GHANA CIVIL AVIATION

(AIR NAVIGATION SERVICES)

DIRECTIVES

PART 23: SUBPART 3 –

AERONAUTICAL TELECOMMUNICATION:

(PART I – DIGITAL DATA COMMUNICATION SYSTEMS
PART II – VOICE COMMUNICATION SYSTEMS)

INTRODUCTION

This Subpart 3 of Part 23 is aligned with Amendment 94 to Annex 10 Volume III – Aeronautical Telecommunications – Communication Systems (Part I Digital Data Communication Systems Part II Voice Communication Systems).

It contains requirements for various air-ground and ground-ground voice and data communication systems, including aeronautical telecommunication network (ATN), aeronautical mobile-satellite service (AMSS), secondary surveillance radar (SSR) Mode S air-ground data link, very high frequency (VHF) air- ground digital link (VDL), aeronautical fixed telecommunication network (AFTN), aircraft addressing system, high frequency data link (HFDL), aeronautical mobile service, selective calling system (SELCAL), aeronautical speech circuits and emergency locator transmitter (ELT).

PART I – DIGITAL DATA COMMUNICATION SYSTEMS

23.3 INTRODUCTION/ PREAMBLE.

Note 1. — All references to "Radio Regulations" are to the Radio Regulations published by the International Telecommunication Union (ITU). 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).

Note 2. — This Part includes provisions for certain forms of equipment for communication systems. While the Republic of Ghana will determine the necessity for specific installations in accordance with the conditions prescribed herein, review of the need for specific installation and the formulation of ICAO opinion and recommendations to Contracting States concerned, is carried out periodically by Council, ordinarily on the basis of recommendations of Regional Air Navigation Meetings (Doc 8144, Directives to Regional Air Navigation Meetings and Rules of Procedure for their Conduct).

Note 3. — This chapter contains general definitions relevant to communication systems. Definitions specific to each of the systems included in this Subpart are contained in the relevant Sections.

Note 4. Material on secondary power supply is contained in Part 23, Subpart 1, Section 23.2.9.

23.3.1 GENERAL

23.3.1.1 APPLICABILITY

23.3.1.2 DEFINITIONS

The following terms under Aeronautical Telecommunication Network have the following meanings:

Aeronautical administrative communications (AAC) mean communications necessary for the exchange of aeronautical administrative messages.

Aeronautical operational control (AOC) *means* communication required for the exercise of authority over the initiation, continuation, diversion or termination of flight for safety, regularity and efficiency reasons.

Aeronautical telecommunication network (ATN) means a global internetwork architecture that allows ground, air-ground and avionic data subnetworks to exchange digital data for the safety of air navigation and for the regular, efficient and economic operation of air traffic services.

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.

Aircraft earth station (AES) means a mobile earth station in the aeronautical mobile-satellite service located on board an aircraft (see also “GES”).

Air traffic service means a generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service).

Application entity (AE) means an AE represents a set of ISO/OSI communication capabilities of a particular application process (see ISO/IEC 9545 for further details).

ATN security services means a set of information security provisions allowing the receiving end system or intermediate system to unambiguously identify (i.e. authenticate) the source of the received information and to verify the integrity of that information.

ATS interfacility data communication (AIDC) means Automated data exchange between air traffic services units in support of flight notification, flight coordination, transfer of control and transfer of communication.

ATS message handling service (ATSMHS) means an ATN application consisting of procedures used to exchange ATS messages in store-and-forward mode over the ATN such that the conveyance of an ATS message is in general not correlated with the conveyance of another ATS message by the service provider.

ATS message handling system (AMHS) means the set of computing and communication resources implemented by ATS organizations to provide the ATS message handling service.

Authorized path means a communication path suitable for a given message category.

Automatic dependent surveillance — contract (ADS-C) means a means by which the terms of an ADS-C agreement will be exchanged between the ground system and the aircraft, via a data link, specifying under what conditions ADS-C reports would be initiated, and what data would be contained in the reports.

Automatic terminal information service (ATIS) means the automatic provision of current, routine information to arriving and departing aircraft throughout 24 hours or a specified portion thereof.

Data link-automatic terminal information service (D-ATIS) means the provision of ATIS via data link.

Voice-automatic terminal information service (Voice-ATIS) means the

provision of ATIS by means of continuous and repetitive voice broadcasts.

Bit error rate (BER) means the number of bit errors in a sample divided by the total number of bits in the sample, generally averaged over many such samples.

Carrier-to-multipath ratio (C/M) means the ratio of the carrier power received directly, i.e. without reflection, to the multipath power, i.e. carrier power received via reflection.

Carrier-to-noise density ratio (C/N_O) means the ratio of the total carrier power to the average noise power in a 1 Hz bandwidth, usually expressed in dBHz.

Channel rate means The rate at which bits are transmitted over the RF channel. These bits include those bits used for framing and error correction, as well as the information bits. For burst transmission, the channel rate refers to the instantaneous burst rate over the period of the burst.

Channel rate accuracy this is relative accuracy of the clock to which the transmitted channel bits are synchronized. For example, at a channel rate of 1.2 kbits/s, maximum error of one part in 10^6 implies the maximum allowed error in the clock is $\pm 1.2 \times 10^{-3}$ Hz.

Circuit mode means a configuration of the communications network which gives the appearance to the application of a dedicated transmission path.

Controller pilot data link communications (CPDLC) means a means of communication between controller and pilot, using data link for ATC communications.

Data link flight information services (D-FIS) means the provision of FIS via data link.

Data link initiation capability (DLIC) means a data link application that provides the ability to exchange addresses, names and version numbers necessary to initiate data link applications (see Doc 4444).

Directory service (DIR) means a service, based on the ITU-T X.500 series of recommendations, providing access to and management of structured information relevant to the operation of the ATN and its users.

Doppler shift means the frequency shift observed at a receiver due to any relative motion between transmitter and receiver.

End-to-end means pertaining or relating to an entire communication path, typically from (1) the interface between the information source and the communication system at the transmitting end to (2) the interface between the communication system and the information user or processor or application at the receiving end.

End-user means an ultimate source and/or consumer of information.

Energy per symbol to noise density ratio (E_S/N_O) means the ratio of the average energy transmitted per channel symbol to the average noise power in a 1 Hz bandwidth, usually expressed in dB. For A-BPSK and A-QPSK, one channel symbol refers to one channel bit.

Equivalent isotropically radiated power (e.i.r.p.) means the product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna *(absolute or isotropic gain).*

Flight information service (FIS) means a service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights.

Forward error correction (FEC) means the process of adding redundant information to the transmitted signal in a manner which allows correction, at the receiver, of errors incurred in the transmission.

Gain-to-noise temperature ratio means the ratio, usually expressed in dB/K, of the antenna gain to the noise at the receiver output of the antenna subsystem. The noise is expressed as the temperature that a 1 ohm resistor must be raised to produce the same noise power density.

Ground earth station (GES) means an earth station in the fixed satellite service, or, in some cases, in the aeronautical mobile-satellite service, located at a specified fixed point on land to provide a feeder link

for the aeronautical mobile- satellite service.

Required communication performance (RCP) means a statement of the performance requirements for operational communication in support of specific ATM functions (see *Manual on Required Communication Performance (RCP)* (Doc 9869)).

Note. — This definition is used in the ITU's Radio Regulations under the term "aeronautical earth station". The definition herein as "GES" for use in the SARPs is to clearly distinguish it from an aircraft earth station (AES), which is a mobile station on an aircraft.

Mode S subnetwork means a means of performing an interchange of digital data through the use of secondary surveillance radar (SSR) Mode S interrogators and transponders in accordance with defined protocols.

