAS receiver shall be capable of setting an indication for each squitter reception as to whether the reply would have been detected by an ACAS operating with a conventional MTL (-74 dBm).

(3) Squitter receptions received at the conventional MTL shall be passed to the ACAS surveillance function for further processing. Squitter receptions that do not meet this condition shall not be passed to the ACAS surveillance function.

Note 1. — Extended squitters containing position report information will be disseminated for display in connection with an extended squitter application.

Note 2. — Use of the conventional MTL for the ACAS surveillance function preserves the current operation of ACAS surveillance when operating with a receiver with an improved MTL.

(4) Dual or re-triggerable reply processor**.** The ACAS Mode S reply processing function shall:

(a) use separate reply processors for Mode S reply formats received at or above the conventional MTL and a separate reply processor for Mode S reply formats received below the conventional MTL; or,

(b) use a Mode S reply processor that will re-trigger if it detects a Mode S preamble that is 2 to 3 dB stronger than the reply that is currently being processed.

Note. — Care must be taken to ensure that low-level squitters (i.e. those below the conventional MTL) do not interfere with the processing of acquisition squitters for ACAS. This could happen if the low-level squitter is allowed to capture the reply processor. This can be prevented by using a separate reply processor for each function, or by requiring the reply processor to be re-triggered by a higher level squitter.

23.4.5 MODE EXTENDED SQUITTER

Note 1. — A functional model of Mode S extended squitter systems supporting ADS-B and/or TIS-B is depicted in Figure 5-1.

Note 2. — Airborne systems transmit ADS-B messages (ADS-B OUT) and may also receive ADS-B and TIS-B messages (ADS-B IN and TIS-B IN). Ground systems (i.e. ground stations) transmit TIS-B (as an option) and receive ADS-B messages.

Note 3.— Although not explicitly depicted in the functional model presented in Figure 5-1, extended squitter systems installed on aerodrome surface vehicles or fixed obstacles may transmit ADS-B messages (ADS-B OUT).

23.4.5.1 MODE S EXTENDED SQUITTER TRANSMITTING SYSTEM CHARACTERISTICS

Note. — Many of the requirements associated with the transmission of Mode S extended squitter are included in Chapters 2 through 5 for Mode S transponder and non-transponder devices using the message formats defined in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871). The provisions presented within the following subsections are focused on requirements applicable to specific classes of airborne and ground transmitting systems that are supporting the applications of ADS-B and TIS-B.*

(1) ADS-B out requirements. Aircraft, surface vehicles and fixed obstacles supporting an ADS-B capability shall incorporate the ADS-B message generation function and the ADS-B message exchange function (transmit) as depicted in Figure 5-1.

(a) ADS-B transmissions from aircraft shall be in accordance with 23.4.3.1.2.8.6(3) for transponder-based systems or 23.4.3.1.2.8.7(3)(b) for non-transponder-based systems~~include position, aircraft identification and type, airborne velocity, periodic status and event driven messages including emergency/priority information~~.

(b) Extended squitter transmitting equipment shall use formats and protocols of the latest version available.

Note 1.— The data formats and protocols for messages transferred via extended squitter are specified in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871).*

(2) Extended squitter ADS-B transmission requirements. Mode S extended squitter transmitting equipment shall be classified according to the unit's intended range capability and the set of parameters that it is capable of transmitting consistent with the following definition of general equipment classes and the specific equipment classes defined in Tables 5-1 and 5-2:

(a) Class A extended squitter airborne systems support an interactive capability incorporating both an extended squitter transmission capability (i.e. ADS-B OUT) with a complementary extended squitter reception capability (i.e. ADS-B IN) in support of onboard ADS-B applications;

(b) Class B extended squitter systems provide a transmission only (i.e. ADS-B OUT without an extended squitter reception capability) for use on aircraft, surface vehicles, or fixed obstructions; and

(c) Class C extended squitter systems have only a reception capability and thus have no transmission requirements.

Table 5-1. ADS-B Class A equipment characteristics

Equipment class	*Minimum transmit power (at antenna terminal)*	*Maximum transmit power (at antenna terminal)*	*Airborne or surface*	*Minimum extended squitter message capability required (see* Note 2*)*
A0 (Minimum)	18.5 dBW (see *Note 1*)	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status
A1 (Basic)	21 dBW	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status
A2 (Enhanced)	21 dBW	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status Target state and status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status
A3 (Extended)	23 dBW	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status Target state and status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status

Note 1.— See Chapter 3, 3.1.2.10.2 for restrictions on the use of this category of Mode S transponder.

Note 2.— The extended squitter messages applicable to Class A equipment are defined in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871).*

Table 5-2. ADS-B Class B equipment characteristics

Equipment class	*Minimum transmit power (at antenna terminal)*	*Maximum transmit power (at antenna terminal)*	*Airborne or surface*	*Minimum extended squitter message capability required*
B0 (Airborne)	18.5 dBW (see *Note 1*)	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status
B1 (Airborne)	21 dBW	27 dBW	Airborne	Airborne position Aircraft identification and category Airborne velocity Aircraft operational status Extended squitter aircraft status
			Surface	Surface position Aircraft identification and category Aircraft operational status Extended squitter aircraft status
B2 Low (Ground Vehicle)	8.5 dBW	< 18.5 dBW (see *Note 2*)	Surface	Surface position Aircraft identification and category Aircraft operational status
B2 (Ground Vehicle)	18.5 dBW	27 dBW (see *Note 2*)	Surface	Surface position Aircraft identification and category Aircraft operational status
B3 (Fixed Obstacle)	18.5 dBW	27 dBW (see *Note 2*)	Airborne (see *Note 3*)	Airborne position Aircraft identification and category Aircraft operational status

Note 1.— See Chapter 3, 3.1.2.10.2 for restrictions on the use of this category of Mode S transponder.

Note 2.— The appropriate ATS authority is expected to get the maximum power level permitted.

Note 3.— Fixed obstacles use the airborne ADS-B message formats since knowledge of their location is of primary interest to airborne aircraft.

23.4.5.1.2 TIS-B OUT REQUIREMENTS

(1) Ground stations supporting a TIS-B capability shall incorporate the TIS-B message generation function and the TIS-B message exchange function (transmit).

(2) The extended squitter messages for TIS-B shall be transmitted by an extended squitter ground station when connected to an appropriate source of surveillance data.

Note 1. — Extended squitter messages for TIS-B are specified in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871).*

Note 2. — Ground stations supporting TIS-B use an extended squitter transmission capability. The characteristics of such ground stations, in terms of transmitter power, antenna gain, transmission rates, etc., are to be tailored to the desired TIS-B service volume of the specific ground station assuming airborne users are equipped with (at least) Class A1 receiving systems.

(3) The maximum transmission rates and effective radiated power of the transmissions shall be controlled to avoid unacceptable levels of RF interference to other 1 090 MHz systems (i.e. SSR and ACAS).

23.4.5.1.3 ADS-B OUT REQUIREMENTS FOR SURFACE VEHICLES

(1) All surface vehicles supporting any versions of extended squitter ADS-B capability shall transmit extended squitter messages as per 23.4.5.1(2).

(2) Extended squitter version 2 or later required system performance. The position source and equipment installed in surface vehicles to transmit extended squitter version 2 or later messages shall support the following performance characteristics:

(a) The NACP for the navigation position data shall be greater than or equal to 9, a 95 per cent accuracy bound on horizontal position less than 30 metres.

Note. — NACP is calculated based on satellite performance.

(b) The NACV for the navigation velocity data shall be greater than or equal to 2, a velocity error less than 3 metres per second.

(c) The NACP and NACV minimum values shall be met at a minimum availability of 95 per cent.

(d) The system design assurance parameter shall be equal to 1 or more, which defines the probability of a failure resulting in transmission of false or misleading information to be less than or equal to 1 × 10–3.

Note 1.— These minimum performance requirements for extended squitter version 2 or later transmitted position data from surface vehicles are necessary to support aircraft-based alerting applications.

Note 2.— Guidance material for implementation of surface vehicle ADS-B systems is contained in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

23.4.5.2 MODE S EXTENDED SQUITTER RECEIVING SYSTEM CHARACTERISTICS (ADS-B IN AND TIS-B IN)

Note 1.— The paragraphs herein describe the required capabilities for 1 090 MHz receivers used for the reception of Mode S extended squitter transmissions that convey ADS-B and/or TIS-B messages. Airborne receiving systems support ADS- B and TIS-B reception while ground receiving systems support only ADS-B reception.

Note 2.— Detailed technical provisions for Mode S extended squitter receivers can be found within RTCA DO-260B/EUROCAE ED-102B, "Minimum Operational Performance Standards for 1 090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS B)."

(1) Mode S extended squitter receiving system functional requirements

(a) Mode S extended squitter receiving systems shall perform the message exchange function (receive) and the report assembler function.

Note. — The extended squitter receiving system receives ADS-B

Mode S extended squitter messages and outputs ADS-B reports to client applications. Airborne receiving systems also receive TIS-B extended squitter messages and output TIS-B reports to client applications. This functional model (shown in Figure 5-1) depicts both airborne and ground 1 090 MHz ADS-B receiving systems.

(b) Mode S extended squitter receiver classes. The required functionality and performance characteristics for the Mode S extended squitter receiving system will vary depending on the ADS-B and TIS-B client applications to be supported and the operational use of the system. Airborne Mode S extended squitter receivers shall be consistent with the definition of receiving system classes shown in Table 5-3.

Note. — Different equipment classes of Mode S extended squitter installations are possible. The characteristics of the receiver associated with a given equipment class are intended to be appropriate to support the required level of operational capability. Equipment classes A0 through A3 are applicable to those Mode S extended airborne installations that include a Mode S extended squitter transmission (ADS OUT) and reception (ADS-B IN) capability. Equipment classes B0 through B3 are applicable to Mode S extended installations with only a transmission (ADS-B OUT) capability and includes equipment classes applicable to airborne, surface vehicles and fixed obstructions. Equipment classes C1 through C3 are applicable to Mode S extended squitter ground receiving systems.

(2) Message exchange function

(a) The message exchange function shall include the 1 090 MHz receiving antenna and the radio equipment (receiver/demodulator/decoder/data buffer) sub-functions.

(b) Message exchange functional characteristics. The airborne Mode S extended squitter receiving system shall support the reception and decoding of all extended squitter messages as listed in Table 5-3. The ground ADS-B extended squitter receiving system shall, as a minimum, support the reception and decoding of all of the extended squitter message types that convey information needed to support the generation of the ADS-B reports of the types required by the client ATM ground applications.

Table 5-3. Reception performance for airborne receiving systems

Receiver class	*Intended air-to-air operational range*	*Receiver minimum trigger threshold level (MTL) (see Note 1)*	*Reception Technique (see Note 2)*	*Required extended squitter ADS-B message support (includes ADS-R and ADS-SLR)*	*Required extended squitter TIS-B message support (includes management messages)*
A0 (Basic VFR)	10 NM	–72 dBm	Standard	Airborne position Surface position Airborne velocity Aircraft identification and category ~~Extended squitter airborne~~ Aircraft status Aircraft operational status	Fine airborne position ~~Coarse airborne position~~ Fine surface position Aircraft identification and category Airborne velocity Management
A1 (Basic IFR)	20 NM	–79 dBm	Enhanced	Airborne position Surface position Airborne velocity Aircraft identification and category ~~Extended squitter airborne~~ Aircraft status Aircraft operational status	Fine airborne position ~~Coarse airborne position~~ Fine surface position Aircraft identification and category Airborne velocity Management
A2 (Enhanced IFR)	40 NM	–79 dBm	Enhanced	Airborne position Surface position Airborne velocity Aircraft identification and category ~~Extended squitter airborne~~ Aircraft status Aircraft operational status Target state and status	Fine airborne position ~~Coarse airborne position~~ Fine surface position Aircraft identification and category Airborne velocity Management
A3 (Extended capability)	90 NM	–84 dBm (and –87 dBm at 15% probability of reception)	Enhanced	Airborne position Surface position Airborne velocity Aircraft identification and category ~~Extended squitter airborne~~ Aircraft status Aircraft operational status Target state and status	Fine airborne position ~~Coarse airborne position~~ Fine surface position Aircraft identification and category Airborne velocity Management

Note 1.— Specific MTL is referenced to the signal level at the output terminal of the antenna, assuming a passive antenna. If electronic amplification is integrated into the antenna assembly, then the MTL is referenced at the input to the amplifier. For Class A3 receivers, a second performance level is defined at a received signal level of –87 dBm where 15 per cent of the messages are to be successfully received. MTL values refer to reception under non-interference conditions.

Note 2.— The extended squitter receiver reception techniques are defined in 5.2.2.4. "Standard" reception techniques refer to the baseline techniques, as required for ACAS 1 090 MHz receivers, that are intended to handle single overlapping Mode A/C fruit. "Enhanced" reception techniques refer to techniques intended to provide improved reception performance in the presence of multiple overlapping Mode A/C fruit and improved decoder re-triggering in the presence of overlapping stronger Mode S fruit. The requirements for the enhanced reception techniques that are applicable to the specific airborne receiver classes are defined in 5.2.2.4.

Note 3.— Management messages include TIS-B, ADS-R and ADS-SLR services. ADS-Rebroadcast (ADS-R) and ADS-Same Link Rebroadcast (ADS-SLR) are defined in Doc 9871.

. . .

(c) Required message reception performance**.** The airborne Mode S extended squitter receiver/demodulation/ decoder shall employ the reception techniques and have a receiver minimum trigger threshold level (MTL) as listed in Table 5-3 as a function of the airborne receiver class. The reception technique and MTL for extended squitter ground receiver shall be selected to provide the reception performance (i.e. range and update rates) as required by the client ATM ground applications.

(d) Enhanced reception techniques. Class A1, A2 and A3 airborne receiving systems shall include the following features to provide improved probability of Mode S extended squitter reception in the presence of multiple overlapping Mode A/C fruit and/or in the presence of an overlapping stronger Mode S fruit, as compared to the performance of the standard reception technique required for Class A0 airborne receiving systems:

(i) Improved Mode S extended squitter preamble detection.

(ii) Enhanced error detection and correction.

(iii) Enhanced bit and confidence declaration techniques applied to the airborne receiver classes as shown below:

(A) Class A1 — Performance equivalent to or better than the use of the "Centre Amplitude" technique.

(B) Class A2 — Performance equivalent to or better than the use of the "Multiple Amplitude Samples" baseline technique, where at least 8 samples are taken for each Mode S bit position and are used in the decision process.

(C) Class A3 — Performance equivalent to or better than the use of the "Multiple Amplitude Samples" baseline technique, where at least 10 samples are taken for each Mode S bit position and are used in the decision process.

(iv) Advanced range receiver techniques for Class A3 receivers, which includes optional additional performance enhancements from the use of multiple receivers and antenna sectorization.

Note 1.— The above enhanced reception techniques are as

defined in RTCA DO-260B/EUROCAE ED-102B, Appendix I.

Note 2.— The performance provided for each of the above enhanced reception techniques when used in a high fruit environment (i.e. with multiple overlapping Mode A/C fruit) is expected to be at least equivalent to that provided by the use of the techniques described in RTCA DO-260C/EUROCAE ED-102A, Appendix I.

Note 3.— It is considered appropriate for ground extended squitter receiving systems to employ the enhanced reception techniques equivalent to those specified for airborne Class A2 or A3 receiving systems.

(3) Report assembler function

(a) The report assembler function shall include the message decoding, report assembly, and output interface sub- functions.

(b) When an extended squitter message is received, the message shall be decoded and the applicable ADS-B report(s) of the types defined in 23.4.5.2(3)(c) shall be generated within 0.5 seconds.

Note 1. — Two configurations of extended squitter airborne receiving systems, which include the reception portion of the ADS-B message exchange function and the ADS-B/TIS-B report assembly function, are allowed:

(i) Type I extended squitter receiving systems receive ADS-B and TIS-B messages and produce application-specific subsets of ADS-B and TIS-B reports. Type I extended squitter receiving systems are customized to the particular client applications using ADS-B and TIS-B reports. Type I extended squitter receiving systems may additionally be controlled by an external entity to produce installation-defined subsets of the reports that those systems are capable of producing.

(ii) Type II extended squitter receiving systems receive ADS-B and TIS-B messages and are capable of producing complete ADS-B and TIS-B reports in accordance with the equipment

class. Type II extended squitter receiving systems may be controlled by an external entity to produce installation-defined subsets of the reports that those systems are capable of producing.

Note 2. — Extended squitter ground receiving systems receive ADS-B messages and produce either application-specific subsets or complete ADS-B reports based on the needs of the ground service provider, including the client applications to be supported. Ground receiving systems may also generate ADS-B Wx Pilot Reports (PIREPs) based upon ADS-B Wx PIREP messages. Additional information on ADS-B Wx PIREP messages can be found in Doc 9871.