Point-to-point means pertaining or relating to the interconnection of two devices, particularly end-user instruments. A communication path of service intended to connect two discrete end-users; as distinguished from broadcast or multipoint service.

Slotted aloha means a random access strategy whereby multiple users access the same communications channel independently, but each communication must be confined to a fixed time slot. The same timing slot structure is known to all users, but there is no other coordination between the users.

Time division multiple access (TDMA) means a multiple access scheme based on time-shared use of an RF channel employing:

(1) discrete contiguous time slots as the fundamental shared resource; and

(2) a set of operating protocols that allows users to interact with a master control station to mediate access to the channel.

Time division multiplex (TDM) means a channel sharing strategy in which packets of information from the same source but with different destinations are sequenced in time on the same channel.

Transit delay means in packet data systems, the elapsed time between a request to transmit an assembled data packet and an indication at the receiving end that the corresponding packet has been received and is ready to be used or forwarded.

VHF digital link (VDL) means a constituent mobile subnetwork of the aeronautical telecommunication network (ATN), operating in the aeronautical mobile VHF frequency band. In addition, the VDL may provide non-ATN functions such as, for instance, digitized voice.

23.3.2 AERONAUTICAL TELECOMMUNICATION NETWORK

Note 1.— Detailed technical specifications for ATN/OSI applications are contained in the Manual on Detailed Technical Specifications for the Aeronautical Telecommunication Network (ATN) using ISO/OSI Standards and Protocols (Doc 9880) and in the Manual of Technical Provisions for the Aeronautical Telecommunication Network (ATN) (Doc 9705).

Note 2. Detailed technical specifications for ATN/IPS applications are contained in the Manual for the Aeronautical Telecommunication Network (ATN) using Internet Protocol Suite (IPS) Standards and Protocols (Doc 9896) (available electronically on the ICAO-Net).

23.3.2.1 INTRODUCTION

The ATN is specifically and exclusively intended to provide voice and data communications services to air traffic service provider organizations and aircraft operators in support of:

(a) air traffic services communications (ATSC) with aircraft;

(b) air traffic services communications between ATS units;

(c) aeronautical operational control communications (AOC); and

(d) aeronautical administrative communications (AAC).

23.3.2.2 GENERAL

(1) ATN communication services shall support ATN applications.

(2) Requirements for implementation of the ATN shall be made on the basis of regional air navigation agreements. These agreements shall specify the area in which the communication standards for the ATN/OSI or the ATN/IPS are applicable.

Note — The standards in sections 23.3.2 to 23.3.2.4.5 define the minimum required protocols and services that will enable the global implementation of the aeronautical telecommunication network (ATN).

23.3.2.3 GENERAL REQUIREMENTS

(1) The ATN shall either use International Organization for Standardization (ISO) communication standards for open systems interconnection (OSI) or use the Internet Society (ISOC) communications standards for the Internet Protocol Suite (IPS).

Note 1.— Guidance material on interoperability between ATN/OSI and ATN/IPS is contained in the Manual on the Aeronautical Telecommunication Network (ATN) using Internet Protocol Suite (IPS) Standards and Protocols (Doc 9896).

(2) The AFTN/AMHS gateway shall ensure the interoperability of AFTN and CIDIN stations and networks with the ATN.

(3) The ATN shall transmit, relay and deliver messages in accordance with the QoS required for the ATN operation. ~~An authorized path(s) shall be defined on the basis of a predefined routing policy.~~

(4) The ATN shall transmit, relay and deliver messages in accordance with the applicable security policy. ~~priority classifications and without discrimination or undue delay.~~

(5) The ATN shall transmit, relay and deliver messages in accordance with the applicable routing policy.~~The ATN shall provide means to define data communications that can be carried only over authorized paths for the traffic type and category specified by the user.~~

(6)

Note. – The QoS as well as the applicable security and routing policies are determined and agreed by the entity responsible (such as air traffic services provider and/or aircraft operator) for the specific traffic types.

(7) The ATN shall provide communication in accordance with the prescribed required communication (RCP) specifications and the required surveillance performance (RSP) specification.

Note.— For more guidance on RCP and RSP specifications, refer to the Performance-based Communication and Surveillance (PBCS) Manual (Doc 9869).

(8) The ATN shall operate in accordance with the communication priorities defined in Table 3-1[**] and Table 3-2.

(9) The ATN shall notify the appropriate application(s) if a message cannot be successfully delivered.

Note. - It is the responsibility of the ATN upper layer communication services, such as dialogue services, to determine the successful delivery of a message to the communication peer and to notify a delivery failure event to the message originator and associated application in the absence of a delivery confirmation from the peer.

(10) The ATN shall make provisions for the efficient use of limited

[**] Tables 3-1 and 3-2 are located at the end of this chapter.

bandwidth subnetworks.~~enable exchange of application information when one or more authorized paths exist.~~

(11) The ATN/IPS shall be capable of supporting multilink.~~ notify the appropriate application processes when no authorized path exists.~~

Note 1. – For guidance, refer to the Manual on the Aeronautical Telecommunication Network (ATN) using Internet Protocol Suite (IPS) Standards and Protocol (Doc 9896).

Note 2. ATN/OSI may also be used to support multilink. For relevant guidance, refer to Technical Specification for ATN using ISO/OSI Standards and Protocols (Doc 9880).

(11) Where the absolute time of day is used within the ATN, it shall be accurate to within 1 second of coordinated universal time (UTC).

Note. — The time accuracy value results in synchronization errors of up to two seconds.

23.3.2.4 ATN APPLICATIONS REQUIREMENTS

23.3.2.4.1 System applications

Note. — System applications provide services that are necessary for operation of the ATN.

(1) The ATN shall support the data link initiation capability (DLIC) applications when air-ground data links are implemented.

Note. — The Global Operational Data Link (Gold) Manual (Doc 10037) provides guidance on the use of the DLIC application.

(2) The ATN shall support the following directory services (DIR) functions when ATSMHS is implemented:~~/OSI end system shall support the following directory services (DIR) application functions when AMHS and/or security protocols are implemented:~~

(a) directory information retrieval; and

(b) directory information modification.

Note. DIR can also be used when security protocols are implemented.

23.3.2.4.2 Air-ground applications

(1) The ATN shall be capable of supporting ~~one or more of~~ the following applications:

(a) ADS-C; and

(b) CPDLC

Note.— The Global Operational Data Link (GOLD) Manual (Doc 10037) provides guidance on the use of ADS-C and CPDLC.

23.3.2.4.3 Ground-ground applications

(1) The ATN shall be capable of supporting the following applications:

(a) ATS interfacility data communication (AIDC);

(b) ATS message handling services applications (ATSMHS).

(c) Aeronautical Voice communications; and

(d) System-wide information management (SWIM)- enabled applications.

23.3.2.5

ATN NAMING AND ADDRESSING REQUIREMENTS

Note. — The ATN naming and addressing scheme supports the principles of unambiguous identification of intermediate systems (routers) and end-systems (hosts) and provides global address standardization.

(1) The ATN shall provide provisions for unambiguous application identification.

The ATN shall have the capability to uniquely identify source and destination entities.~~provide provisions for unambiguous addressing.~~

(2)

(3) The ATN shall provide means to ~~unambiguously~~ uniquely address all ATN end-systems (hosts) and intermediate systems (routers).

Note. - An ATN end-system is an ATN host in IPS terminology; An ATN host is an ATN-end system in OSI terminology.

(4) The ATN addressing and naming plans shall allow States and organizations to assign addresses and names within their own administrative domains.

23.3.2.6

ATN SECURITY REQUIREMENTS

(1) The ATN shall make provisions whereby only the controlling ATS unit may provide ATC instructions to aircraft operating in its airspace.

(2) The ATN shall enable the recipient of a message to identify the originator of that message.

(3) ATN end-systems supporting ATN security services shall be capable of authenticating the identity of peer end- systems, authenticating the source of messages and ensuring the data integrity of the messages.

Note.— The capability to authenticate the identity of peer end-systems is intended to provide protection against spoofing, 'phantom controllers' or 'phantam aircraft'.

(4) The ATN services shall be protected against service attacks to a level consistent with the application service requirements and to a level commensurate with security risks and applicable policy.

Note. – Detailed information on security risks and applicable policy for ATN and their mitigation are provided in the Manual of security Risk Assessment (SRA) for Aeronautical Communications (Doc 10145).

Table 3-1. Mapping of ATN communication priorities

Message categories	*ATN application*	*Corresponding protocol*	
		Transport layer priority	*Network layer priority*
Network/systems management		0	144
Distress communications		1	13
Urgent communications		2	12
High-priority flight safety messages	CPDLC, ADS-C	3	11
Normal-priority flight safety	AIDC, ATIS	4	10
Meteorological communications	METAR	5	9
Flight regularity communications	DLIC, ATSMHS	6	8
Aeronautical information service		7	7
Network/systems administration	DIR	8	6
Aeronautical administrative		9	5
<unassigned>		10	4
Urgent-priority administrative and U.N. Charter communications		11	3
High-priority administrative and State/ Government communications		12	2
Normal-priority administrative communications		13	1
Low-priority administrative communications and aeronautical passenger communications		14	0
Note. — The network layer priorities shown in the table apply only to connectionless network priority and do not apply to subnetwork priority.			

Table 3-2. Mapping of ATN network priority to mobile subnetwork priority

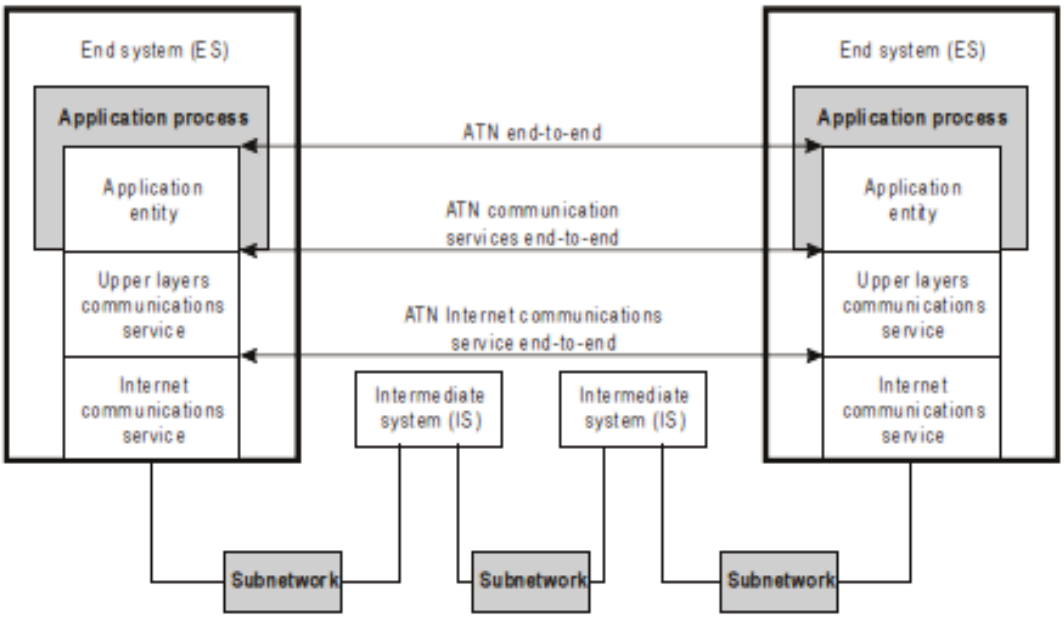
Message categories	*ATN network layer priority*	*Corresponding mobile subnetwork priority (see Note 4)*					
		AMSS	*VDL Mode 2*	*VDL Mode 3*	*VDL Mode 4*	*SSR Mode S*	*HFDL*
Network/systems management	14	14	see Note 1	3	14	high	14
Distress communications	13	14	see Note 1	2	13	high	14
Urgent communications	12	14	see Note 1	2	12	high	14
High-priority flight safety messages	11	11	see Note 1	2	11	high	11
Normal-priority flight safety messages	10	11	see Note 1	2	10	high	11
Meteorological communications	9	8	see Note 1	1	9	low	8
Flight regularity communications	8	7	see Note 1	1	8	low	7
Aeronautical information service messages	7	6	see Note 1	0	7	low	6
Network/systems administration	6	5	see Note 1	0	6	low	5
Aeronautical administrative messages	5	5	not allowed	not allowed	not allowed	not allowed	not allowed
<unassigned>	4	unassigne	unassigned	unassigne	unassigne	unassigne	unassigne
Urgent-priority administrative and U.N. Charter communications	3	3	not allowed	not allowed	not allowed	not allowed	not allowed
High-priority administrative and State/Government communications	2	2	not allowed	not allowed	not allowed	not allowed	not allowed
Normal-priority administrative	1	1	not allowed	not allowed	not allowed	not allowed	not allowed
Low-priority administrative communications and aeronautical passenger	0	0	not allowed	not allowed	not allowed	not allowed	not allowed

Note 1.— VDL Mode 2 has no specific subnetwork priority mechanisms.

Note 2. — The AMSS SARPs specify mapping of message categories to subnetwork priority without explicitly referencing ATN network layer priority.

Note 3. — The term "not allowed" means that only communications related to safety and regularity of flight are authorized to pass over this subnetwork as defined in the subnetwork SARPs.

Note 4. — Only those mobile subnetworks are listed for which subnetwork SARPs exist and for which explicit support is provided by the ATN boundary intermediate system (BIS) technical provisions.



Note 1.— Shading indicates elements outside the scope of these SARPs. User requirements define the interface between the application entity and the user and ensure the functionality and interoperability of the ATN.

Note 2.— The figure represents a simplified model of the ATN and does not depict all of its capabilities (e.g. the store and forward capability which is provided for ATS message handling service).

Note 3.— Various end-to-end points have been defined within the ATN to specify certain end-to-end performance requirements. It may be necessary, however, to define different end-to-end points to facilitate the qualification of implementations to those performance requirements. In such cases, the end-to-end points should be clearly defined and correlated with the end-to-end points shown in the figure.

Note 4.— An IS is a conceptual representation of functionality and does not correspond precisely to a router. A router which implements the system management application requires the protocols of an end system and when using the system management application is also acting as an end system.

23.3.3 AERONAUTICAL MOBILE-SATELLITE (ROUTE) SERVICE (AMS(R)S)

Note 1. — This chapter contains Standards and Recommended Practices applicable to the use of Aeronautical Mobile-Satellite (R) Service communications technologies. The Standards and Recommended Practices in this chapter are service- and performance-oriented and are not tied to a specific technology or technique..

Note 2. — Detailed Technical Specifications of AMS(R)S Systems are contained in the manual on AMS(R)S. This document also provides a detailed description of the AMS(R)S, including details on the Standards and Recommended Practices below.

23.3.3.1 DEFINITIONS

Connection establishment delay means connection establishment delay, as defined in ISO 8348, includes a component, attributable to the called subnetwork (SN) service user, which is the time between the SN-CONNECT indication and the SN-CONNECT response. This user component is due to actions outside the boundaries of the satellite subnetwork and is therefore excluded from the AMS(R)S specifications.