Note 3. — The extended squitter message reception function may be physically partitioned into hardware separate from those that implement the report assembly function.

(c) ADS-B REPORT TYPES

Note 1. — The ADS-B report refers to the restructuring of ADS-B message data received from Mode S extended squitter broadcasts into various reports that can be used directly by a set of client applications. Five ADS-B report types are defined by the following subparagraphs and additional two ADS-B report types (ADS-B Wx Air Report (AIREP)and Aircraft State Report) are defined in Doc 9871 for output to client applications. Additional information on the ADS-B report contents and the applicable mapping from extended squitter messages to ADS-B reports can be found in RTCA DO-260C / EUROCAE ED-102B.

Note 2.— The ADS-B Wx Air Report is an optional report that will be generated when weather information is received in ADS-B Wx subtype 1 and 2 messages along with additional weather information received in aircraft status subtype 1 extended squitter messages. The aircraft state report is an optional report that will be generated when information is received in ADS-B Wx subtype 0 messages. The ADS B Wx subtype 0, 1 and 2 messages are defined in Doc 9871. Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant.

(i) State vector report. The state vector report shall contain time of applicability, information about an airborne or

vehicle's current kinematic state (e.g. position, velocity), as well as a measure of the integrity of the navigation data, based on information received in airborne or surface position, airborne velocity, identification and category and aircraft operational status extended squitter messages. Since separate messages are used for position and velocity, the time of applicability shall be reported individually for the position related report parameters and the velocity related report parameters. Also, the state vector report shall include a time of applicability for the estimated position and/or estimated velocity information (i.e. not based on a message with updated position or velocity information) when such estimated position and/or velocity information is included in the state vector report.

Note. — Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant (ground or airborne). The state vector data is the most dynamic of the four ADS-B reports; hence, the applications require frequent updates

of the state vector to meet the required accuracy for the operational dynamics of the typical airborne or ground operations of airborne and surface vehicles.

(ii) Mode status report. The mode status report shall contain time of applicability and current operational information about the transmitting participant, including airborne/vehicle address, call sign, ADS-B version number, airborne/vehicle length and width information, state vector quality information, and other information based on information received in aircraft operational status, target state and status, aircraft identification and category, airborne velocity and aircraft status extended squitter messages. Each time that a mode status report is generated, the report assembler function shall update the report time of applicability. Parameters for which valid data is not available shall either be indicated as invalid or omitted from the mode status report.

Note 1. — Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant (ground or airborne).

Note 2. — The age of the information being reported within the various data elements of a mode status report may vary

as a result of the information having been received within different extended squitter messages at different times. In the absence of item-specific timestamp information, the mode status report includes an optional data update flag that provides applications with the means to establish data age.

(iii) Air referenced velocity report. Air referenced velocity reports shall be generated when air referenced velocity information is received in airborne velocity or ADS-B Wx AIREP extended squitter messages. The air referenced velocity report shall contain time of applicability, airspeed and heading information. Only certain classes of extended squitter receiving systems, as defined in 23.4.5.2(3)(e), are required to generate air referenced velocity reports. Each time that an individual air referenced velocity ~~mode status~~ report is generated, the report assembly function shall update the report time of applicability.

Note 1. — The air referenced velocity report contains velocity information that is received in airborne velocity or ADS-B Wx AIREP messages along with additional information received in airborne identification and category extended squitter messages. Air referenced velocity reports are not generated for surface participants.

Note 2. — Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant.

(iv) Resolution advisory (RA) report. The RA report shall contain time of applicability and the contents of an active ACAS resolution advisory (RA) as received in a Type=28 and Subtype=2 extended squitter message.

Note. — The RA report is only intended to be generated by ground receiving subsystems when supporting a ground ADS-B client application(s) requiring active RA information. An RA report will nominally be generated each time a Type=28, Subtype=2 extended squitter message is received.

(v) *target state report*

Note. — The target state report will be generated when information is received in target state and status

messages, along with additional information received in airborne identification and category extended squitter messages. The target state and status message is defined in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871). Specific requirements for the customization of this type of report may vary according to the needs of the client applications of each participant (ground or airborne).*

(d) TIS-B REPORT TYPES

(i) As TIS-B messages are received by airborne receiving *systems, the information shall be reported to client* applications. Each time that an individual TIS-B report is generated, the report assembly function shall update the report time of applicability to the current time.

Note 1.— The TIS-B message formats are defined in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

Note 2. — The TIS-B report refers to the restructuring of TIS-B message data received from ground Mode S extended squitter broadcasts into reports that can be used by a set of client applications. Two ADS-B report types are defined by the following subparagraphs for output to client applications. Additional information on the TIS-B report contents and the applicable mapping from extended squitter messages to ADS-B reports can be found in the Technical Provisions for Mode S Services and Extended Squitter (Doc 9871).

(ii) TIS-B target report. All received information elements other than position, shall be reported rectly, including all reserved fields for the TIS-B fine format messages. The reporting format is not specified in detail, except that the information content reported shall be the same as the information content received.

(iii) When a TIS-B position message is received, it is compared with tracks to determine whether it can be decoded into target position (i.e. correlated to an existing track). If the message is decoded into target position, a report shall be generated within 0.5 seconds. The report shall contain the received position information with a time of applicability, the most recently received velocity

measurement with a time of applicability, the estimated position and velocity applicable to a common time of applicability, airborne/vehicle address, and all other information in the received message. The estimated values shall be based on the received position information and the track history of the target.

(iv) When a TIS-B velocity message is received, if it is correlated to a complete track, a report shall be generated, within 0.5 seconds of the message reception. The report shall contain the received velocity information with a time of applicability, the estimated position and velocity applicable to a common time of applicability, airborne/vehicle address, and all other information in the received message. The estimated values shall be based on the received ground reference velocity information and the track history of the target.

(v) Traffic uplink management report. The entire message content of any received Traffic uplink management message shall be reported directly to the client applications. The information content reported shall be the same as the information content received.

(vi) The contents of any received Traffic uplink~~TIS-B~~ management message shall be reported bit-for-bit to the client applications

(vii)

(e) REPORT TIME OF APPLICABILITY

The receiving system shall use a local source of reference time as the basis for reporting the time of applicability, as defined for each specific ADS-B and TIS-B report type (see 23.4.5.2(3)(e)and 23.4.5.2(3)(d))

(i) GNSS UTC measure time reference. For receiving systems that generate ADS-B and/or TIS-B reports that use GNSS UTC measured time for the purpose of generating the report time applicability, UTC measured time data shall have a minimum range of 300 seconds and a resolution of 0.0078125 (1/128) second.

(ii) ESTABLISHED INSTALLATION RECEIVER TIME

(A) For receiving systems that generate ADS-B and/or TIS-B reports. that do not use GNSS UTC measure time per 23.4.5.(3)(v)(A) and for which there is no appropriate time reference available, the receiving system shall establish an appropriate internal clock or counter having a maximum clock cycle or count time of 20 milliseconds. The established cycle or clock count shall have a minimum range of 300 seconds and a resolution of 0.0078125 (1/128) seconds.

Note. — The use of a time reference as described above is intended to allow the report time of applicability to accurately reflect the time intervals applicable to reports within a sequence. For example, the applicable time interval between state vector

reports could be accurately determined by a client application, even though the absolute time would not be indicated by the report.

(f) REPORTING REQUIREMENTS

(i) Reporting requirements for Type I Mode S extended squitter airborne receiving systems. As a minimum, the report assembler function associated with Type I Mode S extended squitter receiving systems, as defined in 23.4.5.2(3), shall support that subset of ADS-B and TIS-B reports and report parameters, that are required by the specific client applications being served by that receiving system.

(ii) Reporting requirements for Type II Mode S extended squitter airborne receiving systems. The report assembler function associated with Type II receiving systems, as defined in 23.4.5.2(3), shall generate ADS-B and TIS-B reports according to the class of the receiving system as shown in Table 5-4 when the prerequisite ADS-B and/or TIS-B messages are being received.

Table 5-4. Mode S extended squitter airborne receiving system reporting requirements

Receiver class	*Minimum ADS-B reporting requirements*	*Minimum TIS-B reporting requirements*
A0 (Basic VFR)	ADS-B state vector report (per 5.2.3.3.1) and ADS-B mode status report (per 5.2.3.3.2)	TIS-B state report and ~~TIS-B~~Traffic uplink management report
A1 (Basic IFR)	ADS-B state vector report (per 5.2.3.3.1) and ADS-B mode status report (per 5.2.3.3.2) and ADS-B air referenced velocity report (ARV) (per 5.2.3.3.3)	TIS-B state report and ~~TIS-B~~Traffic uplink management report
A2 (Enhanced IFR)	ADS-B state vector report (per 5.2.3.3.1) and ADS-B mode status report (per 5.2.3.3.2) and ADS-B ARV report (per 5.2.3.3.3) and ADS-B target state report (per 5.2.3.3.5)	TIS-B state report and ~~TIS-B~~Traffic uplink management report
A3 (Extended capability)	ADS-B state vector report (per 5.2.3.3.1) and ADS-B mode status report (per 5.2.3.3.2) and ADS-B ARV report (per 5.2.3.3.3) and ADS-B target state report (per 5.2.3.3.5)	TIS-B state report and ~~TIS-B~~Traffic uplink management report
Note.— Traffic uplink management reports include TIS-B, ADS-R and ADS-SLR service status.		

(iii) Reporting requirements for Mode S extended squitter ground receiving systems. As a minimum, the report assembler function associated with Mode S extended squitter ground receiving systems, as defined in 23.4.5.2(3), shall support that subset of ADS-B reports and report parameters, that are required by the specific client applications being served by that receiving system.

(4) Interoperability

The Mode S extended squitter receiving system shall provide interoperability between the different versions of extended squitter ADS-B message formats.

Note 1.— All defined ADS-B versions and their corresponding message formats are contained in the Technical Provisions for Mode S Services and Extended Squitter *(Doc 9871) and are identified by a version number.*

Note 2. — ADS-B message formats are defined with backward compatibility with previous versions. An extended squitter receiver can recognize and decode signals of its own version, as well as the message formats from lower versions. The receiver, however, can decode the portion of messages received from a higher version transponder according to its own capability.

(a) INITIAL MESSAGE DECODING

(i) The Mode S extended squitter receiving system shall, upon acquiring a new ADS-B target, initially apply the decoding provisions applicable to version 0 (zero) ADS B messages until or unless an aircraft operational status message is received indicating that a higher version message format is in use.

(b) APPLYING VERSION NUMBER

(i) The Mode S extended squitter receiving system shall decode the version number information conveyed in the aircraft operational status message and shall apply the corresponding decoding rules for the reported version, up to the highest version supported by the receiving system, for the decoding of the subsequent extended squitter ADS-B messages from that specific aircraft or vehicle.

(c) HANDLING OF RESERVED MESSAGE SUBFIELDS

(i) The Mode S extended squitter receiving system shall ignore the contents of any message subfield defined as reserved.

Note. — This provision supports interoperability between message versions by allowing the definition of additional parameters that will be ignored by earlier receiver versions and correctly decoded by newer receiver versions.

FIGURE FOR CHAPTER 5

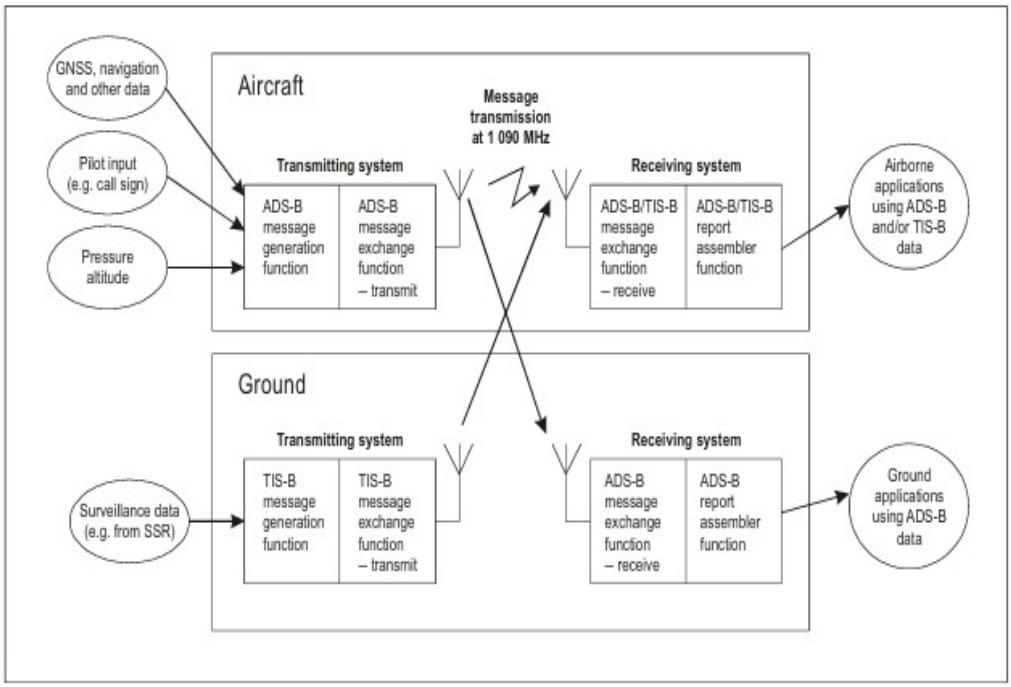


Figure 5-1. ADS-B/TIS-B system functional model

23.4.6 MULTILATERATION SYSTEMS

Note 1. — Multilateration (MLAT) systems use the time difference of arrival (TDOA) of the transmissions of an SSR transponder (or the extended squitter transmissions of a non-transponder device) between several ground receivers to determine the position of the aircraft (or ground vehicle). A multilateration system can be:

(1) passive, using transponder replies to other interrogations or spontaneous squitter transmissions;

(2) active, in which case the system itself interrogates aircraft in the coverage area; or

(3) a combination of a) and b).

Note 2.— Material contained in EUROCAE ED-117 – MOPS for Mode S Multilateration Systems for Use in A-SMGCS and ED-142 – Technical Specifications for Wide Area Multilateration System (WAM) provides a good basis for planning, implementation and satisfactory operation of MLAT systems for most applications.

23.4.6.1 DEFINITIONS

Multilateration (MLAT) System means a group of equipment configured to provide position derived from the secondary surveillance radar (SSR) transponder signals (replies or squitters) primarily using time difference of arrival (TDOA) techniques. Additional information, including identification, can be extracted from the received signals.

Time Difference of Arrival (TDOA) means the difference in relative time that a transponder signal from the same aircraft (or ground vehicle) is received at different receivers.

Wide area multilateration (WAM) system means a multilateration system deployed to support en-route surveillance, terminal area surveillance and other applications such as height monitoring and precision runway monitoring (PRM).

23.4.6.2 FUNCTIONAL REQUIREMENTS

(1) Radio frequency characteristics, structure and data contents of signals used in 1 090 MHz MLAT systems shall conform to the provisions of Section 23.4.3.

(2) An MLAT system used for air traffic surveillance shall be capable of determining aircraft position and identity.

Note 1. — Depending on the application, either two- or three-dimensional position of the aircraft may be required.

Note 2. — Aircraft identity may be determined from:

(a) Mode A code contained in Mode A or Mode S replies; or

(b) Aircraft identification contained in Mode S replies or extended squitter identity and category message.

Note 3. — Other aircraft information can be obtained by analysing transmissions of opportunity (i.e. squitters or replies to other ground interrogations) or by direct interrogation by the MLAT system.

(3) Where an MLAT system is equipped to decode additional position information contained in transmissions, it shall report such information separately from the aircraft position calculated based on TDOA.

23.4.6.3 PROTECTION OF THE RADIO FREQUENCY ENVIRONMENT

Note. — This section only applies to active MLAT systems.

(1) In order to minimize system interferences, the effective radiated power of active interrogators shall be reduced to the lowest value consistent with the operationally required range of each individual interrogator site.

Note. — Guidance material on power consideration is contained in the Aeronautical Surveillance Manual *(Doc 9924).*

(2) An active MLAT system shall not use active interrogations to obtain information that can be obtained by passive reception within each required update period.

Note. — Transponder occupancy will be increased by the use of omnidirectional antennas. It is particularly significant for Mode S selective interrogations because of their higher transmission rate. All Mode S transponders will be occupied decoding each selective interrogation not just the addressed transponder.

(3) An active MLAT system consisting of a set of transmitters shall be considered as a single Mode S interrogator.

(4) The set of transmitters used by all active MLAT systems in any part of the airspace shall not cause any transponder to be impacted such that its occupancy, because of the aggregate of all MLAT 1 030 MHz interrogations, is greater than 2 per cent at any time.