Data transfer delay (95th percentile) means the 95th percentile of the statistical distribution of delays for which transit delay is the average.

Data transit delay means in accordance with ISO 8348, the average value of the statistical distribution of data delays. This delay represents the subnetwork delay and does not include the connection establishment delay.

Network (N) means the word “network” and its abbreviation “N” in ISO 8348 are replaced by the word “subnetwork” and its abbreviation “SN”, respectively, wherever they appear in relation to the subnetwork layer packet data performance.

Residual error rate means the ratio of incorrect, lost and duplicate subnetwork service data units (SNSDUs) to the total number of SNSDUs that were sent.

Spot beam means satellite antenna directivity whose main lobe

encompasses significantly less than the earth's surface that is within line-of-sight view of the satellite. May be designed so as to improve system resource efficiency with respect to geographical distribution of user earth stations.

Subnetwork (SN) means see Network (N).

Subnetwork service data unit (SNSDU) means an amount of subnetwork user data, the identity of which is preserved from one end of a subnetwork connection to the other.

Total voice transfer delay means the elapsed time commencing at the instant that speech is presented to the AES or GES and concluding at the instant that the speech enters the interconnecting network of the counterpart GES or AES. This delay includes vocoder processing time, physical layer delay, RF propagation delay and any other delays within an AMS(R)S subnetwork.

Note. — The following terms used in this chapter are defined in Part 23 as follows:

- *Aeronautical telecommunication network (ATN): Subpart 3, Section 23.3.1.*
- *Aeronautical mobile-satellite (route) service (AMS(R)S): Subpart 2, Section 23.2.1.(1).*
- *Aircraft earth station (AES): Subpart 3, Section 23.3.1.*
- *Ground earth station (GES): Subpart 3, Section 23.3.1.*
- *Subnetwork layer: Subpart 3, Section 23.3.4.1.*

23.3.3.2 GENERAL

(1) Any mobile-satellite system intended to provide AMS(R)S shall conform to the requirements of this chapter.

(2) An AMS(R)S system shall support packet data service, or voice service, or both.

(3) Requirements for mandatory carriage of AMS(R)S system equipment including the level of system capability shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales for the carriage of equipment. A level of system capability shall include the performance of the AES, the satellite and the GES.

(4) The agreements indicated in 23.3.3.2(3) shall provide at least two years' notice of mandatory carriage of airborne systems.

(5) The Authority ~~shall~~ will coordinate with national authorities and service providers those implementation aspects of an AMS(R)S system that will permit its worldwide interoperability and optimum use, as appropriate.

23.3.3.3 RF CHARACTERISTICS

23.3.3.3.1 FREQUENCY BANDS

When providing AMS(R)S communications, an AMS(R)S system shall operate only in frequency bands which are appropriately allocated to AMS(R)S and protected by the ITU Radio Regulations.
Note. — ITU Radio Regulations permit systems providing mobile-satellite service to use the same spectrum as AMS(R)S without requiring such systems to offer safety services. This situation has the potential to reduce the spectrum available for AMS(R)S. It is critical that States consider this issue in frequency planning and in the establishment of national or regional spectrum requirements.

23.3.3.3.2 EMISSIONS

The total emissions of the AES necessary to meet designed system performance shall be controlled to avoid harmful interference to other systems necessary to support safety and regularity of air navigation, installed on the same or other aircraft.

Note 1. — Harmful interference can result from radiated and/or conducted emissions that include harmonics, discrete spurious, intermodulation

product and noise emissions, and are not necessarily limited to the "transmitter on" state.

Note 2. Protection requirements for GNSS are contained in Part 23 Subpart 1.

23.3.3.3.2.1 INTERFERENCE TO OTHER AMS(R)S EQUIPMENT

Emissions from an AMS(R)S system AES shall not cause harmful interference to an AES providing AMS(R)S on a different aircraft.

Note. — One method of complying with 23.3.3.3.2.1(1) is by limiting emissions in the operating band of other AMS(R)S equipment to a level consistent with the intersystem interference requirements such as contained in RTCA document DO-215. RTCA and EUROCAE may establish new performance standards for future AMS(R)S which may describe methods of compliance with this requirement.

23.3.3.3.3 SUSCEPTIBILITY

The AES equipment shall operate properly in an interference environment causing a cumulative relative change in its receiver noise temperature (ΔT/T) of 25 per cent.

23.3.3.4 PRIORITY AND PRE-EMPTIVE ACCESS

(1) Every aircraft earth station and ground earth station shall be designed to ensure that messages transmitted in accordance with Part 23 Subpart 2, Section 23.2.5.2, including their order of priority, are not delayed by the transmission and/or reception of other types of messages. If necessary, as a means to comply with the above requirement, message types not defined in Part 23 Subpart 2, Section 23.2.5.2 shall be terminated even without warning, to allow Part 23 Subpart 2, Section 23.2.5.2 type messages to be transmitted and received.

(2) All AMS(R)S data packets and all AMS(R)S voice calls shall be identified as to their associated priority.

(3) Within the same message category, the system shall provide voice communications priority over data communications.

23.3.3.5 SIGNAL ACQUISITION AND TRACKING

(1) The AES, GES and satellites shall properly acquire and track service link signals when the aircraft is moving at a ground speed of up to 1 500 km/h (800 knots) along any heading.

(2) The AES, GES and satellites shall properly acquire and track service link signals when the aircraft is moving at a ground speed of up to 2 800 km/h (1 500 knots) along any heading.

(3) The AES, GES and satellites shall properly acquire and track service link signals when the component of the aircraft acceleration vector in the plane of the satellite orbit is up to 0.6 g.

(4) The AES, GES and satellites shall properly acquire and track service link signals when the component of the aircraft acceleration vector in the plane of the satellite orbit is up to 1.2 g.

23.3.3.6 PERFORMANCE REQUIREMENTS

23.3.3.6.1 DESIGNATED OPERATIONAL COVERAGE

An AMS(R)S system shall provide AMS(R)S throughout its designated operational coverage (DOC).

23.3.3.6.2 FAILURE NOTIFICATION

(1) In the event of a service failure, an AMS(R)S system shall provide timely predictions of the time, location and duration of any resultant outages until full service is restored.

Note. — Service outages may, for example, be caused by the failure of a satellite, satellite spot beam, or GES. The geographic areas affected by such outages may be a function of the satellite orbit and system design and may vary with time.

(2) The system shall annunciate a loss of communications capability within 30 seconds of the time when it detects such a loss.

23.3.3.6.3 AES REQUIREMENTS

(1) The AES shall meet the relevant performance requirements contained in 23.3.3.6.4 and 23.3.3.6.5 for aircraft in straight and level flight throughout the designated operational coverage of the satellite system.

(2) The AES shall meet the relevant performance requirements contained in 23.3.3.6.4 and 23.3.3.6.5 for aircraft attitudes of +20/-5 degrees of pitch and +/-25 degrees of roll throughout the DOC of the satellite system.

23.3.3.6.4 Packet data service performance

(1) If the system provides AMS(R)S packet data service, it shall meet the standards of the following subparagraphs.

Note. — System performance standards for packet data service may also be found in RTCA Document DO-270.

(2) An AMS(R)S system providing a packet data service shall be capable of operating as a constituent mobile subnetwork of the ATN.

Note. — In addition, an AMS(R)S may provide non-ATN data functions.

23.3.3.6.4.1 DELAY PARAMETERS

(1) Connection establishment delay. Connection establishment delay shall not be greater than 70 seconds.

Note. — The term "highest priority service" denotes the priority which is reserved for distress, urgency and certain infrequent network system management messages. The term "lowest priority service" denotes the priority used for regularity of flight messages. All delay parameters are under peak-hour traffic loading conditions.

(2) Connection establishment delay shall not be greater than 50 seconds

(3) In accordance with ISO 8348, data transit delay values shall be based on a fixed subnetwork service data unit (SNSDU) length of 128 octets. Data transit delays shall be defined as average values.

(4) Data transit delay, from-aircraft, highest priority. From-aircraft data transit delay shall not be greater than 40 seconds for the highest priority data service.

(5) Data transit delay, from-aircraft, highest priority. From-aircraft data transit shall not be greater than 23 seconds for the highest priority data service.

(6) Data transit delay, from-aircraft, lowest priority. From-aircraft data transit shall not be greater than 28 seconds for the lowest priority data service.

(7) Data transit delay, to-aircraft, highest priority. To-aircraft data transit delay shall not be greater than 12 seconds for the highest priority data service.

(8) Data transit delay, to-aircraft, lowest priority. To-aircraft data transit delay shall not be greater than 28 seconds for the lowest priority data service.

(9) Data transfer delay (95th percentile), from-aircraft, highest priority. From-aircraft data transfer delay (95th percentile) shall not be greater than 80 seconds for the highest priority data service.

(10) Data transfer delay (95th percentile), from-aircraft, highest priority. From-aircraft data transfer delay (95th percentile) shall not be greater than 40 seconds for the highest priority data service.

(11) Data transfer delay (95th percentile), from-aircraft, lowest priority.

From-aircraft data transfer delay (95th percentile) shall not be greater than 60 seconds for the lowest priority data service.

(12) Data transfer delay (95th percentile),to-aircraft, highest priority. To-aircraft data transfer delay (95th percentile) shall not be greater than 15 seconds for the highest priority data service.

(13) Data transfer delay (95th percentile), to-aircraft, lowest priority. To-aircraft data transfer delay (95th percentile) shall not be greater than 30 seconds for the lowest priority data service.

(14) Connection release delay (95th percentile). The connection release delay (95th percentile) shall not be greater than 30 seconds in either direction.

(15) The connection release delay (95th percentile) shall not be greater than 25 seconds in either direction.

23.3.3.6.4.2 INTEGRITY

(1) Residual error rate, from-aircraft. The residual error rate in the from-aircraft direction shall not be greater than 10^{-4} per SNSDU.

(2) The residual error rate in the from-aircraft direction shall not be greater than 10^{-6} per SNSDU.

(3) Residual error rate, to-aircraft. The residual error rate in the to-aircraft direction shall not be greater than 10^{-6} per SNSDU.

(4) Connection resilience. The probability of a subnetwork connection (SNC) provider-invoked SNC release shall not be greater than 10^{-4} over ~~any one~~anyone-hour interval.

Note. — Connection releases resulting from GES-to-GES handover, AES log-off or virtual circuit pre-emption are excluded from this specification.

(5) The probability of an SNC provider-invoked reset shall not be greater

than 10^{-1} over ~~any one~~anyone-hour interval.

23.3.3.6.5 VOICE SERVICE PERFORMANCE

If the system provides AMS(R)S voice service, it shall meet the requirements of the following subparagraphs.

23.3.3.6.5.1 CALL PROCESSING DELAY

(1) AES origination. The 95th percentile of the time delay for a GES to present a call origination event to the terrestrial network interworking interface after a call origination event has arrived at the AES interface shall not be greater than 20 seconds.

(2) GES origination. The 95th percentile of the time delay for an AES to present a call origination event at its aircraft interface after a call origination event has arrived at the terrestrial network interworking interface shall not be greater than 20 seconds.

23.3.3.6.5.2 VOICE QUALITY

(1) The voice transmission shall provide overall intelligibility performance suitable for the intended operational and ambient noise environment.

(2) The total allowable transfer delay within an AMS(R)S subnetwork shall not be greater than 0.485 seconds.

(3) Due account shall be taken of the effects of tandem vocoders and/or other analog/digital conversions.

23.3.3.6.5.3 VOICE CAPACITY

The system shall have sufficient available voice traffic channel resources such that an AES- or GES- originated AMS(R)S voice call presented to the system shall experience a probability of blockage of no more than 10-2.

Note. — Available voice traffic channel resources include all pre-emptable resources, including those in use by non- AMS(R)S communications.

23.3.3.6.6 SECURITY

(1) The system shall provide features for the protection of messages in transit from tampering.

(2) The system shall provide features for protection against denial of service, degraded performance characteristics, or reduction of system capacity when subjected to external attacks

Note. — Possible methods of such attack include intentional flooding with spurious messages, intentional corruption of system software or databases, or physical destruction of the support infrastructure.

(3) The system shall provide features for protection against unauthorized entry.

Note. — These features are intended to provide protection against spoofing and "phantom controllers".

23.3.3.7 SYSTEM INTERFACES

An AMS(R)S system shall allow subnetwork users to address AMS(R)S communications to specific aircraft by means of the ICAO 24-bit aircraft address.

Note. — Provisions on the allocation and assignment of ICAO 24-bit

addresses are contained in the IS: 23.3.3.7.

23.3.3.7.1 PACKET DATA SERVICE INTERFACES

(1) If the system provides AMS(R)S packet data service, it shall provide an interface to the ATN.

(2) If the system provides AMS(R)S packet data service, it shall provide a connectivity notification (CN) function.

[Deleted: former section 23.3.4, SSR Mode S air-ground data link, is deleted in full in line with Amendment 94. The sections that follow are renumbered.]

23.3.4 VHF AIR-GROUND DIGITAL LINK (VDL)

23.3.4.1 DEFINITIONS AND SYSTEM CAPABILITIES

23.3.4.1.1 Definitions

Note 1.— The very high frequency (VHF) digital link (VDL) Mode 2 and the VDL Mode 4 provide data service capabilities. The VDL Mode 3 provides both voice and data service capabilities. The data capability is a constituent mobile subnetwork of the aeronautical telecommunication network (ATN). In addition, the VDL may provide non-ATN functions. Standards and Recommended Practices (SARPs) for the VDL are defined and referenced below.

Note 2.— Additional information on VDL is contained in the Manuals on VHF VDL Mode 2, VDL Mode 3 and VDL Mode 4 Technical Specifications (Docs 9776, 9805 and 9816).

Note 3.— Subpart 23.3.4.1.2 to 23.3.4.8.2 contain provisions for VDL Modes 2 and 3. Section 23.3.4.9 contains provisions for VDL Mode 4.

Automatic dependent surveillance-broadcast (ADS-B) *a means by*

which aircraft, aerodrome vehicles and other objects can automatically transmit and/or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via a data link.

Broadcast *means a transmission of information relating to air navigation that is not addressed to a specific station or stations.*

Burst *means a time-defined, contiguous set of one or more related signal units which may convey user information and protocols, signaling, and any necessary preamble.*

Current slot *means the slot in which a received transmission begins.*

Data circuit-terminating equipment (DCE) *means a DCE is a network provider equipment used to facilitate communications between DTEs.*

Data link entity (DLE) *means a protocol state machine capable of setting up and managing a single data link connection.*

Data link service (DLS) sublayer *means the sublayer that resides above the MAC sublayer. For VDL Mode 4, the DLS sublayer resides above the VSS sublayer. The DLS manages the transmit queue, creates and destroys DLEs for connection- oriented communications, provides facilities for the LME to manage the DLS, and provides facilities for connectionless communications.*

Data terminal equipment (DTE) *means a DTE is an endpoint of a subnetwork connection.*

Extended Golay Code *means an error correction code capable of correcting multiple bit errors.*

Frame *means the link layer frame is composed of a sequence of address, control, FCS and information fields. For VDL Mode 2, these fields are bracketed by opening and closing flag sequences, and a frame may or may not include a variable-length information field.*

Gaussian filtered frequency shift keying (GFSK) *means a continuous-*

phase, frequency shift keying technique using two tones and a Gaussian pulse shape filter.