Note 1. — This represents a minimum requirement. Some regions may impose stricter requirements.

Note 2.— For an MLAT system using only Mode S interrogations, 2 per cent is equivalent to no more than 400 Mode S interrogations per second received by any aircraft from all systems using MLAT technology.

(5) Active MLAT systems shall not use Mode S All-Call interrogations.

Note. — Mode S aircraft can be acquired by the reception of acquisition squitter or extended squitter even in airspace where there are no active interrogators.

23.4.6.4 PERFORMANCE REQUIREMENTS

The performance characteristics of the MLAT system used for air traffic surveillance shall be such that the intended operational service(s) can be satisfactorily supported.

23.4.7 TECHNICAL REQUIREMENTS FOR AIRBORNE SURVEILLANCE APPLICATIONS

Note 1. — Airborne surveillance applications are based on aircraft receiving and using ADS-B message information transmitted by other aircraft/vehicles or ground stations. The capability of an

aircraft to receive and use ADS-B/TIS-B message information is referred to as ADS-B/TIS-B IN.

Note 2.— Initial airborne surveillance applications use ADS-B messages on 1 090 MHz extended squitter to provide airborne traffic situational awareness (ATSA) and are expected to include "In-trail procedures" and "Enhanced visual separation on approach".

Note 3.— Detailed description of aforementioned applications can be found in RTCA/DO-289 and DO-312.

(1) GENERAL REQUIREMENTS

(a) Traffic data functions

Note. — The aircraft transmitting ADS-B messages used by other aircraft for airborne surveillance applications is referred to as the reference aircraft.

(i) identifying the reference aircraft. The system shall support a function to identify unambiguously each reference aircraft relevant to the application.

(ii) tracking the reference aircraft. The system shall support a function to monitor the movements and behaviour of each reference aircraft relevant to the application.

(iii) trajectory of the reference aircraft. The system shall support a computational function to predict the future position of a reference aircraft beyond simple extrapolation.

Note. — It is anticipated that this function will be required for future applications.

(b) Displaying traffic

Note. — Provisions contained in this section apply to

cases wherein tracks generated by ACAS and by reception of ADS-B/TIS-B IN messages are shown on a single display.

(i) The system shall display only one track for each distinct aircraft on a given display.

Note. — This is to ensure that tracks established by ACAS and ADS-B/TIS-B IN are properly correlated and mutually validated before being displayed.

(ii) Where a track generated by ADS-B/TIS-B IN and a track generated by ACAS have been determined to belong to the same aircraft, the track generated by ADS-B/TIS-B IN shall be displayed.

Note. — At close distances, it is possible that the track generated by ACAS provides better accuracy than the track generated by ADS-B/TIS-B IN. The requirement above ensures the continuity of the display.

(iii) The display of the tracks shall comply with the requirements of ACAS traffic display.

Note. — 23.4.4.3 addresses colour coding and readability of the display.

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PART 23 SUBPART 4 – IMPLEMENTING STANDARDS

For ease of reference, the number assigned to each implementing standard corresponds to its associated regulation. For example, IS 23.4.1 would reflect a standard required in subsection 23.4.1

IS: 23.4.3.1.1.7(12)(f) SSR AUTOMATIC PRESSURE-ALTITUDE TRANSMISSION CODE (PULSE POSITION ASSIGNMENT)

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
B1 000 to B950	0	0	0	0	0	0	0	0	0	1	0
B950 to B850	0	0	0	0	0	0	0	0	1	1	0
B850 to B750	0	0	0	0	0	0	0	0	1	0	0
B750 to B650	0	0	0	0	0	0	0	1	1	0	0
B650 to B550	0	0	0	0	0	0	0	1	1	1	0
B550 to B450	0	0	0	0	0	0	0	1	0	1	0
B450 to B350	0	0	0	0	0	0	0	1	0	1	1
B350 to B250	0	0	0	0	0	0	0	1	0	0	1
B250 to B150	0	0	0	0	0	0	1	1	0	0	1
B150 to B50	0	0	0	0	0	0	1	1	0	1	1
B50 to 50	0	0	0	0	0	0	1	1	0	1	0
50 to 150	0	0	0	0	0	0	1	1	1	1	0
150 to 250	0	0	0	0	0	0	1	1	1	0	0
250 to 350	0	0	0	0	0	0	1	0	1	0	0
350 to 450	0	0	0	0	0	0	1	0	1	1	0
450 to 550	0	0	0	0	0	0	1	0	0	1	0
550 to 650	0	0	0	0	0	0	1	0	0	1	1
650 to 750	0	0	0	0	0	0	1	0	0	0	1
750 to 850	0	0	0	0	0	1	1	0	0	0	1
850 to 950	0	0	0	0	0	1	1	0	0	1	1
950 to 1 050	0	0	0	0	0	1	1	0	0	1	0
1 050 to 1 150	0	0	0	0	0	1	1	0	1	1	0
1 150 to 1 250	0	0	0	0	0	1	1	0	1	0	0
1 250 to 1 350	0	0	0	0	0	1	1	1	1	0	0
1 350 to 1 450	0	0	0	0	0	1	1	1	1	1	0
1 450 to 1 550	0	0	0	0	0	1	1	1	0	1	0
1 550 to 1 650	0	0	0	0	0	1	1	1	0	1	1
1 650 to 1 750	0	0	0	0	0	1	1	1	0	0	1
1 750 to 1 850	0	0	0	0	0	1	0	1	0	0	1
1 850 to 1 950	0	0	0	0	0	1	0	1	0	1	1
1 950 to 2 050	0	0	0	0	0	1	0	1	0	1	0
2 050 to 2 150	0	0	0	0	0	1	0	1	1	1	0
2 150 to 2 250	0	0	0	0	0	1	0	1	1	0	0
2 250 to 2 350	0	0	0	0	0	1	0	0	1	0	0
2 350 to 2 450	0	0	0	0	0	1	0	0	1	1	0
2 450 to 2 550	0	0	0	0	0	1	0	0	0	1	0
2 550 to 2 650	0	0	0	0	0	1	0	0	0	1	1
2 650 to 2 750	0	0	0	0	0	1	0	0	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
2 750 to 2 850	0	0	0	0	1	1	0	0	0	0	1
2 850 to 2 950	0	0	0	0	1	1	0	0	0	1	1
2 950 to 3 050	0	0	0	0	1	1	0	0	0	1	0
3 050 to 3 150	0	0	0	0	1	1	0	0	1	1	0
3 150 to 3 250	0	0	0	0	1	1	0	0	1	0	0
3 250 to 3 350	0	0	0	0	1	1	0	1	1	0	0
3 350 to 3 450	0	0	0	0	1	1	0	1	1	1	0
3 450 to 3 550	0	0	0	0	1	1	0	1	0	1	0
3 550 to 3 650	0	0	0	0	1	1	0	1	0	1	1
3 650 to 3 750	0	0	0	0	1	1	0	1	0	0	1
3 750 to 3 850	0	0	0	0	1	1	1	1	0	0	1
3 850 to 3 950	0	0	0	0	1	1	1	1	0	1	1
3 950 to 4 050	0	0	0	0	1	1	1	1	0	1	0
4 050 to 4 150	0	0	0	0	1	1	1	1	1	1	0
4 150 to 4 250	0	0	0	0	1	1	1	1	1	0	0
4 250 to 4 350	0	0	0	0	1	1	1	0	1	0	0
4 350 to 4 450	0	0	0	0	1	1	1	0	1	1	0
4 450 to 4 550	0	0	0	0	1	1	1	0	0	1	0
4 550 to 4 650	0	0	0	0	1	1	1	0	0	1	1
4 650 to 4 750	0	0	0	0	1	1	1	0	0	0	1
4 750 to 4 850	0	0	0	0	1	0	1	0	0	0	1
4 850 to 4 950	0	0	0	0	1	0	1	0	0	1	1
4 950 to 5 050	0	0	0	0	1	0	1	0	0	1	0
5 050 to 5 150	0	0	0	0	1	0	1	0	1	1	0
5 150 to 5 250	0	0	0	0	1	0	1	0	1	0	0
5 250 to 5 350	0	0	0	0	1	0	1	1	1	0	0
5 350 to 5 450	0	0	0	0	1	0	1	1	1	1	0
5 450 to 5 550	0	0	0	0	1	0	1	1	0	1	0
5 550 to 5 650	0	0	0	0	1	0	1	1	0	1	1
5 650 to 5 750	0	0	0	0	1	0	1	1	0	0	1
5 750 to 5 850	0	0	0	0	1	0	0	1	0	0	1
5 850 to 5 950	0	0	0	0	1	0	0	1	0	1	1
5 950 to 6 050	0	0	0	0	1	0	0	1	0	1	0
6 050 to 6 150	0	0	0	0	1	0	0	1	1	1	0
6 150 to 6 250	0	0	0	0	1	0	0	1	1	0	0
6 250 to 6 350	0	0	0	0	1	0	0	0	1	0	0
6 350 to 6 450	0	0	0	0	1	0	0	0	1	1	0
6 450 to 6 550	0	0	0	0	1	0	0	0	0	1	0
6 550 to 6 650	0	0	0	0	1	0	0	0	0	1	1
6 650 to 6 750	0	0	0	0	1	0	0	0	0	0	1
6 750 to 6 850	0	0	0	1	1	0	0	0	0	0	1
6 850 to 6 950	0	0	0	1	1	0	0	0	0	1	1
6 950 to 7 050	0	0	0	1	1	0	0	0	0	1	0
7 050 to 7 150	0	0	0	1	1	0	0	0	1	1	0

7 150 to 7 250	0	0	0	1	1	0	0	0	1	0	0

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
7 250 to 7 350	0	0	0	1	1	0	0	1	1	0	0
7 350 to 7 450	0	0	0	1	1	0	0	1	1	1	0
7 450 to 7 550	0	0	0	1	1	0	0	1	0	1	0
7 550 to 7 650	0	0	0	1	1	0	0	1	0	1	1
7 650 to 7 750	0	0	0	1	1	0	0	1	0	0	1
7 750 to 7 850	0	0	0	1	1	0	1	1	0	0	1
7 850 to 7 950	0	0	0	1	1	0	1	1	0	1	1
7 950 to 8 050	0	0	0	1	1	0	1	1	0	1	0
8 050 to 8 150	0	0	0	1	1	0	1	1	1	1	0
8 150 to 8 250	0	0	0	1	1	0	1	1	1	0	0
8 250 to 8 350	0	0	0	1	1	0	1	0	1	0	0
8 350 to 8 450	0	0	0	1	1	0	1	0	1	1	0
8 450 to 8 550	0	0	0	1	1	0	1	0	0	1	0
8 550 to 8 650	0	0	0	1	1	0	1	0	0	1	1
8 650 to 8 750	0	0	0	1	1	0	1	0	0	0	1
8 750 to 8 850	0	0	0	1	1	1	1	0	0	0	1
8 850 to 8 950	0	0	0	1	1	1	1	0	0	1	1
8 950 to 9 050	0	0	0	1	1	1	1	0	0	1	0
9 050 to 9 150	0	0	0	1	1	1	1	0	1	1	0
9 150 to 9 250	0	0	0	1	1	1	1	0	1	0	0
9 250 to 9 350	0	0	0	1	1	1	1	1	1	0	0
9 350 to 9 450	0	0	0	1	1	1	1	1	1	1	0
9 450 to 9 550	0	0	0	1	1	1	1	1	0	1	0
9 550 to 9 650	0	0	0	1	1	1	1	1	0	1	1
9 650 to 9 750	0	0	0	1	1	1	1	1	0	0	1
9 750 to 9 850	0	0	0	1	1	1	0	1	0	0	1
9 850 to 9 950	0	0	0	1	1	1	0	1	0	1	1
9 950 to 10 050	0	0	0	1	1	1	0	1	0	1	0
10 050 to 10 150	0	0	0	1	1	1	0	1	1	1	0
10 150 to 10 250	0	0	0	1	1	1	0	1	1	0	0
10 250 to 10 350	0	0	0	1	1	1	0	0	1	0	0
10 350 to 10 450	0	0	0	1	1	1	0	0	1	1	0
10 450 to 10 550	0	0	0	1	1	1	0	0	0	1	0
10 550 to 10 650	0	0	0	1	1	1	0	0	0	1	1
10 650 to 10 750	0	0	0	1	1	1	0	0	0	0	1
10 750 to 10 850	0	0	0	1	0	1	0	0	0	0	1
10 850 to 10 950	0	0	0	1	0	1	0	0	0	1	1
10 950 to 11 050	0	0	0	1	0	1	0	0	0	1	0
11 050 to 11 150	0	0	0	1	0	1	0	0	1	1	0
11 150 to 11 250	0	0	0	1	0	1	0	0	1	0	0
11 250 to 11 350	0	0	0	1	0	1	0	1	1	0	0
11 350 to 11 450	0	0	0	1	0	1	0	1	1	1	0
11 450 to 11 550	0	0	0	1	0	1	0	1	0	1	0

11 550	to	11 650	0	0	0	1	0	1	0	1	0	1	1
11 650	to	11 750	0	0	0	1	0	1	0	1	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
11 750 to 11	0	0	0	1	0	1	1	1	0	0	1
11 850 to 11	0	0	0	1	0	1	1	1	0	1	1
11 950 to 12	0	0	0	1	0	1	1	1	0	1	0
12 050 to 12	0	0	0	1	0	1	1	1	1	1	0
12 150 to 12	0	0	0	1	0	1	1	1	1	0	0
12 250 to 12	0	0	0	1	0	1	1	0	1	0	0
12 350 to 12	0	0	0	1	0	1	1	0	1	1	0
12 450 to 12	0	0	0	1	0	1	1	0	0	1	0
12 550 to 12	0	0	0	1	0	1	1	0	0	1	1
12 650 to 12	0	0	0	1	0	1	1	0	0	0	1
12 750 to 12	0	0	0	1	0	0	1	0	0	0	1
12 850 to 12	0	0	0	1	0	0	1	0	0	1	1
12 950 to 13	0	0	0	1	0	0	1	0	0	1	0
13 050 to 13	0	0	0	1	0	0	1	0	1	1	0
13 150 to 13	0	0	0	1	0	0	1	0	1	0	0
13 250 to 13	0	0	0	1	0	0	1	1	1	0	0
13 350 to 13	0	0	0	1	0	0	1	1	1	1	0
13 450 to 13	0	0	0	1	0	0	1	1	0	1	0
13 550 to 13	0	0	0	1	0	0	1	1	0	1	1
13 650 to 13	0	0	0	1	0	0	1	1	0	0	1
13 750 to 13	0	0	0	1	0	0	0	1	0	0	1
13 850 to 13	0	0	0	1	0	0	0	1	0	1	1
13 950 to 14	0	0	0	1	0	0	0	1	0	1	0
14 050 to 14	0	0	0	1	0	0	0	1	1	1	0
14 150 to 14	0	0	0	1	0	0	0	1	1	0	0
14 250 to 14	0	0	0	1	0	0	0	0	1	0	0
14 350 to 14	0	0	0	1	0	0	0	0	1	1	0
14 450 to 14	0	0	0	1	0	0	0	0	0	1	0
14 550 to 14	0	0	0	1	0	0	0	0	0	1	1
14 650 to 14	0	0	0	1	0	0	0	0	0	0	1
14 750 to 14	0	0	1	1	0	0	0	0	0	0	1
14 850 to 14	0	0	1	1	0	0	0	0	0	1	1
14 950 to 15	0	0	1	1	0	0	0	0	0	1	0
15 050 to 15	0	0	1	1	0	0	0	0	1	1	0
15 150 to 15	0	0	1	1	0	0	0	0	1	0	0
15 250 to 15	0	0	1	1	0	0	0	1	1	0	0
15 350 to 15	0	0	1	1	0	0	0	1	1	1	0
15 450 to 15	0	0	1	1	0	0	0	1	0	1	0
15 550 to 15	0	0	1	1	0	0	0	1	0	1	1
15 650 to 15	0	0	1	1	0	0	0	1	0	0	1
15 750 to 15	0	0	1	1	0	0	1	1	0	0	1
15 850 to 15	0	0	1	1	0	0	1	1	0	1	1
15 950 to 16	0	0	1	1	0	0	1	1	0	1	0