Global signaling channel (GSC) *means a channel available on a worldwide basis which provides for communication control.*

Link *means a link connects an aircraft DLE and a ground DLE and is uniquely specified by the combination of aircraft DLS address and the ground DLS address. A different subnetwork entity resides above every link endpoint.*

Link layer *means a the layer that lies immediately above the physical layer in the Open Systems Interconnection protocol model. The link layer provides for the reliable transfer of information across the physical media. It is subdivided into the data link sublayer and the media access control sublayer.*

Link management entity (LME) *means a protocol state machine capable of acquiring, establishing and maintaining a connection to a single peer system. An LME establishes data link and subnetwork connections, "hands-off" those connections, and manages the media access control sublayer and physical layer. An aircraft LME tracks how well it can communicate with the ground stations of a single ground system. An aircraft VME instantiates an LME for each ground station that it monitors. Similarly, the ground VME instantiates an LME for each aircraft that it monitors. An LME is deleted when communication with the peer system is no longer viable.*

M burst *means a management channel data block of bits used in VDL Mode 3. This burst contains signalling information needed for media access and link status monitoring.*

Media access control (MAC) *means the sublayer that acquires the data path and controls the movement of bits over the data path.*

Mode 2 *means a data-only VDL mode that uses D8PSK modulation and a carrier sense multiple access (CSMA) control scheme.*

Mode 3 *means a voice and data VDL mode that uses D8PSK modulation and a TDMA media access control scheme.*

Mode 4 *means a data-only VDL mode using a GFSK modulation scheme and self-organizing time division multiple access (STDMA).*

Physical layer *means the lowest level layer in the Open Systems Interconnection protocol model. The physical layer is concerned with the transmission of binary information over the physical medium (e.g. VHF radio).*

Quality of service *means the information relating to data transfer characteristics used by various communication protocols to achieve various levels of performance for network users.*

Reed-Solomon code *means an error correction code capable of correcting symbol errors. Since symbol errors are collections of bits, these codes provide good burst error correction capabilities.*

Self-organizing time division multiple access (STDMA) *means a multiple access scheme based on time-shared use of a radio frequency (RF) channel employing: (1) discrete contiguous time slots as the fundamental shared resource; and (2) a set of operating protocols that allows users to mediate access to these time slots without reliance on a master control station.*

Slot *means one of a series of consecutive time intervals of equal duration. Each burst transmission starts at the beginning of a slot.*

Subnetwork connection *means a long-term association between an aircraft DTE and a ground DTE using successive virtual calls to maintain context across link handoff.*

Subnetwork dependent convergence function (SNDCF) *means a function that matches the characteristics and services of a particular subnetwork to those characteristics and services required by the internetwork facility.*

Subnetwork entity *means in this document, the phrase "ground DCE" will be used for the subnetwork entity in a ground station communicating with an aircraft; the phrase "ground DTE" will be used for the subnetwork entity in a ground router communicating with an aircraft station; and, the phrase "aircraft DTE" will be used for the subnetwork entity in an aircraft*

communicating with the station. A subnetwork entity is a packet layer entity as defined in ISO 8208.

Subnetwork layer *means the layer that establishes, manages and terminates connections across a subnetwork.*

System *means a VDL-capable entity. A system comprises one or more stations and the associated VDL management entity. A system may either be an aircraft system or a ground system.*

Time division multiple access (TDMA) *means a multiple access scheme based on time-shared use of an RF channel employing: (1) discrete contiguous time slots as the fundamental shared resource; and (2) a set of operating protocols that allows users to interact with a master control station to mediate access to the channel.*

User group *means a group of ground and/or aircraft stations which share voice and/or data connectivity. For voice communications, all members of a user group can access all communications. For data, communications include point-to-point connectivity for air-to-ground messages, and point-to-point and broadcast connectivity for ground-to-air messages.*

VDL management entity (VME) *means a VDL-specific entity that provides the quality of service requested by the ATN-defined SN_SME. A VME uses the LMEs (that it creates and destroys) to enquire the quality of service available from peer systems.*

VDL Mode 4 burst *means a VHF digital link (VDL) Mode 4 burst is composed of a sequence of source address, burst ID, information, slot reservation and frame check sequence (FCS) fields, bracketed by opening and closing flag sequences.*

Note.— The start of a burst may occur only at quantized time intervals and this constraint allows the propagation delay between the transmission and reception to be derived.

VDL Mode 4 DLS system *means a VDL system that implements the VDL Mode 4 DLS and subnetwork protocols to carry ATN packets or other packets.*

VDL Mode 4 specific services (VSS) sublayer *means the sublayer that resides above the MAC sublayer and provides VDL Mode 4 specific access protocols including reserved, random and fixed protocols.*

VDL station *means an aircraft-based or ground-based physical entity, capable of VDL Mode 2, 3 or 4.*

Note.— In the context of this Subpart, a VDL station is also referred to as a "station".

Vocoder *means a low bit rate voice encoder/decoder.*

Voice unit *means a device that provides a simplex audio and signaling interface between the user and VDL.*

VSS user *means a user of the VDL Mode 4 specific services. The VSS user could be higher layers in the VDL Mode 4 SARPs or an external application using VDL Mode 4.*

23.3.4.1.2 Radio channels and functional channels

(1) *Aircraft station radio frequency range*. An aircraft station shall be capable of tuning to any of the channels in the range specified in Subpart 23.3.4.1.4(1) within 100 milliseconds after the receipt of an autotune command. In addition, for VDL Mode 3, an aircraft station shall be able to tune to any channel in the range specified in Subpart 23.3.4.1.4(1) within 100 milliseconds after the receipt of any tuning command.

(2) *Ground station radio frequency range*. A ground station shall be capable of operating on its assigned channel within the radio frequency range detailed in 23.3.4.1.4(1)

(3) *Common signalling channel*. Frequency 136.975MHz shall be reserved as a worldwide common signalling channel (CSC) for VDL Mode 2.

23.3.4.1.3 System capabilities

(1) *Data transparency*. The VDL system shall provide code-independent, byte-independent transfer of data.

(2) *Broadcast*. The VDL system shall provide link layer data broadcast services (Mode 2) and/or voice and data broadcast services (Mode 3). For VDL Mode 3, the data broadcast service shall support network multicasting capability originating from the ground.

(3) *Connection management. The VDL system shall establish and maintain a reliable communications path between the aircraft and the ground system while allowing but not requiring manual intervention.*

Note. — In this context "reliable" is defined by the BER requirement specified in 23.3.4.3.3(1).

(4) *Ground network transition. A VDL-equipped aircraft shall transition from one ground station to another when circumstances dictate.*

(5) *Voice capability. The VDL Mode 3 system shall support a transparent, simplex voice operation based on a "Listen-Before-Push-To-Talk" channel access.*

23.3.4.1.4 Air-ground VHF digital link communications system characteristics

(1) *The radio frequencies used shall be selected from the radio frequencies in the band 117.975–137 MHz. The lowest assignable frequency shall be 118.000 MHz, and the highest assignable frequency shall be 136.975 MHz. The separation between assignable frequencies (channel spacing) shall be 25 kHz.*

Note. — Subpart 5 specifies that the block of frequencies from 136.9 – 136.975 MHz inclusive is reserved for VHF air-ground digital communications.