16 050	to	16	0	0	1	1	0	0	1	1	1	1	0
16 150	to	16	0	0	1	1	0	0	1	1	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
16 250	to	16	0	0	1	1	0	0	1	0	1	0	0
16 350	to	16	0	0	1	1	0	0	1	0	1	1	0
16 450	to	16	0	0	1	1	0	0	1	0	0	1	0
16 550	to	16	0	0	1	1	0	0	1	0	0	1	1
16 650	to	16	0	0	1	1	0	0	1	0	0	0	1
16 750	to	16	0	0	1	1	0	1	1	0	0	0	1
16 850	to	16	0	0	1	1	0	1	1	0	0	1	1
16 950	to	17	0	0	1	1	0	1	1	0	0	1	0
17 050	to	17	0	0	1	1	0	1	1	0	1	1	0
17 150	to	17	0	0	1	1	0	1	1	0	1	0	0
17 250	to	17	0	0	1	1	0	1	1	1	1	0	0
17 350	to	17	0	0	1	1	0	1	1	1	1	1	0
17 450	to	17	0	0	1	1	0	1	1	1	0	1	0
17 550	to	17	0	0	1	1	0	1	1	1	0	1	1
17 650	to	17	0	0	1	1	0	1	1	1	0	0	1
17 750	to	17	0	0	1	1	0	1	0	1	0	0	1
17 850	to	17	0	0	1	1	0	1	0	1	0	1	1
17 950	to	18	0	0	1	1	0	1	0	1	0	1	0
18 050	to	18	0	0	1	1	0	1	0	1	1	1	0
18 150	to	18	0	0	1	1	0	1	0	1	1	0	0
18 250	to	18	0	0	1	1	0	1	0	0	1	0	0
18 350	to	18	0	0	1	1	0	1	0	0	1	1	0
18 450	to	18	0	0	1	1	0	1	0	0	0	1	0
18 550	to	18	0	0	1	1	0	1	0	0	0	1	1
18 650	to	18	0	0	1	1	0	1	0	0	0	0	1
18 750	to	18	0	0	1	1	1	1	0	0	0	0	1
18 850	to	18	0	0	1	1	1	1	0	0	0	1	1
18 950	to	19	0	0	1	1	1	1	0	0	0	1	0
19 050	to	19	0	0	1	1	1	1	0	0	1	1	0
19 150	to	19	0	0	1	1	1	1	0	0	1	0	0
19 250	to	19	0	0	1	1	1	1	0	1	1	0	0
19 350	to	19	0	0	1	1	1	1	0	1	1	1	0
19 450	to	19	0	0	1	1	1	1	0	1	0	1	0
19 550	to	19	0	0	1	1	1	1	0	1	0	1	1
19 650	to	19	0	0	1	1	1	1	0	1	0	0	1
19 750	to	19	0	0	1	1	1	1	1	1	0	0	1
19 850	to	19	0	0	1	1	1	1	1	1	0	1	1
19 950	to	20	0	0	1	1	1	1	1	1	0	1	0
20 050	to	20	0	0	1	1	1	1	1	1	1	1	0
20 150	to	20	0	0	1	1	1	1	1	1	1	0	0
20 250	to	20	0	0	1	1	1	1	1	0	1	0	0
20 350	to	20	0	0	1	1	1	1	1	0	1	1	0
20 450	to	20	0	0	1	1	1	1	1	0	0	1	0
20 550	to	20	0	0	1	1	1	1	1	0	0	1	1

20 650	to	20	0	0	1	1	1	1	1	0	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
20 750	to	20	0	0	1	1	1	0	1	0	0	0	1
20 850	to	20	0	0	1	1	1	0	1	0	0	1	1
20 950	to	21	0	0	1	1	1	0	1	0	0	1	0
21 050	to	21	0	0	1	1	1	0	1	0	1	1	0
21 150	to	21	0	0	1	1	1	0	1	0	1	0	0
21 250	to	21	0	0	1	1	1	0	1	1	1	0	0
21 350	to	21	0	0	1	1	1	0	1	1	1	1	0
21 450	to	21	0	0	1	1	1	0	1	1	0	1	0
21 550	to	21	0	0	1	1	1	0	1	1	0	1	1
21 650	to	21	0	0	1	1	1	0	1	1	0	0	1
21 750	to	21	0	0	1	1	1	0	0	1	0	0	1
21 850	to	21	0	0	1	1	1	0	0	1	0	1	1
21 950	to	22	0	0	1	1	1	0	0	1	0	1	0
22 050	to	22	0	0	1	1	1	0	0	1	1	1	0
22 150	to	22	0	0	1	1	1	0	0	1	1	0	0
22 250	to	22	0	0	1	1	1	0	0	0	1	0	0
22 350	to	22	0	0	1	1	1	0	0	0	1	1	0
22 450	to	22	0	0	1	1	1	0	0	0	0	1	0
22 550	to	22	0	0	1	1	1	0	0	0	0	1	1
22 650	to	22	0	0	1	1	1	0	0	0	0	0	1
22 750	to	22	0	0	1	0	1	0	0	0	0	0	1
22 850	to	22	0	0	1	0	1	0	0	0	0	1	1
22 950	to	23	0	0	1	0	1	0	0	0	0	1	0
23 050	to	23	0	0	1	0	1	0	0	0	1	1	0
23 150	to	23	0	0	1	0	1	0	0	0	1	0	0
23 250	to	23	0	0	1	0	1	0	0	1	1	0	0
23 350	to	23	0	0	1	0	1	0	0	1	1	1	0
23 450	to	23	0	0	1	0	1	0	0	1	0	1	0
23 550	to	23	0	0	1	0	1	0	0	1	0	1	1
23 650	to	23	0	0	1	0	1	0	0	1	0	0	1
23 750	to	23	0	0	1	0	1	0	1	1	0	0	1
23 850	to	23	0	0	1	0	1	0	1	1	0	1	1
23 950	to	24	0	0	1	0	1	0	1	1	0	1	0
24 050	to	24	0	0	1	0	1	0	1	1	1	1	0
24 150	to	24	0	0	1	0	1	0	1	1	1	0	0
24 250	to	24	0	0	1	0	1	0	1	0	1	0	0
24 350	to	24	0	0	1	0	1	0	1	0	1	1	0
24 450	to	24	0	0	1	0	1	0	1	0	0	1	0
24 550	to	24	0	0	1	0	1	0	1	0	0	1	1
24 650	to	24	0	0	1	0	1	0	1	0	0	0	1
24 750	to	24	0	0	1	0	1	1	1	0	0	0	1
24 850	to	24	0	0	1	0	1	1	1	0	0	1	1
24 950	to	25	0	0	1	0	1	1	1	0	0	1	0
25 050	to	25	0	0	1	0	1	1	1	0	1	1	0

25 150	to	25	0	0	1	0	1	1	1	0	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
25 250	to	25	0	0	1	0	1	1	1	1	1	0	0
25 350	to	25	0	0	1	0	1	1	1	1	1	1	0
25 450	to	25	0	0	1	0	1	1	1	1	0	1	0
25 550	to	25	0	0	1	0	1	1	1	1	0	1	1
25 650	to	25	0	0	1	0	1	1	1	1	0	0	1
25 750	to	25	0	0	1	0	1	1	0	1	0	0	1
25 850	to	25	0	0	1	0	1	1	0	1	0	1	1
25 950	to	26	0	0	1	0	1	1	0	1	0	1	0
26 050	to	26	0	0	1	0	1	1	0	1	1	1	0
26 150	to	26	0	0	1	0	1	1	0	1	1	0	0
26 250	to	26	0	0	1	0	1	1	0	0	1	0	0
26 350	to	26	0	0	1	0	1	1	0	0	1	1	0
26 450	to	26	0	0	1	0	1	1	0	0	0	1	0
26 550	to	26	0	0	1	0	1	1	0	0	0	1	1
26 650	to	26	0	0	1	0	1	1	0	0	0	0	1
26 750	to	26	0	0	1	0	0	1	0	0	0	0	1
26 850	to	26	0	0	1	0	0	1	0	0	0	1	1
26 950	to	27	0	0	1	0	0	1	0	0	0	1	0
27 050	to	27	0	0	1	0	0	1	0	0	1	1	0
27 150	to	27	0	0	1	0	0	1	0	0	1	0	0
27 250	to	27	0	0	1	0	0	1	0	1	1	0	0
27 350	to	27	0	0	1	0	0	1	0	1	1	1	0
27 450	to	27	0	0	1	0	0	1	0	1	0	1	0
27 550	to	27	0	0	1	0	0	1	0	1	0	1	1
27 650	to	27	0	0	1	0	0	1	0	1	0	0	1
27 750	to	27	0	0	1	0	0	1	1	1	0	0	1
27 850	to	27	0	0	1	0	0	1	1	1	0	1	1
27 950	to	28	0	0	1	0	0	1	1	1	0	1	0
28 050	to	28	0	0	1	0	0	1	1	1	1	1	0
28 150	to	28	0	0	1	0	0	1	1	1	1	0	0
28 250	to	28	0	0	1	0	0	1	1	0	1	0	0
28 350	to	28	0	0	1	0	0	1	1	0	1	1	0
28 450	to	28	0	0	1	0	0	1	1	0	0	1	0
28 550	to	28	0	0	1	0	0	1	1	0	0	1	1
28 650	to	28	0	0	1	0	0	1	1	0	0	0	1
28 750	to	28	0	0	1	0	0	0	1	0	0	0	1
28 850	to	28	0	0	1	0	0	0	1	0	0	1	1
28 950	to	29	0	0	1	0	0	0	1	0	0	1	0
29 050	to	29	0	0	1	0	0	0	1	0	1	1	0
29 150	to	29	0	0	1	0	0	0	1	0	1	0	0
29 250	to	29	0	0	1	0	0	0	1	1	1	0	0
29 350	to	29	0	0	1	0	0	0	1	1	1	1	0
29 450	to	29	0	0	1	0	0	0	1	1	0	1	0
29 550	to	29	0	0	1	0	0	0	1	1	0	1	1
29 650	to	29	0	0	1	0	0	0	1	1	0	0	1

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
29 750	to	29	0	0	1	0	0	0	0	1	0	0	1
29 850	to	29	0	0	1	0	0	0	0	1	0	1	1
29 950	to	30	0	0	1	0	0	0	0	1	0	1	0
30 050	to	30	0	0	1	0	0	0	0	1	1	1	0
30 150	to	30	0	0	1	0	0	0	0	1	1	0	0
30 250	to	30	0	0	1	0	0	0	0	0	1	0	0
30 350	to	30	0	0	1	0	0	0	0	0	1	1	0
30 450	to	30	0	0	1	0	0	0	0	0	0	1	0
30 550	to	30	0	0	1	0	0	0	0	0	0	1	1
30 650	to	30	0	0	1	0	0	0	0	0	0	0	1
30 750	to	30	0	1	1	0	0	0	0	0	0	0	1
30 850	to	30	0	1	1	0	0	0	0	0	0	1	1
30 950	to	31	0	1	1	0	0	0	0	0	0	1	0
31 050	to	31	0	1	1	0	0	0	0	0	1	1	0
31 150	to	31	0	1	1	0	0	0	0	0	1	0	0
31 250	to	31	0	1	1	0	0	0	0	1	1	0	0
31 350	to	31	0	1	1	0	0	0	0	1	1	1	0
31 450	to	31	0	1	1	0	0	0	0	1	0	1	0
31 550	to	31	0	1	1	0	0	0	0	1	0	1	1
31 650	to	31	0	1	1	0	0	0	0	1	0	0	1
31 750	to	31	0	1	1	0	0	0	1	1	0	0	1
31 850	to	31	0	1	1	0	0	0	1	1	0	1	1
31 950	to	32	0	1	1	0	0	0	1	1	0	1	0
32 050	to	32	0	1	1	0	0	0	1	1	1	1	0
32 150	to	32	0	1	1	0	0	0	1	1	1	0	0
32 250	to	32	0	1	1	0	0	0	1	0	1	0	0
32 350	to	32	0	1	1	0	0	0	1	0	1	1	0
32 450	to	32	0	1	1	0	0	0	1	0	0	1	0
32 550	to	32	0	1	1	0	0	0	1	0	0	1	1
32 650	to	32	0	1	1	0	0	0	1	0	0	0	1
32 750	to	32	0	1	1	0	0	1	1	0	0	0	1
32 850	to	32	0	1	1	0	0	1	1	0	0	1	1
32 950	to	33	0	1	1	0	0	1	1	0	0	1	0
33 050	to	33	0	1	1	0	0	1	1	0	1	1	0
33 150	to	33	0	1	1	0	0	1	1	0	1	0	0
33 250	to	33	0	1	1	0	0	1	1	1	1	0	0
33 350	to	33	0	1	1	0	0	1	1	1	1	1	0
33 450	to	33	0	1	1	0	0	1	1	1	0	1	0
33 550	to	33	0	1	1	0	0	1	1	1	0	1	1
33 650	to	33	0	1	1	0	0	1	1	1	0	0	1
33 750	to	33	0	1	1	0	0	1	0	1	0	0	1
33 850	to	33	0	1	1	0	0	1	0	1	0	1	1
33 950	to	34	0	1	1	0	0	1	0	1	0	1	0
34 050	to	34	0	1	1	0	0	1	0	1	1	1	0
34 150	to	34	0	1	1	0	0	1	0	1	1	0	0

RANGE			PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments			D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
34 250	to	34	0	1	1	0	0	1	0	0	1	0	0
34 350	to	34	0	1	1	0	0	1	0	0	1	1	0
34 450	to	34	0	1	1	0	0	1	0	0	0	1	0
34 550	to	34	0	1	1	0	0	1	0	0	0	1	1
34 650	to	34	0	1	1	0	0	1	0	0	0	0	1
34 750	to	34	0	1	1	0	1	1	0	0	0	0	1
34 850	to	34	0	1	1	0	1	1	0	0	0	1	1
34 950	to	35	0	1	1	0	1	1	0	0	0	1	0
35 050	to	35	0	1	1	0	1	1	0	0	1	1	0
35 150	to	35	0	1	1	0	1	1	0	0	1	0	0
35 250	to	35	0	1	1	0	1	1	0	1	1	0	0
35 350	to	35	0	1	1	0	1	1	0	1	1	1	0
35 450	to	35	0	1	1	0	1	1	0	1	0	1	0
35 550	to	35	0	1	1	0	1	1	0	1	0	1	1
35 650	to	35	0	1	1	0	1	1	0	1	0	0	1
35 750	to	35	0	1	1	0	1	1	1	1	0	0	1
35 850	to	35	0	1	1	0	1	1	1	1	0	1	1
35 950	to	36	0	1	1	0	1	1	1	1	0	1	0
36 050	to	36	0	1	1	0	1	1	1	1	1	1	0
36 150	to	36	0	1	1	0	1	1	1	1	1	0	0
36 250	to	36	0	1	1	0	1	1	1	0	1	0	0
36 350	to	36	0	1	1	0	1	1	1	0	1	1	0
36 450	to	36	0	1	1	0	1	1	1	0	0	1	0
36 550	to	36	0	1	1	0	1	1	1	0	0	1	1
36 650	to	36	0	1	1	0	1	1	1	0	0	0	1
36 750	to	36	0	1	1	0	1	0	1	0	0	0	1
36 850	to	36	0	1	1	0	1	0	1	0	0	1	1
36 950	to	37	0	1	1	0	1	0	1	0	0	1	0
37 050	to	37	0	1	1	0	1	0	1	0	1	1	0
37 150	to	37	0	1	1	0	1	0	1	0	1	0	0
37 250	to	37	0	1	1	0	1	0	1	1	1	0	0
37 350	to	37	0	1	1	0	1	0	1	1	1	1	0
37 450	to	37	0	1	1	0	1	0	1	1	0	1	0
37 550	to	37	0	1	1	0	1	0	1	1	0	1	1
37 650	to	37	0	1	1	0	1	0	1	1	0	0	1
37 750	to	37	0	1	1	0	1	0	0	1	0	0	1
37 850	to	37	0	1	1	0	1	0	0	1	0	1	1
37 950	to	38	0	1	1	0	1	0	0	1	0	1	0
38 050	to	38	0	1	1	0	1	0	0	1	1	1	0
38 150	to	38	0	1	1	0	1	0	0	1	1	0	0
38 250	to	38	0	1	1	0	1	0	0	0	1	0	0
38 350	to	38	0	1	1	0	1	0	0	0	1	1	0
38 450	to	38	0	1	1	0	1	0	0	0	0	1	0
38 550	to	38	0	1	1	0	1	0	0	0	0	1	1
38 650	to	38	0	1	1	0	1	0	0	0	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
38 750 to 38 850	0	1	1	1	1	0	0	0	0	0	1
38 850 to 38 950	0	1	1	1	1	0	0	0	0	1	1
38 950 to 39 050	0	1	1	1	1	0	0	0	0	1	0
39 050 to 39 150	0	1	1	1	1	0	0	0	1	1	0
39 150 to 39 250	0	1	1	1	1	0	0	0	1	0	0
39 250 to 39 350	0	1	1	1	1	0	0	1	1	0	0
39 350 to 39 450	0	1	1	1	1	0	0	1	1	1	0
39 450 to 39 550	0	1	1	1	1	0	0	1	0	1	0
39 550 to 39 650	0	1	1	1	1	0	0	1	0	1	1
39 650 to 39 750	0	1	1	1	1	0	0	1	0	0	1
39 750 to 39 850	0	1	1	1	1	0	1	1	0	0	1
39 850 to 39 950	0	1	1	1	1	0	1	1	0	1	1
39 950 to 40 050	0	1	1	1	1	0	1	1	0	1	0
40 050 to 40 150	0	1	1	1	1	0	1	1	1	1	0
40 150 to 40 250	0	1	1	1	1	0	1	1	1	0	0
40 250 to 40 350	0	1	1	1	1	0	1	0	1	0	0
40 350 to 40 450	0	1	1	1	1	0	1	0	1	1	0
40 450 to 40 550	0	1	1	1	1	0	1	0	0	1	0
40 550 to 40 650	0	1	1	1	1	0	1	0	0	1	1
40 650 to 40 750	0	1	1	1	1	0	1	0	0	0	1
40 750 to 40 850	0	1	1	1	1	1	1	0	0	0	1
40 850 to 40 950	0	1	1	1	1	1	1	0	0	1	1
40 950 to 41 050	0	1	1	1	1	1	1	0	0	1	0
41 050 to 41 150	0	1	1	1	1	1	1	0	1	1	0
41 150 to 41 250	0	1	1	1	1	1	1	0	1	0	0
41 250 to 41 350	0	1	1	1	1	1	1	1	1	0	0
41 350 to 41 450	0	1	1	1	1	1	1	1	1	1	0
41 450 to 41 550	0	1	1	1	1	1	1	1	0	1	0
41 550 to 41 650	0	1	1	1	1	1	1	1	0	1	1
41 650 to 41 750	0	1	1	1	1	1	1	1	0	0	1
41 750 to 41 850	0	1	1	1	1	1	0	1	0	0	1
41 850 to 41 950	0	1	1	1	1	1	0	1	0	1	1
41 950 to 42 050	0	1	1	1	1	1	0	1	0	1	0
42 050 to 42 150	0	1	1	1	1	1	0	1	1	1	0
42 150 to 42 250	0	1	1	1	1	1	0	1	1	0	0
42 250 to 42 350	0	1	1	1	1	1	0	0	1	0	0
42 350 to 42 450	0	1	1	1	1	1	0	0	1	1	0
42 450 to 42 550	0	1	1	1	1	1	0	0	0	1	0
42 550 to 42 650	0	1	1	1	1	1	0	0	0	1	1
42 650 to 42 750	0	1	1	1	1	1	0	0	0	0	1
42 750 to 42 850	0	1	1	1	0	1	0	0	0	0	1
42 850 to 42 950	0	1	1	1	0	1	0	0	0	1	1
42 950 to 43 050	0	1	1	1	0	1	0	0	0	1	0
43 050 to 43 150	0	1	1	1	0	1	0	0	1	1	0
43 150 to 43 250	0	1	1	1	0	1	0	0	1	0	0