(2) *The design polarization of emissions shall be vertical.*

23.3.4.2 SYSTEM CHARACTERISTICS OF THE GROUND INSTALLATION

23.3.4.2.1 GROUND STATION TRANSMITTING FUNCTION

Frequency stability. The radio frequency of VDL ground station equipment operation shall not vary more than plus or minus 0.0002 per cent (2 parts per million) from the assigned frequency.

Note. — The frequency stability for VDL ground stations using DSB-AM modulation is specified in Part II this Subpart, Subpart 2 for 25 kHz channel spacing.

23.3.4.2.2 POWER

The effective radiated power shall be such as to provide a field strength of at least 75 microvolts per metre (minus 109 dBW/m^2) within the defined operational coverage of the facility, on the basis of free-space propagation.

23.3.4.2.3 SPURIOUS EMISSIONS

Spurious emissions shall be kept at the lowest value which the state of the technique and the nature of the service permit.

Note.— Appendix S3 to the Radio Regulations specifies the levels of spurious emissions to which transmitters must conform.

23.3.4.2.4 ADJACENT CHANNEL EMISSIONS

(1) The amount of power from a VDL ground transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the first adjacent channel shall not exceed 0 dBm.

(2) After 1 January 2002, the amount of power from all new installations of a

VDL ground transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the first adjacent channel shall not exceed 2 dBm.

(3) The amount of power from a VDL ground transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the second adjacent channel shall be less than minus 25 dBm and from thereon it shall monotonically decrease at the minimum rate of 5 dB per octave to a maximum value of minus 52 dBm.

(4) After 1 January 2002, the amount of power from all new installations of a VDL ground transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the second adjacent channel shall be less than minus 28 dBm.

(5) After 1 January 2002, the amount of power from all new installations of a VDL ground transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the fourth adjacent channel shall be less than minus 38 dBm, and from thereon it shall monotonically decrease at the minimum rate of 5 dB per octave to a maximum value of minus 53 dBm.

(6) The amount of power from a VDL ground transmitter under all operating conditions when measured over a 16 kHz channel bandwidth centred on the first adjacent channel shall not exceed minus 20 dBm.

(7) After 1 January 2002, the amount of power from all new installations of a VDL ground transmitter under all operating conditions when measured over a 16 kHz channel bandwidth centred on the first adjacent channel shall not exceed minus 18 dBm.

(8) After 1 January 2005, all VDL ground transmitters shall meet the provisions of 23.3.4.2.4(2), 23.3.4.2.4(4), 23.3.4.2.4(5) and 23.3.4.2.4(7), subject to the conditions of 23.3.4.2.4(9).

(9) Requirements of mandatory compliance of the provisions of 23.3.4.2.4(8) shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales. The agreements shall provide at least two years' notice of mandatory compliance of ground systems.

23.3.4.3 SYSTEM CHARACTERISTICS OF THE AIRCRAFT INSTALLATION

(1) *Frequency stability*. The radio frequency of VDL aircraft equipment shall not vary more than plus or minus 0.0005 per cent (5 parts per million) from the assigned frequency.

(2) *Power*. The effective radiated power shall be such as to provide a field strength of at least 20 microvolts per metre (minus 120 dBW/m^2) on the basis of free-space propagation, at ranges and altitudes appropriate to the operational conditions pertaining to the areas over which the aircraft is operated.

23.3.4.3.1 SPURIOUS EMISSIONS

Spurious emissions shall be kept at the lowest value which the state of the technique and the nature of the service permit.

Note. — Appendix S3 to the Radio Regulations specifies the levels of spurious emissions to which transmitters must conform.

23.3.4.3.2 ADJACENT CHANNEL EMISSIONS

(1) The amount of power from a VDL aircraft transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the first adjacent channel shall not exceed 0 dBm.

(2) After 1 January 2002, the amount of power from all new installations of a VDL aircraft transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the first adjacent channel shall not exceed 2 dBm.

(3) The amount of power from a VDL aircraft transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the second adjacent channel shall be less than minus 25 dBm and from thereon it shall monotonically decrease at the minimum rate of 5 dB per octave to a maximum value of minus 52 dBm.

(4) After 1 January 2002, the amount of power from all new installations of a VDL aircraft transmitter under all operating conditions when measured

over the 25 kHz channel bandwidth of the second adjacent channel shall be less than minus 28 dBm.

(5) After 1 January 2002, the amount of power from all new installations of a VDL aircraft transmitter under all operating conditions when measured over the 25 kHz channel bandwidth of the fourth adjacent channel shall be less than minus 38 dBm, and from thereon it shall monotonically decrease at the minimum rate of 5 dB per octave to a maximum value of minus 53 dBm.

(6) The amount of power from a VDL aircraft transmitter under all operating conditions when measured over a 16 kHz channel bandwidth centred on the first adjacent channel shall not exceed minus 20 dBm.

(7) After 1 January 2002, the amount of power from all new installations of a VDL aircraft transmitter under all operating conditions when measured over a 16 kHz channel bandwidth centred on the first adjacent channel shall not exceed minus 18 dBm.

(8) After 1 January 2005, all VDL aircraft transmitters shall meet the provisions of 23.3.4.3.4(2), 23.3.4.3.4(4), 23.3.4.3.4(5) and 23.3.4.3.4(7), subject to the conditions of 23.3.4.3.4(9).

(9) Requirements of mandatory compliance of the provisions of 23.3.4.3.4(8) shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales. The agreements shall provide at least two years' notice of mandatory compliance of aircraft systems.

23.3.4.3.3 RECEIVING FUNCTION

(1) *Specified error rate*. The specified error rate for Mode 2 operation shall be the maximum corrected Bit Error Rate (BER) of 1 in 10^4. The specified error rate for Mode 3 operation shall be the maximum uncorrected BER of 1 in 10^3. The specified error rate for Mode 4

operation shall be the maximum uncorrected BER of 1 in 10^4.

Note. — The above physical layer BER requirements are derived from the BER requirement imposed by ATN at the subnetwork interface.

(2) *Sensitivity*. The receiving function shall satisfy the specified error rate with a desired signal strength of not more than 20 microvolts per metre (minus 120 dBW/m^2).

Note. — The required signal strength at the edge of the service Subpart takes into account the requirements of the system and signal losses within the system, and considers environmental noise sources.

(3) *Out-of-band immunity performance. The receiving function shall satisfy the specified error rate with a desired signal field strength of not more than 40 microvolts per metre (minus 114 dBW/m2) and with an undesired DSB-AM D8PSK or GFSK signal on the adjacent or any other assignable channel being at least 40 dB higher than the desired signal.*

(4) *After 1 January 2002, the receiving function of all new installations of VDL shall satisfy the specified error rate with a desired signal field strength of not more than 40 microvolts per metre (minus 114 dBW/m2) and with an undesired VHF DSB-AM, D8PSK or GFSK signal at least 60 dB higher than the desired signal on any assignable channel 100 kHz or more away from the assigned channel of the desired signal.*

Note. — This level of interference immunity performance provides a receiver performance consistent with the influence of the VDL RF spectrum mask as specified in 6.3.4 with an effective isolation transmitter/receiver isolation of 69 dB. Better transmitter and receiver performance could result in less isolation required. Guidance material on the measurement technique is included in the Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of approved ICAO policies (Doc 9718).