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
43 250 to 43 350	0	1	1	1	0	1	0	1	1	0	0
43 350 to 43 450	0	1	1	1	0	1	0	1	1	1	0
43 450 to 43 550	0	1	1	1	0	1	0	1	0	1	0
43 550 to 43 650	0	1	1	1	0	1	0	1	0	1	1
43 650 to 43 750	0	1	1	1	0	1	0	1	0	0	1
43 750 to 43 850	0	1	1	1	0	1	1	1	0	0	1
43 850 to 43 950	0	1	1	1	0	1	1	1	0	1	1
43 950 to 44 050	0	1	1	1	0	1	1	1	0	1	0
44 050 to 44 150	0	1	1	1	0	1	1	1	1	1	0
44 150 to 44 250	0	1	1	1	0	1	1	1	1	0	0
44 250 to 44 350	0	1	1	1	0	1	1	0	1	0	0
44 350 to 44 450	0	1	1	1	0	1	1	0	1	1	0
44 450 to 44 550	0	1	1	1	0	1	1	0	0	1	0
44 550 to 44 650	0	1	1	1	0	1	1	0	0	1	1
44 650 to 44 750	0	1	1	1	0	1	1	0	0	0	1
44 750 to 44 850	0	1	1	1	0	0	1	0	0	0	1
44 850 to 44 950	0	1	1	1	0	0	1	0	0	1	1
44 950 to 45 050	0	1	1	1	0	0	1	0	0	1	0
45 050 to 45 150	0	1	1	1	0	0	1	0	1	1	0
45 150 to 45 250	0	1	1	1	0	0	1	0	1	0	0
45 250 to 45 350	0	1	1	1	0	0	1	1	1	0	0
45 350 to 45 450	0	1	1	1	0	0	1	1	1	1	0
45 450 to 45 550	0	1	1	1	0	0	1	1	0	1	0
45 550 to 45 650	0	1	1	1	0	0	1	1	0	1	1
45 650 to 45 750	0	1	1	1	0	0	1	1	0	0	1
45 750 to 45 850	0	1	1	1	0	0	0	1	0	0	1
45 850 to 45 950	0	1	1	1	0	0	0	1	0	1	1
45 950 to 46 050	0	1	1	1	0	0	0	1	0	1	0
46 050 to 46 150	0	1	1	1	0	0	0	1	1	1	0
46 150 to 46 250	0	1	1	1	0	0	0	1	1	0	0
46 250 to 46 350	0	1	1	1	0	0	0	0	1	0	0
46 350 to 46 450	0	1	1	1	0	0	0	0	1	1	0
46 450 to 46 550	0	1	1	1	0	0	0	0	0	1	0
46 550 to 46 650	0	1	1	1	0	0	0	0	0	1	1
46 650 to 46 750	0	1	1	1	0	0	0	0	0	0	1
46 750 to 46 850	0	1	0	1	0	0	0	0	0	0	1
46 850 to 46 950	0	1	0	1	0	0	0	0	0	1	1
46 950 to 47 050	0	1	0	1	0	0	0	0	0	1	0
47 050 to 47 150	0	1	0	1	0	0	0	0	1	1	0
47 150 to 47 250	0	1	0	1	0	0	0	0	1	0	0
47 250 to 47 350	0	1	0	1	0	0	0	1	1	0	0
47 350 to 47 450	0	1	0	1	0	0	0	1	1	1	0
47 450 to 47 550	0	1	0	1	0	0	0	1	0	1	0
47 550 to 47 650	0	1	0	1	0	0	0	1	0	1	1
47 650 to 47 750	0	1	0	1	0	0	0	1	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
47 750 to 47 850	0	1	0	1	0	0	1	1	0	0	1
47 850 to 47 950	0	1	0	1	0	0	1	1	0	1	1
47 950 to 48 050	0	1	0	1	0	0	1	1	0	1	0
48 050 to 48 150	0	1	0	1	0	0	1	1	1	1	0
48 150 to 48 250	0	1	0	1	0	0	1	1	1	0	0
48 250 to 48 350	0	1	0	1	0	0	1	0	1	0	0
48 350 to 48 450	0	1	0	1	0	0	1	0	1	1	0
48 450 to 48 550	0	1	0	1	0	0	1	0	0	1	0
48 550 to 48 650	0	1	0	1	0	0	1	0	0	1	1
48 650 to 48 750	0	1	0	1	0	0	1	0	0	0	1
48 750 to 48 850	0	1	0	1	0	1	1	0	0	0	1
48 850 to 48 950	0	1	0	1	0	1	1	0	0	1	1
48 950 to 49 050	0	1	0	1	0	1	1	0	0	1	0
49 050 to 49 150	0	1	0	1	0	1	1	0	1	1	0
49 150 to 49 250	0	1	0	1	0	1	1	0	1	0	0
49 250 to 49 350	0	1	0	1	0	1	1	1	1	0	0
49 350 to 49 450	0	1	0	1	0	1	1	1	1	1	0
49 450 to 49 550	0	1	0	1	0	1	1	1	0	1	0
49 550 to 49 650	0	1	0	1	0	1	1	1	0	1	1
49 650 to 49 750	0	1	0	1	0	1	1	1	0	0	1
49 750 to 49 850	0	1	0	1	0	1	0	1	0	0	1
49 850 to 49 950	0	1	0	1	0	1	0	1	0	1	1
49 950 to 50 050	0	1	0	1	0	1	0	1	0	1	0
50 050 to 50 150	0	1	0	1	0	1	0	1	1	1	0
50 150 to 50 250	0	1	0	1	0	1	0	1	1	0	0
50 250 to 50 350	0	1	0	1	0	1	0	0	1	0	0
50 350 to 50 450	0	1	0	1	0	1	0	0	1	1	0
50 450 to 50 550	0	1	0	1	0	1	0	0	0	1	0
50 550 to 50 650	0	1	0	1	0	1	0	0	0	1	1
50 650 to 50 750	0	1	0	1	0	1	0	0	0	0	1
50 750 to 50 850	0	1	0	1	1	1	0	0	0	0	1
50 850 to 50 950	0	1	0	1	1	1	0	0	0	1	1
50 950 to 51 050	0	1	0	1	1	1	0	0	0	1	0
51 050 to 51 150	0	1	0	1	1	1	0	0	1	1	0
51 150 to 51 250	0	1	0	1	1	1	0	0	1	0	0
51 250 to 51 350	0	1	0	1	1	1	0	1	1	0	0
51 350 to 51 450	0	1	0	1	1	1	0	1	1	1	0
51 450 to 51 550	0	1	0	1	1	1	0	1	0	1	0
51 550 to 51 650	0	1	0	1	1	1	0	1	0	1	1
51 650 to 51 750	0	1	0	1	1	1	0	1	0	0	1
51 750 to 51 850	0	1	0	1	1	1	1	1	0	0	1
51 850 to 51 950	0	1	0	1	1	1	1	1	0	1	1
51 950 to 52 050	0	1	0	1	1	1	1	1	0	1	0
52 050 to 52 150	0	1	0	1	1	1	1	1	1	1	0

52 150 to 52 250	0	1	0	1	1	1	1	1	1	0	0

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
52 250 to 52 350	0	1	0	1	1	1	1	0	1	0	0
52 350 to 52 450	0	1	0	1	1	1	1	0	1	1	0
52 450 to 52 550	0	1	0	1	1	1	1	0	0	1	0
52 550 to 52 650	0	1	0	1	1	1	1	0	0	1	1
52 650 to 52 750	0	1	0	1	1	1	1	0	0	0	1
52 750 to 52 850	0	1	0	1	1	0	1	0	0	0	1
52 850 to 52 950	0	1	0	1	1	0	1	0	0	1	1
52 950 to 53 050	0	1	0	1	1	0	1	0	0	1	0
53 050 to 53 150	0	1	0	1	1	0	1	0	1	1	0
53 150 to 53 250	0	1	0	1	1	0	1	0	1	0	0
53 250 to 53 350	0	1	0	1	1	0	1	1	1	0	0
53 350 to 53 450	0	1	0	1	1	0	1	1	1	1	0
53 450 to 53 550	0	1	0	1	1	0	1	1	0	1	0
53 550 to 53 650	0	1	0	1	1	0	1	1	0	1	1
53 650 to 53 750	0	1	0	1	1	0	1	1	0	0	1
53 750 to 53 850	0	1	0	1	1	0	0	1	0	0	1
53 850 to 53 950	0	1	0	1	1	0	0	1	0	1	1
53 950 to 54 050	0	1	0	1	1	0	0	1	0	1	0
54 050 to 54 150	0	1	0	1	1	0	0	1	1	1	0
54 150 to 54 250	0	1	0	1	1	0	0	1	1	0	0
54 250 to 54 350	0	1	0	1	1	0	0	0	1	0	0
54 350 to 54 450	0	1	0	1	1	0	0	0	1	1	0
54 450 to 54 550	0	1	0	1	1	0	0	0	0	1	0
54 550 to 54 650	0	1	0	1	1	0	0	0	0	1	1
54 650 to 54 750	0	1	0	1	1	0	0	0	0	0	1
54 750 to 54 850	0	1	0	0	1	0	0	0	0	0	1
54 850 to 54 950	0	1	0	0	1	0	0	0	0	1	1
54 950 to 55 050	0	1	0	0	1	0	0	0	0	1	0
55 050 to 55 150	0	1	0	0	1	0	0	0	1	1	0
55 150 to 55 250	0	1	0	0	1	0	0	0	1	0	0
55 250 to 55 350	0	1	0	0	1	0	0	1	1	0	0
55 350 to 55 450	0	1	0	0	1	0	0	1	1	1	0
55 450 to 55 550	0	1	0	0	1	0	0	1	0	1	0
55 550 to 55 650	0	1	0	0	1	0	0	1	0	1	1
55 650 to 55 750	0	1	0	0	1	0	0	1	0	0	1
55 750 to 55 850	0	1	0	0	1	0	1	1	0	0	1
55 850 to 55 950	0	1	0	0	1	0	1	1	0	1	1
55 950 to 56 050	0	1	0	0	1	0	1	1	0	1	0
56 050 to 56 150	0	1	0	0	1	0	1	1	1	1	0
56 150 to 56 250	0	1	0	0	1	0	1	1	1	0	0
56 250 to 56 350	0	1	0	0	1	0	1	0	1	0	0
56 350 to 56 450	0	1	0	0	1	0	1	0	1	1	0
56 450 to 56 550	0	1	0	0	1	0	1	0	0	1	0
56 550 to 56 650	0	1	0	0	1	0	1	0	0	1	1
56 650 to 56 750	0	1	0	0	1	0	1	0	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
56 750 to 56 850	0	1	0	0	1	1	1	0	0	0	1
56 850 to 56 950	0	1	0	0	1	1	1	0	0	1	1
56 950 to 57 050	0	1	0	0	1	1	1	0	0	1	0
57 050 to 57 150	0	1	0	0	1	1	1	0	1	1	0
57 150 to 57 250	0	1	0	0	1	1	1	0	1	0	0
57 250 to 57 350	0	1	0	0	1	1	1	1	1	0	0
57 350 to 57 450	0	1	0	0	1	1	1	1	1	1	0
57 450 to 57 550	0	1	0	0	1	1	1	1	0	1	0
57 550 to 57 650	0	1	0	0	1	1	1	1	0	1	1
57 650 to 57 750	0	1	0	0	1	1	1	1	0	0	1
57 750 to 57 850	0	1	0	0	1	1	0	1	0	0	1
57 850 to 57 950	0	1	0	0	1	1	0	1	0	1	1
57 950 to 58 050	0	1	0	0	1	1	0	1	0	1	0
58 050 to 58 150	0	1	0	0	1	1	0	1	1	1	0
58 150 to 58 250	0	1	0	0	1	1	0	1	1	0	0
58 250 to 58 350	0	1	0	0	1	1	0	0	1	0	0
58 350 to 58 450	0	1	0	0	1	1	0	0	1	1	0
58 450 to 58 550	0	1	0	0	1	1	0	0	0	1	0
58 550 to 58 650	0	1	0	0	1	1	0	0	0	1	1
58 650 to 58 750	0	1	0	0	1	1	0	0	0	0	1
58 750 to 58 850	0	1	0	0	0	1	0	0	0	0	1
58 850 to 58 950	0	1	0	0	0	1	0	0	0	1	1
58 950 to 59 050	0	1	0	0	0	1	0	0	0	1	0
59 050 to 59 150	0	1	0	0	0	1	0	0	1	1	0
59 150 to 59 250	0	1	0	0	0	1	0	0	1	0	0
59 250 to 59 350	0	1	0	0	0	1	0	1	1	0	0
59 350 to 59 450	0	1	0	0	0	1	0	1	1	1	0
59 450 to 59 550	0	1	0	0	0	1	0	1	0	1	0
59 550 to 59 650	0	1	0	0	0	1	0	1	0	1	1
59 650 to 59 750	0	1	0	0	0	1	0	1	0	0	1
59 750 to 59 850	0	1	0	0	0	1	1	1	0	0	1
59 850 to 59 950	0	1	0	0	0	1	1	1	0	1	1
59 950 to 60 050	0	1	0	0	0	1	1	1	0	1	0
60 050 to 60 150	0	1	0	0	0	1	1	1	1	1	0
60 150 to 60 250	0	1	0	0	0	1	1	1	1	0	0
60 250 to 60 350	0	1	0	0	0	1	1	0	1	0	0
60 350 to 60 450	0	1	0	0	0	1	1	0	1	1	0
60 450 to 60 550	0	1	0	0	0	1	1	0	0	1	0
60 550 to 60 650	0	1	0	0	0	1	1	0	0	1	1
60 650 to 60 750	0	1	0	0	0	1	1	0	0	0	1
60 750 to 60 850	0	1	0	0	0	0	1	0	0	0	1
60 850 to 60 950	0	1	0	0	0	0	1	0	0	1	1
60 950 to 61 050	0	1	0	0	0	0	1	0	0	1	0
61 050 to 61 150	0	1	0	0	0	0	1	0	1	1	0
61 150 to 61 250	0	1	0	0	0	0	1	0	1	0	0

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
61 250 to 61 350	0	1	0	0	0	0	1	1	1	0	0
61 350 to 61 450	0	1	0	0	0	0	1	1	1	1	0
61 450 to 61 550	0	1	0	0	0	0	1	1	0	1	0
61 550 to 61 650	0	1	0	0	0	0	1	1	0	1	1
61 650 to 61 750	0	1	0	0	0	0	1	1	0	0	1
61 750 to 61 850	0	1	0	0	0	0	0	1	0	0	1
61 850 to 61 950	0	1	0	0	0	0	0	1	0	1	1
61 950 to 62 050	0	1	0	0	0	0	0	1	0	1	0
62 050 to 62 150	0	1	0	0	0	0	0	1	1	1	0
62 150 to 62 250	0	1	0	0	0	0	0	1	1	0	0
62 250 to 62 350	0	1	0	0	0	0	0	0	1	0	0
62 350 to 62 450	0	1	0	0	0	0	0	0	1	1	0
62 450 to 62 550	0	1	0	0	0	0	0	0	0	1	0
62 550 to 62 650	0	1	0	0	0	0	0	0	0	1	1
62 650 to 62 750	0	1	0	0	0	0	0	0	0	0	1
62 750 to 62 850	1	1	0	0	0	0	0	0	0	0	1
62 850 to 62 950	1	1	0	0	0	0	0	0	0	1	1
62 950 to 63 050	1	1	0	0	0	0	0	0	0	1	0
63 050 to 63 150	1	1	0	0	0	0	0	0	1	1	0
63 150 to 63 250	1	1	0	0	0	0	0	0	1	0	0
63 250 to 63 350	1	1	0	0	0	0	0	1	1	0	0
63 350 to 63 450	1	1	0	0	0	0	0	1	1	1	0
63 450 to 63 550	1	1	0	0	0	0	0	1	0	1	0
63 550 to 63 650	1	1	0	0	0	0	0	1	0	1	1
63 650 to 63 750	1	1	0	0	0	0	0	1	0	0	1
63 750 to 63 850	1	1	0	0	0	0	1	1	0	0	1
63 850 to 63 950	1	1	0	0	0	0	1	1	0	1	1
63 950 to 64 050	1	1	0	0	0	0	1	1	0	1	0
64 050 to 64 150	1	1	0	0	0	0	1	1	1	1	0
64 150 to 64 250	1	1	0	0	0	0	1	1	1	0	0
64 250 to 64 350	1	1	0	0	0	0	1	0	1	0	0
64 350 to 64 450	1	1	0	0	0	0	1	0	1	1	0
64 450 to 64 550	1	1	0	0	0	0	1	0	0	1	0
64 550 to 64 650	1	1	0	0	0	0	1	0	0	1	1
64 650 to 64 750	1	1	0	0	0	0	1	0	0	0	1
64 750 to 64 850	1	1	0	0	0	1	1	0	0	0	1
64 850 to 64 950	1	1	0	0	0	1	1	0	0	1	1
64 950 to 65 050	1	1	0	0	0	1	1	0	0	1	0
65 050 to 65 150	1	1	0	0	0	1	1	0	1	1	0
65 150 to 65 250	1	1	0	0	0	1	1	0	1	0	0
65 250 to 65 350	1	1	0	0	0	1	1	1	1	0	0
65 350 to 65 450	1	1	0	0	0	1	1	1	1	1	0
65 450 to 65 550	1	1	0	0	0	1	1	1	0	1	0
65 550 to 65 650	1	1	0	0	0	1	1	1	0	1	1
65 650 to 65 750	1	1	0	0	0	1	1	1	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
65 750 to 65 850	1	1	0	0	0	1	0	1	0	0	1
65 850 to 65 950	1	1	0	0	0	1	0	1	0	1	1
65 950 to 66 050	1	1	0	0	0	1	0	1	0	1	0
66 050 to 66 150	1	1	0	0	0	1	0	1	1	1	0
66 150 to 66 250	1	1	0	0	0	1	0	1	1	0	0
66 250 to 66 350	1	1	0	0	0	1	0	0	1	0	0
66 350 to 66 450	1	1	0	0	0	1	0	0	1	1	0
66 450 to 66 550	1	1	0	0	0	1	0	0	0	1	0
66 550 to 66 650	1	1	0	0	0	1	0	0	0	1	1
66 650 to 66 750	1	1	0	0	0	1	0	0	0	0	1
66 750 to 66 850	1	1	0	0	1	1	0	0	0	0	1
66 850 to 66 950	1	1	0	0	1	1	0	0	0	1	1
66 950 to 67 050	1	1	0	0	1	1	0	0	0	1	0
67 050 to 67 150	1	1	0	0	1	1	0	0	1	1	0
67 150 to 67 250	1	1	0	0	1	1	0	0	1	0	0
67 250 to 67 350	1	1	0	0	1	1	0	1	1	0	0
67 350 to 67 450	1	1	0	0	1	1	0	1	1	1	0
67 450 to 67 550	1	1	0	0	1	1	0	1	0	1	0
67 550 to 67 650	1	1	0	0	1	1	0	1	0	1	1
67 650 to 67 750	1	1	0	0	1	1	0	1	0	0	1
67 750 to 67 850	1	1	0	0	1	1	1	1	0	0	1
67 850 to 67 950	1	1	0	0	1	1	1	1	0	1	1
67 950 to 68 050	1	1	0	0	1	1	1	1	0	1	0
68 050 to 68 150	1	1	0	0	1	1	1	1	1	1	0
68 150 to 68 250	1	1	0	0	1	1	1	1	1	0	0
68 250 to 68 350	1	1	0	0	1	1	1	0	1	0	0
68 350 to 68 450	1	1	0	0	1	1	1	0	1	1	0
68 450 to 68 550	1	1	0	0	1	1	1	0	0	1	0
68 550 to 68 650	1	1	0	0	1	1	1	0	0	1	1
68 650 to 68 750	1	1	0	0	1	1	1	0	0	0	1
68 750 to 68 850	1	1	0	0	1	0	1	0	0	0	1
68 850 to 68 950	1	1	0	0	1	0	1	0	0	1	1
68 950 to 69 050	1	1	0	0	1	0	1	0	0	1	0
69 050 to 69 150	1	1	0	0	1	0	1	0	1	1	0
69 150 to 69 250	1	1	0	0	1	0	1	0	1	0	0
69 250 to 69 350	1	1	0	0	1	0	1	1	1	0	0
69 350 to 69 450	1	1	0	0	1	0	1	1	1	1	0
69 450 to 69 550	1	1	0	0	1	0	1	1	0	1	0
69 550 to 69 650	1	1	0	0	1	0	1	1	0	1	1
69 650 to 69 750	1	1	0	0	1	0	1	1	0	0	1
69 750 to 69 850	1	1	0	0	1	0	0	1	0	0	1
69 850 to 69 950	1	1	0	0	1	0	0	1	0	1	1
69 950 to 70 050	1	1	0	0	1	0	0	1	0	1	0
70 050 to 70 150	1	1	0	0	1	0	0	1	1	1	0
70 150 to 70 250	1	1	0	0	1	0	0	1	1	0	0

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
70 250 to 70 350	1	1	0	0	1	0	0	0	1	0	0
70 350 to 70 450	1	1	0	0	1	0	0	0	1	1	0
70 450 to 70 550	1	1	0	0	1	0	0	0	0	1	0
70 550 to 70 650	1	1	0	0	1	0	0	0	0	1	1
70 650 to 70 750	1	1	0	0	1	0	0	0	0	0	1
70 750 to 70 850	1	1	0	1	1	0	0	0	0	0	1
70 850 to 70 950	1	1	0	1	1	0	0	0	0	1	1
70 950 to 71 050	1	1	0	1	1	0	0	0	0	1	0
71 050 to 71 150	1	1	0	1	1	0	0	0	1	1	0
71 150 to 71 250	1	1	0	1	1	0	0	0	1	0	0
71 250 to 71 350	1	1	0	1	1	0	0	1	1	0	0
71 350 to 71 450	1	1	0	1	1	0	0	1	1	1	0
71 450 to 71 550	1	1	0	1	1	0	0	1	0	1	0
71 550 to 71 650	1	1	0	1	1	0	0	1	0	1	1
71 650 to 71 750	1	1	0	1	1	0	0	1	0	0	1
71 750 to 71 850	1	1	0	1	1	0	1	1	0	0	1
71 850 to 71 950	1	1	0	1	1	0	1	1	0	1	1
71 950 to 72 050	1	1	0	1	1	0	1	1	0	1	0
72 050 to 72 150	1	1	0	1	1	0	1	1	1	1	0
72 150 to 72 250	1	1	0	1	1	0	1	1	1	0	0
72 250 to 72 350	1	1	0	1	1	0	1	0	1	0	0
72 350 to 72 450	1	1	0	1	1	0	1	0	1	1	0
72 450 to 72 550	1	1	0	1	1	0	1	0	0	1	0
72 550 to 72 650	1	1	0	1	1	0	1	0	0	1	1
72 650 to 72 750	1	1	0	1	1	0	1	0	0	0	1
72 750 to 72 850	1	1	0	1	1	1	1	0	0	0	1
72 850 to 72 950	1	1	0	1	1	1	1	0	0	1	1
72 950 to 73 050	1	1	0	1	1	1	1	0	0	1	0
73 050 to 73 150	1	1	0	1	1	1	1	0	1	1	0
73 150 to 73 250	1	1	0	1	1	1	1	0	1	0	0
73 250 to 73 350	1	1	0	1	1	1	1	1	1	0	0
73 350 to 73 450	1	1	0	1	1	1	1	1	1	1	0
73 450 to 73 550	1	1	0	1	1	1	1	1	0	1	0
73 550 to 73 650	1	1	0	1	1	1	1	1	0	1	1
73 650 to 73 750	1	1	0	1	1	1	1	1	0	0	1
73 750 to 73 850	1	1	0	1	1	1	0	1	0	0	1
73 850 to 73 950	1	1	0	1	1	1	0	1	0	1	1
73 950 to 74 050	1	1	0	1	1	1	0	1	0	1	0
74 050 to 74 150	1	1	0	1	1	1	0	1	1	1	0
74 150 to 74 250	1	1	0	1	1	1	0	1	1	0	0
74 250 to 74 350	1	1	0	1	1	1	0	0	1	0	0
74 350 to 74 450	1	1	0	1	1	1	0	0	1	1	0
74 450 to 74 550	1	1	0	1	1	1	0	0	0	1	0
74 550 to 74 650	1	1	0	1	1	1	0	0	0	1	1
74 650 to 74 750	1	1	0	1	1	1	0	0	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position*										
Increments	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
74 750 to 74 850	1	1	0	1	0	1	0	0	0	0	1
74 850 to 74 950	1	1	0	1	0	1	0	0	0	1	1
74 950 to 75 050	1	1	0	1	0	1	0	0	0	1	0
75 050 to 75 150	1	1	0	1	0	1	0	0	1	1	0
75 150 to 75 250	1	1	0	1	0	1	0	0	1	0	0
75 250 to 75 350	1	1	0	1	0	1	0	1	1	0	0
75 350 to 75 450	1	1	0	1	0	1	0	1	1	1	0
75 450 to 75 550	1	1	0	1	0	1	0	1	0	1	0
75 550 to 75 650	1	1	0	1	0	1	0	1	0	1	1
75 650 to 75 750	1	1	0	1	0	1	0	1	0	0	1
75 750 to 75 850	1	1	0	1	0	1	1	1	0	0	1
75 850 to 75 950	1	1	0	1	0	1	1	1	0	1	1
75 950 to 76 050	1	1	0	1	0	1	1	1	0	1	0
76 050 to 76 150	1	1	0	1	0	1	1	1	1	1	0
76 150 to 76 250	1	1	0	1	0	1	1	1	1	0	0
76 250 to 76 350	1	1	0	1	0	1	1	0	1	0	0
76 350 to 76 450	1	1	0	1	0	1	1	0	1	1	0
76 450 to 76 550	1	1	0	1	0	1	1	0	0	1	0
76 550 to 76 650	1	1	0	1	0	1	1	0	0	1	1
76 650 to 76 750	1	1	0	1	0	1	1	0	0	0	1
76 750 to 76 850	1	1	0	1	0	0	1	0	0	0	1
76 850 to 76 950	1	1	0	1	0	0	1	0	0	1	1
76 950 to 77 050	1	1	0	1	0	0	1	0	0	1	0
77 050 to 77 150	1	1	0	1	0	0	1	0	1	1	0
77 150 to 77 250	1	1	0	1	0	0	1	0	1	0	0
77 250 to 77 350	1	1	0	1	0	0	1	1	1	0	0
77 350 to 77 450	1	1	0	1	0	0	1	1	1	1	0
77 450 to 77 550	1	1	0	1	0	0	1	1	0	1	0
77 550 to 77 650	1	1	0	1	0	0	1	1	0	1	1
77 650 to 77 750	1	1	0	1	0	0	1	1	0	0	1
77 750 to 77 850	1	1	0	1	0	0	0	1	0	0	1
77 850 to 77 950	1	1	0	1	0	0	0	1	0	1	1
77 950 to 78 050	1	1	0	1	0	0	0	1	0	1	0
78 050 to 78 150	1	1	0	1	0	0	0	1	1	1	0
78 150 to 78 250	1	1	0	1	0	0	0	1	1	0	0
78 250 to 78 350	1	1	0	1	0	0	0	0	1	0	0
78 350 to 78 450	1	1	0	1	0	0	0	0	1	1	0
78 450 to 78 550	1	1	0	1	0	0	0	0	0	1	0
78 550 to 78 650	1	1	0	1	0	0	0	0	0	1	1
78 650 to 78 750	1	1	0	1	0	0	0	0	0	0	1
78 750 to 78 850	1	1	1	1	0	0	0	0	0	0	1
78 850 to 78 950	1	1	1	1	0	0	0	0	0	1	1
78 950 to 79 050	1	1	1	1	0	0	0	0	0	1	0
79 050 to 79 150	1	1	1	1	0	0	0	0	1	1	0
79 150 to 79 250	1	1	1	1	0	0	0	0	1	0	0

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
79 250 to 79 350	1	1	1	1	0	0	0	1	1	0	0
79 350 to 79 450	1	1	1	1	0	0	0	1	1	1	0
79 450 to 79 550	1	1	1	1	0	0	0	1	0	1	0
79 550 to 79 650	1	1	1	1	0	0	0	1	0	1	1
79 650 to 79 750	1	1	1	1	0	0	0	1	0	0	1
79 750 to 79 850	1	1	1	1	0	0	1	1	0	0	1
79 850 to 79 950	1	1	1	1	0	0	1	1	0	1	1
79 950 to 80 050	1	1	1	1	0	0	1	1	0	1	0
80 050 to 80 150	1	1	1	1	0	0	1	1	1	1	0
80 150 to 80 250	1	1	1	1	0	0	1	1	1	0	0
80 250 to 80 350	1	1	1	1	0	0	1	0	1	0	0
80 350 to 80 450	1	1	1	1	0	0	1	0	1	1	0
80 450 to 80 550	1	1	1	1	0	0	1	0	0	1	0
80 550 to 80 650	1	1	1	1	0	0	1	0	0	1	1
80 650 to 80 750	1	1	1	1	0	0	1	0	0	0	1
80 750 to 80 850	1	1	1	1	0	1	1	0	0	0	1
80 850 to 80 950	1	1	1	1	0	1	1	0	0	1	1
80 950 to 81 050	1	1	1	1	0	1	1	0	0	1	0
81 050 to 81 150	1	1	1	1	0	1	1	0	1	1	0
81 150 to 81 250	1	1	1	1	0	1	1	0	1	0	0
81 250 to 81 350	1	1	1	1	0	1	1	1	1	0	0
81 350 to 81 450	1	1	1	1	0	1	1	1	1	1	0
81 450 to 81 550	1	1	1	1	0	1	1	1	0	1	0
81 550 to 81 650	1	1	1	1	0	1	1	1	0	1	1
81 650 to 81 750	1	1	1	1	0	1	1	1	0	0	1
81 750 to 81 850	1	1	1	1	0	1	0	1	0	0	1
81 850 to 81 950	1	1	1	1	0	1	0	1	0	1	1
81 950 to 82 050	1	1	1	1	0	1	0	1	0	1	0
82 050 to 82 150	1	1	1	1	0	1	0	1	1	1	0
82 150 to 82 250	1	1	1	1	0	1	0	1	1	0	0
82 250 to 82 350	1	1	1	1	0	1	0	0	1	0	0
82 350 to 82 450	1	1	1	1	0	1	0	0	1	1	0
82 450 to 82 550	1	1	1	1	0	1	0	0	0	1	0
82 550 to 82 650	1	1	1	1	0	1	0	0	0	1	1
82 650 to 82 750	1	1	1	1	0	1	0	0	0	0	1
82 750 to 82 850	1	1	1	1	1	1	0	0	0	0	1
82 850 to 82 950	1	1	1	1	1	1	0	0	0	1	1
82 950 to 83 050	1	1	1	1	1	1	0	0	0	1	0
83 050 to 83 150	1	1	1	1	1	1	0	0	1	1	0
83 150 to 83 250	1	1	1	1	1	1	0	0	1	0	0
83 250 to 83 350	1	1	1	1	1	1	0	1	1	0	0
83 350 to 83 450	1	1	1	1	1	1	0	1	1	1	0
83 450 to 83 550	1	1	1	1	1	1	0	1	0	1	0
83 550 to 83 650	1	1	1	1	1	1	0	1	0	1	1
83 650 to 83 750	1	1	1	1	1	1	0	1	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
83 750 to 83 850	1	1	1	1	1	1	1	1	0	0	1
83 850 to 83 950	1	1	1	1	1	1	1	1	0	1	1
83 950 to 84 050	1	1	1	1	1	1	1	1	0	1	0
84 050 to 84 150	1	1	1	1	1	1	1	1	1	1	0
84 150 to 84 250	1	1	1	1	1	1	1	1	1	0	0
84 250 to 84 350	1	1	1	1	1	1	1	0	1	0	0
84 350 to 84 450	1	1	1	1	1	1	1	0	1	1	0
84 450 to 84 550	1	1	1	1	1	1	1	0	0	1	0
84 550 to 84 650	1	1	1	1	1	1	1	0	0	1	1
84 650 to 84 750	1	1	1	1	1	1	1	0	0	0	1
84 750 to 84 850	1	1	1	1	1	0	1	0	0	0	1
84 850 to 84 950	1	1	1	1	1	0	1	0	0	1	1
84 950 to 85 050	1	1	1	1	1	0	1	0	0	1	0
85 050 to 85 150	1	1	1	1	1	0	1	0	1	1	0
85 150 to 85 250	1	1	1	1	1	0	1	0	1	0	0
85 250 to 85 350	1	1	1	1	1	0	1	1	1	0	0
85 350 to 85 450	1	1	1	1	1	0	1	1	1	1	0
85 450 to 85 550	1	1	1	1	1	0	1	1	0	1	0
85 550 to 85 650	1	1	1	1	1	0	1	1	0	1	1
85 650 to 85 750	1	1	1	1	1	0	1	1	0	0	1
85 750 to 85 850	1	1	1	1	1	0	0	1	0	0	1
85 850 to 85 950	1	1	1	1	1	0	0	1	0	1	1
85 950 to 86 050	1	1	1	1	1	0	0	1	0	1	0
86 050 to 86 150	1	1	1	1	1	0	0	1	1	1	0
86 150 to 86 250	1	1	1	1	1	0	0	1	1	0	0
86 250 to 86 350	1	1	1	1	1	0	0	0	1	0	0
86 350 to 86 450	1	1	1	1	1	0	0	0	1	1	0
86 450 to 86 550	1	1	1	1	1	0	0	0	0	1	0
86 550 to 86 650	1	1	1	1	1	0	0	0	0	1	1
86 650 to 86 750	1	1	1	1	1	0	0	0	0	0	1
86 750 to 86 850	1	1	1	0	1	0	0	0	0	0	1
86 850 to 86 950	1	1	1	0	1	0	0	0	0	1	1
86 950 to 87 050	1	1	1	0	1	0	0	0	0	1	0
87 050 to 87 150	1	1	1	0	1	0	0	0	1	1	0
87 150 to 87 250	1	1	1	0	1	0	0	0	1	0	0
87 250 to 87 350	1	1	1	0	1	0	0	1	1	0	0
87 350 to 87 450	1	1	1	0	1	0	0	1	1	1	0
87 450 to 87 550	1	1	1	0	1	0	0	1	0	1	0
87 550 to 87 650	1	1	1	0	1	0	0	1	0	1	1
87 650 to 87 750	1	1	1	0	1	0	0	1	0	0	1
87 750 to 87 850	1	1	1	0	1	0	1	1	0	0	1
87 850 to 87 950	1	1	1	0	1	0	1	1	0	1	1
87 950 to 88 050	1	1	1	0	1	0	1	1	0	1	0
88 050 to 88 150	1	1	1	0	1	0	1	1	1	1	0
88 150 to 88 250	1	1	1	0	1	0	1	1	1	0	0

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
88 250 to 88 350	1	1	1	0	1	0	1	0	1	0	0
88 350 to 88 450	1	1	1	0	1	0	1	0	1	1	0
88 450 to 88 550	1	1	1	0	1	0	1	0	0	1	0
88 550 to 88 650	1	1	1	0	1	0	1	0	0	1	1
88 650 to 88 750	1	1	1	0	1	0	1	0	0	0	1
88 750 to 88 850	1	1	1	0	1	1	1	0	0	0	1
88 850 to 88 950	1	1	1	0	1	1	1	0	0	1	1
88 950 to 89 050	1	1	1	0	1	1	1	0	0	1	0
89 050 to 89 150	1	1	1	0	1	1	1	0	1	1	0
89 150 to 89 250	1	1	1	0	1	1	1	0	1	0	0
89 250 to 89 350	1	1	1	0	1	1	1	1	1	0	0
89 350 to 89 450	1	1	1	0	1	1	1	1	1	1	0
89 450 to 89 550	1	1	1	0	1	1	1	1	0	1	0
89 550 to 89 650	1	1	1	0	1	1	1	1	0	1	1
89 650 to 89 750	1	1	1	0	1	1	1	1	0	0	1
89 750 to 89 850	1	1	1	0	1	1	0	1	0	0	1
89 850 to 89 950	1	1	1	0	1	1	0	1	0	1	1
89 950 to 90 050	1	1	1	0	1	1	0	1	0	1	0
90 050 to 90 150	1	1	1	0	1	1	0	1	1	1	0
90 150 to 90 250	1	1	1	0	1	1	0	1	1	0	0
90 250 to 90 350	1	1	1	0	1	1	0	0	1	0	0
90 350 to 90 450	1	1	1	0	1	1	0	0	1	1	0
90 450 to 90 550	1	1	1	0	1	1	0	0	0	1	0
90 550 to 90 650	1	1	1	0	1	1	0	0	0	1	1
90 650 to 90 750	1	1	1	0	1	1	0	0	0	0	1
90 750 to 90 850	1	1	1	0	0	1	0	0	0	0	1
90 850 to 90 950	1	1	1	0	0	1	0	0	0	1	1
90 950 to 91 050	1	1	1	0	0	1	0	0	0	1	0
91 050 to 91 150	1	1	1	0	0	1	0	0	1	1	0
91 150 to 91 250	1	1	1	0	0	1	0	0	1	0	0
91 250 to 91 350	1	1	1	0	0	1	0	1	1	0	0
91 350 to 91 450	1	1	1	0	0	1	0	1	1	1	0
91 450 to 91 550	1	1	1	0	0	1	0	1	0	1	0
91 550 to 91 650	1	1	1	0	0	1	0	1	0	1	1
91 650 to 91 750	1	1	1	0	0	1	0	1	0	0	1
91 750 to 91 850	1	1	1	0	0	1	1	1	0	0	1
91 850 to 91 950	1	1	1	0	0	1	1	1	0	1	1
91 950 to 92 050	1	1	1	0	0	1	1	1	0	1	0
92 050 to 92 150	1	1	1	0	0	1	1	1	1	1	0
92 150 to 92 250	1	1	1	0	0	1	1	1	1	0	0
92 250 to 92 350	1	1	1	0	0	1	1	0	1	0	0
92 350 to 92 450	1	1	1	0	0	1	1	0	1	1	0
92 450 to 92 550	1	1	1	0	0	1	1	0	0	1	0
92 550 to 92 650	1	1	1	0	0	1	1	0	0	1	1
92 650 to 92 750	1	1	1	0	0	1	1	0	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
92 750 to 92 850	1	1	1	0	0	0	1	0	0	0	1
92 850 to 92 950	1	1	1	0	0	0	1	0	0	1	1
92 950 to 93 050	1	1	1	0	0	0	1	0	0	1	0
93 050 to 93 150	1	1	1	0	0	0	1	0	1	1	0
93 150 to 93 250	1	1	1	0	0	0	1	0	1	0	0
93 250 to 93 350	1	1	1	0	0	0	1	1	1	0	0
93 350 to 93 450	1	1	1	0	0	0	1	1	1	1	0
93 450 to 93 550	1	1	1	0	0	0	1	1	0	1	0
93 550 to 93 650	1	1	1	0	0	0	1	1	0	1	1
93 650 to 93 750	1	1	1	0	0	0	1	1	0	0	1
93 750 to 93 850	1	1	1	0	0	0	0	1	0	0	1
93 850 to 93 950	1	1	1	0	0	0	0	1	0	1	1
93 950 to 94 050	1	1	1	0	0	0	0	1	0	1	0
94 050 to 94 150	1	1	1	0	0	0	0	1	1	1	0
94 150 to 94 250	1	1	1	0	0	0	0	1	1	0	0
94 250 to 94 350	1	1	1	0	0	0	0	0	1	0	0
94 350 to 94 450	1	1	1	0	0	0	0	0	1	1	0
94 450 to 94 550	1	1	1	0	0	0	0	0	0	1	0
94 550 to 94 650	1	1	1	0	0	0	0	0	0	1	1
94 650 to 94 750	1	1	1	0	0	0	0	0	0	0	1
94 750 to 94 850	1	0	1	0	0	0	0	0	0	0	1
94 850 to 94 950	1	0	1	0	0	0	0	0	0	1	1
94 950 to 95 050	1	0	1	0	0	0	0	0	0	1	0
95 050 to 95 150	1	0	1	0	0	0	0	0	1	1	0
95 150 to 95 250	1	0	1	0	0	0	0	0	1	0	0
95 250 to 95 350	1	0	1	0	0	0	0	1	1	0	0
95 350 to 95 450	1	0	1	0	0	0	0	1	1	1	0
95 450 to 95 550	1	0	1	0	0	0	0	1	0	1	0
95 550 to 95 650	1	0	1	0	0	0	0	1	0	1	1
95 650 to 95 750	1	0	1	0	0	0	0	1	0	0	1
95 750 to 95 850	1	0	1	0	0	0	1	1	0	0	1
95 850 to 95 950	1	0	1	0	0	0	1	1	0	1	1
95 950 to 96 050	1	0	1	0	0	0	1	1	0	1	0
96 050 to 96 150	1	0	1	0	0	0	1	1	1	1	0
96 150 to 96 250	1	0	1	0	0	0	1	1	1	0	0
96 250 to 96 350	1	0	1	0	0	0	1	0	1	0	0
96 350 to 96 450	1	0	1	0	0	0	1	0	1	1	0
96 450 to 96 550	1	0	1	0	0	0	1	0	0	1	0
96 550 to 96 650	1	0	1	0	0	0	1	0	0	1	1
96 650 to 96 750	1	0	1	0	0	0	1	0	0	0	1
96 750 to 96 850	1	0	1	0	0	1	1	0	0	0	1
96 850 to 96 950	1	0	1	0	0	1	1	0	0	1	1
96 950 to 97 050	1	0	1	0	0	1	1	0	0	1	0
97 050 to 97 150	1	0	1	0	0	1	1	0	1	1	0
97 150 to 97 250	1	0	1	0	0	1	1	0	1	0	0

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
97 250 to 97 350	1	0	1	0	0	1	1	1	1	0	0
97 350 to 97 450	1	0	1	0	0	1	1	1	1	1	0
97 450 to 97 550	1	0	1	0	0	1	1	1	0	1	0
97 550 to 97 650	1	0	1	0	0	1	1	1	0	1	1
97 650 to 97 750	1	0	1	0	0	1	1	1	0	0	1
97 750 to 97 850	1	0	1	0	0	1	0	1	0	0	1
97 850 to 97 950	1	0	1	0	0	1	0	1	0	1	1
97 950 to 98 050	1	0	1	0	0	1	0	1	0	1	0
98 050 to 98 150	1	0	1	0	0	1	0	1	1	1	0
98 150 to 98 250	1	0	1	0	0	1	0	1	1	0	0
98 250 to 98 350	1	0	1	0	0	1	0	0	1	0	0
98 350 to 98 450	1	0	1	0	0	1	0	0	1	1	0
98 450 to 98 550	1	0	1	0	0	1	0	0	0	1	0
98 550 to 98 650	1	0	1	0	0	1	0	0	0	1	1
98 650 to 98 750	1	0	1	0	0	1	0	0	0	0	1
98 750 to 98 850	1	0	1	0	1	1	0	0	0	0	1
98 850 to 98 950	1	0	1	0	1	1	0	0	0	1	1
98 950 to 99 050	1	0	1	0	1	1	0	0	0	1	0
99 050 to 99 150	1	0	1	0	1	1	0	0	1	1	0
99 150 to 99 250	1	0	1	0	1	1	0	0	1	0	0
99 250 to 99 350	1	0	1	0	1	1	0	1	1	0	0
99 350 to 99 450	1	0	1	0	1	1	0	1	1	1	0
99 450 to 99 550	1	0	1	0	1	1	0	1	0	1	0
99 550 to 99 650	1	0	1	0	1	1	0	1	0	1	1
99 650 to 99 750	1	0	1	0	1	1	0	1	0	0	1
99 750 to 99 850	1	0	1	0	1	1	1	1	0	0	1
99 850 to 99 950	1	0	1	0	1	1	1	1	0	1	1
99 950 to 100 050	1	0	1	0	1	1	1	1	0	1	0
100 to 100 150	1	0	1	0	1	1	1	1	1	1	0
100 to 100 250	1	0	1	0	1	1	1	1	1	0	0
100 to 100 350	1	0	1	0	1	1	1	0	1	0	0
100 to 100 450	1	0	1	0	1	1	1	0	1	1	0
100 to 100 550	1	0	1	0	1	1	1	0	0	1	0
100 to 100 650	1	0	1	0	1	1	1	0	0	1	1
100 to 100 750	1	0	1	0	1	1	1	0	0	0	1
100 to 100 850	1	0	1	0	1	0	1	0	0	0	1
100 to 100 950	1	0	1	0	1	0	1	0	0	1	1
100 to 101 050	1	0	1	0	1	0	1	0	0	1	0
101 to 101 150	1	0	1	0	1	0	1	0	1	1	0
101 to 101 250	1	0	1	0	1	0	1	0	1	0	0
101 to 101 350	1	0	1	0	1	0	1	1	1	0	0
101 to 101 450	1	0	1	0	1	0	1	1	1	1	0
101 to 101 550	1	0	1	0	1	0	1	1	0	1	0
101 to 101 650	1	0	1	0	1	0	1	1	0	1	1
101 to 101 750	1	0	1	0	1	0	1	1	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
101 to 101 850	1	0	1	0	1	0	0	1	0	0	1
101 to 101 950	1	0	1	0	1	0	0	1	0	1	1
101 to 102 050	1	0	1	0	1	0	0	1	0	1	0
102 to 102 150	1	0	1	0	1	0	0	1	1	1	0
102 to 102 250	1	0	1	0	1	0	0	1	1	0	0
102 to 102 350	1	0	1	0	1	0	0	0	1	0	0
102 to 102 450	1	0	1	0	1	0	0	0	1	1	0
102 to 102 550	1	0	1	0	1	0	0	0	0	1	0
102 to 102 650	1	0	1	0	1	0	0	0	0	1	1
102 to 102 750	1	0	1	0	1	0	0	0	0	0	1
102 to 102 850	1	0	1	1	1	0	0	0	0	0	1
102 to 102 950	1	0	1	1	1	0	0	0	0	1	1
102 to 103 050	1	0	1	1	1	0	0	0	0	1	0
103 to 103 150	1	0	1	1	1	0	0	0	1	1	0
103 to 103 250	1	0	1	1	1	0	0	0	1	0	0
103 to 103 350	1	0	1	1	1	0	0	1	1	0	0
103 to 103 450	1	0	1	1	1	0	0	1	1	1	0
103 to 103 550	1	0	1	1	1	0	0	1	0	1	0
103 to 103 650	1	0	1	1	1	0	0	1	0	1	1
103 to 103 750	1	0	1	1	1	0	0	1	0	0	1
103 to 103 850	1	0	1	1	1	0	1	1	0	0	1
103 to 103 950	1	0	1	1	1	0	1	1	0	1	1
103 to 104 050	1	0	1	1	1	0	1	1	0	1	0
104 to 104 150	1	0	1	1	1	0	1	1	1	1	0
104 to 104 250	1	0	1	1	1	0	1	1	1	0	0
104 to 104 350	1	0	1	1	1	0	1	0	1	0	0
104 to 104 450	1	0	1	1	1	0	1	0	1	1	0
104 to 104 550	1	0	1	1	1	0	1	0	0	1	0
104 to 104 650	1	0	1	1	1	0	1	0	0	1	1
104 to 104 750	1	0	1	1	1	0	1	0	0	0	1
104 to 104 850	1	0	1	1	1	1	1	0	0	0	1
104 to 104 950	1	0	1	1	1	1	1	0	0	1	1
104 to 105 050	1	0	1	1	1	1	1	0	0	1	0
105 to 105 150	1	0	1	1	1	1	1	0	1	1	0
105 to 105 250	1	0	1	1	1	1	1	0	1	0	0
105 to 105 350	1	0	1	1	1	1	1	1	1	0	0
105 to 105 450	1	0	1	1	1	1	1	1	1	1	0
105 to 105 550	1	0	1	1	1	1	1	1	0	1	0
105 to 105 650	1	0	1	1	1	1	1	1	0	1	1
105 to 105 750	1	0	1	1	1	1	1	1	0	0	1
105 to 105 850	1	0	1	1	1	1	0	1	0	0	1
105 to 105 950	1	0	1	1	1	1	0	1	0	1	1
105 to 106 050	1	0	1	1	1	1	0	1	0	1	0
106 to 106 150	1	0	1	1	1	1	0	1	1	1	0
106 to 106 250	1	0	1	1	1	1	0	1	1	0	0

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
106 to 106 350	1	0	1	1	1	1	0	0	1	0	0
106 to 106 450	1	0	1	1	1	1	0	0	1	1	0
106 to 106 550	1	0	1	1	1	1	0	0	0	1	0
106 to 106 650	1	0	1	1	1	1	0	0	0	1	1
106 to 106 750	1	0	1	1	1	1	0	0	0	0	1
106 to 106 850	1	0	1	1	0	1	0	0	0	0	1
106 to 106 950	1	0	1	1	0	1	0	0	0	1	1
106 to 107 050	1	0	1	1	0	1	0	0	0	1	0
107 to 107 150	1	0	1	1	0	1	0	0	1	1	0
107 to 107 250	1	0	1	1	0	1	0	0	1	0	0
107 to 107 350	1	0	1	1	0	1	0	1	1	0	0
107 to 107 450	1	0	1	1	0	1	0	1	1	1	0
107 to 107 550	1	0	1	1	0	1	0	1	0	1	0
107 to 107 650	1	0	1	1	0	1	0	1	0	1	1
107 to 107 750	1	0	1	1	0	1	0	1	0	0	1
107 to 107 850	1	0	1	1	0	1	1	1	0	0	1
107 to 107 950	1	0	1	1	0	1	1	1	0	1	1
107 to 108 050	1	0	1	1	0	1	1	1	0	1	0
108 to 108 150	1	0	1	1	0	1	1	1	1	1	0
108 to 108 250	1	0	1	1	0	1	1	1	1	0	0
108 to 108 350	1	0	1	1	0	1	1	0	1	0	0
108 to 108 450	1	0	1	1	0	1	1	0	1	1	0
108 to 108 550	1	0	1	1	0	1	1	0	0	1	0
108 to 108 650	1	0	1	1	0	1	1	0	0	1	1
108 to 108 750	1	0	1	1	0	1	1	0	0	0	1
108 to 108 850	1	0	1	1	0	0	1	0	0	0	1
108 to 108 950	1	0	1	1	0	0	1	0	0	1	1
108 to 109 050	1	0	1	1	0	0	1	0	0	1	0
109 to 109 150	1	0	1	1	0	0	1	0	1	1	0
109 to 109 250	1	0	1	1	0	0	1	0	1	0	0
109 to 109 350	1	0	1	1	0	0	1	1	1	0	0
109 to 109 450	1	0	1	1	0	0	1	1	1	1	0
109 to 109 550	1	0	1	1	0	0	1	1	0	1	0
109 to 109 650	1	0	1	1	0	0	1	1	0	1	1
109 to 109 750	1	0	1	1	0	0	1	1	0	0	1
109 to 109 850	1	0	1	1	0	0	0	1	0	0	1
109 to 109 950	1	0	1	1	0	0	0	1	0	1	1
109 to 110 050	1	0	1	1	0	0	0	1	0	1	0
110 to 110 150	1	0	1	1	0	0	0	1	1	1	0
110 to 110 250	1	0	1	1	0	0	0	1	1	0	0
110 to 110 350	1	0	1	1	0	0	0	0	1	0	0
110 to 110 450	1	0	1	1	0	0	0	0	1	1	0
110 to 110 550	1	0	1	1	0	0	0	0	0	1	0
110 to 110 650	1	0	1	1	0	0	0	0	0	1	1
110 to 110 750	1	0	1	1	0	0	0	0	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
110 to 110 850	1	0	0	1	0	0	0	0	0	0	1
110 to 110 950	1	0	0	1	0	0	0	0	0	1	1
110 to 111 050	1	0	0	1	0	0	0	0	0	1	0
111 to 111 150	1	0	0	1	0	0	0	0	1	1	0
111 to 111 250	1	0	0	1	0	0	0	0	1	0	0
111 to 111 350	1	0	0	1	0	0	0	1	1	0	0
111 to 111 450	1	0	0	1	0	0	0	1	1	1	0
111 to 111 550	1	0	0	1	0	0	0	1	0	1	0
111 to 111 650	1	0	0	1	0	0	0	1	0	1	1
111 to 111 750	1	0	0	1	0	0	0	1	0	0	1
111 to 111 850	1	0	0	1	0	0	1	1	0	0	1
111 to 111 950	1	0	0	1	0	0	1	1	0	1	1
111 to 112 050	1	0	0	1	0	0	1	1	0	1	0
112 to 112 150	1	0	0	1	0	0	1	1	1	1	0
112 to 112 250	1	0	0	1	0	0	1	1	1	0	0
112 to 112 350	1	0	0	1	0	0	1	0	1	0	0
112 to 112 450	1	0	0	1	0	0	1	0	1	1	0
112 to 112 550	1	0	0	1	0	0	1	0	0	1	0
112 to 112 650	1	0	0	1	0	0	1	0	0	1	1
112 to 112 750	1	0	0	1	0	0	1	0	0	0	1
112 to 112 850	1	0	0	1	0	1	1	0	0	0	1
112 to 112 950	1	0	0	1	0	1	1	0	0	1	1
112 to 113 050	1	0	0	1	0	1	1	0	0	1	0
113 to 113 150	1	0	0	1	0	1	1	0	1	1	0
113 to 113 250	1	0	0	1	0	1	1	0	1	0	0
113 to 113 350	1	0	0	1	0	1	1	1	1	0	0
113 to 113 450	1	0	0	1	0	1	1	1	1	1	0
113 to 113 550	1	0	0	1	0	1	1	1	0	1	0
113 to 113 650	1	0	0	1	0	1	1	1	0	1	1
113 to 113 750	1	0	0	1	0	1	1	1	0	0	1
113 to 113 850	1	0	0	1	0	1	0	1	0	0	1
113 to 113 950	1	0	0	1	0	1	0	1	0	1	1
113 to 114 050	1	0	0	1	0	1	0	1	0	1	0
114 to 114 150	1	0	0	1	0	1	0	1	1	1	0
114 to 114 250	1	0	0	1	0	1	0	1	1	0	0
114 to 114 350	1	0	0	1	0	1	0	0	1	0	0
114 to 114 450	1	0	0	1	0	1	0	0	1	1	0
114 to 114 550	1	0	0	1	0	1	0	0	0	1	0
114 to 114 650	1	0	0	1	0	1	0	0	0	1	1
114 to 114 750	1	0	0	1	0	1	0	0	0	0	1
114 to 114 850	1	0	0	1	1	1	0	0	0	0	1
114 to 114 950	1	0	0	1	1	1	0	0	0	1	1
114 to 115 050	1	0	0	1	1	1	0	0	0	1	0
115 to 115 150	1	0	0	1	1	1	0	0	1	1	0
115 to 115 250	1	0	0	1	1	1	0	0	1	0	0

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
115 to 115 350	1	0	0	1	1	1	0	1	1	0	0
115 to 115 450	1	0	0	1	1	1	0	1	1	1	0
115 to 115 550	1	0	0	1	1	1	0	1	0	1	0
115 to 115 650	1	0	0	1	1	1	0	1	0	1	1
115 to 115 750	1	0	0	1	1	1	0	1	0	0	1
115 to 115 850	1	0	0	1	1	1	1	1	0	0	1
115 to 115 950	1	0	0	1	1	1	1	1	0	1	1
115 to 116 050	1	0	0	1	1	1	1	1	0	1	0
116 to 116 150	1	0	0	1	1	1	1	1	1	1	0
116 to 116 250	1	0	0	1	1	1	1	1	1	0	0
116 to 116 350	1	0	0	1	1	1	1	0	1	0	0
116 to 116 450	1	0	0	1	1	1	1	0	1	1	0
116 to 116 550	1	0	0	1	1	1	1	0	0	1	0
116 to 116 650	1	0	0	1	1	1	1	0	0	1	1
116 to 116 750	1	0	0	1	1	1	1	0	0	0	1
116 to 116 850	1	0	0	1	1	0	1	0	0	0	1
116 to 116 950	1	0	0	1	1	0	1	0	0	1	1
116 to 117 050	1	0	0	1	1	0	1	0	0	1	0
117 to 117 150	1	0	0	1	1	0	1	0	1	1	0
117 to 117 250	1	0	0	1	1	0	1	0	1	0	0
117 to 117 350	1	0	0	1	1	0	1	1	1	0	0
117 to 117 450	1	0	0	1	1	0	1	1	1	1	0
117 to 117 550	1	0	0	1	1	0	1	1	0	1	0
117 to 117 650	1	0	0	1	1	0	1	1	0	1	1
117 to 117 750	1	0	0	1	1	0	1	1	0	0	1
117 to 117 850	1	0	0	1	1	0	0	1	0	0	1
117 to 117 950	1	0	0	1	1	0	0	1	0	1	1
117 to 118 050	1	0	0	1	1	0	0	1	0	1	0
118 to 118 150	1	0	0	1	1	0	0	1	1	1	0
118 to 118 250	1	0	0	1	1	0	0	1	1	0	0
118 to 118 350	1	0	0	1	1	0	0	0	1	0	0
118 to 118 450	1	0	0	1	1	0	0	0	1	1	0
118 to 118 550	1	0	0	1	1	0	0	0	0	1	0
118 to 118 650	1	0	0	1	1	0	0	0	0	1	1
118 to 118 750	1	0	0	1	1	0	0	0	0	0	1
118 to 118 850	1	0	0	0	1	0	0	0	0	0	1
118 to 118 950	1	0	0	0	1	0	0	0	0	1	1
118 to 119 050	1	0	0	0	1	0	0	0	0	1	0
119 to 119 150	1	0	0	0	1	0	0	0	1	1	0
119 to 119 250	1	0	0	0	1	0	0	0	1	0	0
119 to 119 350	1	0	0	0	1	0	0	1	1	0	0
119 to 119 450	1	0	0	0	1	0	0	1	1	1	0
119 to 119 550	1	0	0	0	1	0	0	1	0	1	0
119 to 119 650	1	0	0	0	1	0	0	1	0	1	1
119 to 119 750	1	0	0	0	1	0	0	1	0	0	1

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
119 to 119 850	1	0	0	0	1	0	1	1	0	0	1
119 to 119 950	1	0	0	0	1	0	1	1	0	1	1
119 to 120 050	1	0	0	0	1	0	1	1	0	1	0
120 to 120 150	1	0	0	0	1	0	1	1	1	1	0
120 to 120 250	1	0	0	0	1	0	1	1	1	0	0
120 to 120 350	1	0	0	0	1	0	1	0	1	0	0
120 to 120 450	1	0	0	0	1	0	1	0	1	1	0
120 to 120 550	1	0	0	0	1	0	1	0	0	1	0
120 to 120 650	1	0	0	0	1	0	1	0	0	1	1
120 to 120 750	1	0	0	0	1	0	1	0	0	0	1
120 to 120 850	1	0	0	0	1	1	1	0	0	0	1
120 to 120 950	1	0	0	0	1	1	1	0	0	1	1
120 to 121 050	1	0	0	0	1	1	1	0	0	1	0
121 to 121 150	1	0	0	0	1	1	1	0	1	1	0
121 to 121 250	1	0	0	0	1	1	1	0	1	0	0
121 to 121 350	1	0	0	0	1	1	1	1	1	0	0
121 to 121 450	1	0	0	0	1	1	1	1	1	1	0
121 to 121 550	1	0	0	0	1	1	1	1	0	1	0
121 to 121 650	1	0	0	0	1	1	1	1	0	1	1
121 to 121 750	1	0	0	0	1	1	1	1	0	0	1
121 to 121 850	1	0	0	0	1	1	0	1	0	0	1
121 to 121 950	1	0	0	0	1	1	0	1	0	1	1
121 to 122 050	1	0	0	0	1	1	0	1	0	1	0
122 to 122 150	1	0	0	0	1	1	0	1	1	1	0
122 to 122 250	1	0	0	0	1	1	0	1	1	0	0
122 to 122 350	1	0	0	0	1	1	0	0	1	0	0
122 to 122 450	1	0	0	0	1	1	0	0	1	1	0
122 to 122 550	1	0	0	0	1	1	0	0	0	1	0
122 to 122 650	1	0	0	0	1	1	0	0	0	1	1
122 to 122 750	1	0	0	0	1	1	0	0	0	0	1
122 to 122 850	1	0	0	0	0	1	0	0	0	0	1
122 to 122 950	1	0	0	0	0	1	0	0	0	1	1
122 to 123 050	1	0	0	0	0	1	0	0	0	1	0
123 to 123 150	1	0	0	0	0	1	0	0	1	1	0
123 to 123 250	1	0	0	0	0	1	0	0	1	0	0
123 to 123 350	1	0	0	0	0	1	0	1	1	0	0
123 to 123 450	1	0	0	0	0	1	0	1	1	1	0
123 to 123 550	1	0	0	0	0	1	0	1	0	1	0
123 to 123 650	1	0	0	0	0	1	0	1	0	1	1
123 to 123 750	1	0	0	0	0	1	0	1	0	0	1
123 to 123 850	1	0	0	0	0	1	1	1	0	0	1
123 to 123 950	1	0	0	0	0	1	1	1	0	1	1
123 to 124 050	1	0	0	0	0	1	1	1	0	1	0
124 to 124 150	1	0	0	0	0	1	1	1	1	1	0
124 to 124 250	1	0	0	0	0	1	1	1	1	0	0

RANGE	PULSE POSITIONS *(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)*										
Increments *(Feet)*	D_2	D_4	A_1	A_2	A_4	B_1	B_2	B_4	C_1	C_2	C_4
124 to 124 350	1	0	0	0	0	1	1	0	1	0	0
124 to 124 450	1	0	0	0	0	1	1	0	1	1	0
124 to 124 550	1	0	0	0	0	1	1	0	0	1	0
124 to 124 650	1	0	0	0	0	1	1	0	0	1	1
124 to 124 750	1	0	0	0	0	1	1	0	0	0	1
124 to 124 850	1	0	0	0	0	0	1	0	0	0	1
124 to 124 950	1	0	0	0	0	0	1	0	0	1	1
124 to 125 050	1	0	0	0	0	0	1	0	0	1	0
125 to 125 150	1	0	0	0	0	0	1	0	1	1	0
125 to 125 250	1	0	0	0	0	0	1	0	1	0	0
125 to 125 350	1	0	0	0	0	0	1	1	1	0	0
125 to 125 450	1	0	0	0	0	0	1	1	1	1	0
125 to 125 550	1	0	0	0	0	0	1	1	0	1	0
125 to 125 650	1	0	0	0	0	0	1	1	0	1	1
125 to 125 750	1	0	0	0	0	0	1	1	0	0	1
125 to 125 850	1	0	0	0	0	0	0	1	0	0	1
125 to 125 950	1	0	0	0	0	0	0	1	0	1	1
125 to 126 050	1	0	0	0	0	0	0	1	0	1	0
126 to 126 150	1	0	0	0	0	0	0	1	1	1	0
126 to 126 250	1	0	0	0	0	0	0	1	1	0	0
126 to 126 350	1	0	0	0	0	0	0	0	1	0	0
126 to 126 450	1	0	0	0	0	0	0	0	1	1	0
126 to 126 550	1	0	0	0	0	0	0	0	0	1	0
126 to 126 650	1	0	0	0	0	0	0	0	0	1	1
126 to 126 750	1	0	0	0	0	0	0	0	0	0	1