(5) *After 1 January 2005, the receiving function of all installations of VDL shall meet the provisions of 23.3.4.3.3(4), subject to the conditions of 23.3.4.3.3(6).*

(6) Requirements of mandatory compliance of the provisions of 23.3.4.3.3(5) shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales. The agreement shall provide for at least two years' notice of mandatory compliance of aircraft systems.

23.3.4.3.3.1 INTERFERENCE IMMUNITY PERFORMANCE

(1) The receiving function shall satisfy the specified error rate with a desired field strength of not more than 40 microvolts per metre, and with one or more out-of-band signals, except for VHF FM broadcast signals, having a total level at the receiver input of minus 33 dBm.

Note. — In areas where adjacent higher band signal interference exceeds this specification, a higher immunity requirement will apply.

(2) The receiving function shall satisfy the specified error rate with a desired field strength of not more than 40 microvolts per metre, and with one or more VHF FM broadcast signals having a total level at the receiver input of minus 5 dBm.

23.3.4.4 PHYSICAL LAYER PROTOCOLS AND SERVICES

The aircraft and ground stations shall access the physical medium operating in simplex mode.

23.3.4.4.1 FUNCTIONS

(1) The physical layer shall provide the following functions:

(a) transmitter and receiver frequency control;
(b) digital reception by the receiver;
(c) digital transmission by the transmitter; and
(d) notification services.

(2) Transmitter/receiver frequency control. The VDL physical layer shall set the transmitter or receiver frequency as commanded by the link management entity (LME).

Note.— The LME is a link layer entity as contained in the Manuals on VDL Mode 2 and VDL Mode 3 Technical Specifications.

(3) Digital reception by the receiver. The receiver shall decode input signals and forward them to the higher layers for processing.

(4) Digital transmission. The VDL physical layer shall appropriately encode and transmit information received from higher layers over the RF channel.

23.3.4.4.2 MODES 2 AND 3 COMMON PHYSICAL LAYER

(1) *Modulation scheme.* Modes 2 and 3 shall use differentially encoded 8 phase shift keying (D8PSK), using a raised cosine filter with α = 0.6 (nominal value). The information to be transmitted shall be differentially encoded with 3 bits per symbol (baud) transmitted as changes in phase rather than absolute phase. The data stream to be transmitted shall be divided into groups of 3 consecutive data bits, least significant bit first. Zeros shall be padded to the end of the transmissions if needed for the final channel symbol.

(2) *Data encoding.* A binary data stream entering a differential data encoder shall be converted into three separate binary streams X, Y, and Z so that bits 3n form X, bits 3n + 1 form Y, and bits 3n + 2 form Z. The triplet at time k (X_k, Y_k, Z_k) shall be converted to a change in phase as shown in Table 6-1**, and the absolute phase ϕ_k is the accumulated series of $\Delta\phi_k$, that is:

$$\phi_k = \phi_{k-1} + \Delta\phi_k$$

(3) *Transmitted signal form.* The phase-modulated baseband signal as defined in 23.3.4.4.2(2) shall excite the pulse shape filter.

$$s(t) = \sum_{k=-\infty}^{+\infty} h(\phi_k, t - kT_s)$$

** All tables are located at the end of this chapter.

where:

h is the complex impulse response of the pulse shape filter;
k is defined in 23.3.4.4.2(2).
is defined by the equation in 23.3.4.4.2(2);
t is time;
T_S is time duration of each symbol.

The output (function of time) of the pulse shape filter (s(t)) shall modulate the carrier frequency. The pulse shape filter shall have a nominal complex frequency response of a raised-cosine filter with α =0.6.

(4) *Modulation rate*. The symbol rate shall be 10 500 symbols/second, resulting in a nominal bit rate of 31 500 bits/s. The modulation stability requirements for Modes 2 and 3 are provided in Table 6-2.

23.3.4.4.3 MODE 2 SPECIFIC PHYSICAL LAYER

Note. — The Mode 2 specific physical layer specification includes a description of the Mode 2 training sequence, forward error correction (FEC), interleaving, bit scrambling, channel sensing, and physical layer system parameters.

(1) To transmit a sequence of frames, a station shall insert the bit numbers and flags (per the data link service description for Mode 2 as contained in the Manual on VDL Mode 2 Technical Specifications), compute the FEC (per 23.3.4.4.3(10)), interleave (per 23.3.4.4.3(17)), prepend the training sequence (per 23.3.4.4.3(2)), carry out bit scrambling (per 23.3.4.4.3(18)) and finally encode and modulate the RF signal (per 23.3.4.4.2(1)).

(2) *Training sequence*. Data transmission shall begin with a demodulator training sequence consisting of five segments:

(a) transmitter ramp-up and power stabilization;

(b) synchronization and ambiguity resolution;

(c) reserved symbol;

(d) transmission length; and

(e) header FEC.

Note.— Immediately after these segments follows an AVLC frame with the format as contained in the data link service description in the Manual on VDL Mode 2 Technical Specifications.

(3) *Transmitter ramp-up and power stabilization*. The purpose of the first segment of the training sequence, called the ramp-up, is to provide for transmitter power stabilization and receiver AGC settling, and it shall immediately precede the first symbol of the unique word. The duration of the ramp-up shall be five symbol periods. The time reference point (t), for the following specification is the centre of the first unique word symbol, a point that occurs half a symbol period after the end of the ramp-up. Conversely stated, the beginning of the ramp-up starts at t = –5.5 symbol periods. The transmitted power shall be less than –40 dBc prior to time t = –5.5 symbol periods. The ramp-up shall provide that at time t = –3.0 symbol periods the transmitted power is 90 per cent of the manufacturer's stated output power or greater (see Figure 6-1**). Regardless of the method used to implement (or truncate) the raised cosine filter, the output of the transmitter between times t = –3.0 and t = –0.5 will appear as if '000' symbols were transmitted during the ramp-up period.

Note. 1.— For Mode 3, the timing reference point is the same as the "power reference point".

Note 2.— It is desirable to maximize the time allowed for the AGC settling time. Efforts shall be made to have power above 90 per cent of nominal output power at – 3.5 symbol periods.

(4) Synchronization and ambiguity resolution. The second segment of the training sequence shall consist of the unique word:
000 010 011 110 000 001 101 110 001 100 011 111 101 111 100 010

** All figures are located at the end of this chapter.

and shall be transmitted from left to right.

(5) Reserved symbol. The third segment of the training sequence shall consist of the single symbol representing 000.

Note.— This field is reserved for future definition.

(6) *Transmission length. To allow the receiver to determine the length of the final Reed-Solomon block, the transmitter shall send a 17-bit word, from least significant bit (lsb) to most significant bit (msb), indicating the total number of data bits that follow the header FEC.*

(7) *Note.— The length does not include those bits transmitted for: the Reed Solomon FEC, extra bits padded to ensure that the interleaver generates an integral number of 8-bit words, or the extra bits padded to ensure that the data encoder generates an integral number of 3-bit symbols.*

(8) *Header FEC. To correct bit errors in the header, a (25, 20) block code shall be computed over the reserved symbol and the transmission length segments. The block code shall be transmitted as the fifth segment. The encoder shall accept the header in the bit sequence that is being transmitted. The five parity bits to be transmitted shall be generated using the following equation:*

[P1 , ... , P5] = [R1 , ... , R3 , TL1 , ... , TL17] HT

where:

P is the parity symbol (P1 shall be transmitted first); R is the reserved symbol;
TL is the transmission Length symbol;

T is the matrix transpose function; and

H is the parity matrix defined below:

$$H = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \end{bmatrix}$$

(9) *Bit transmission order. The five parity bits of the resultant vector product shall be transmitted from the left bit first.*

(10) *Forward error correction. In order to improve the effective channel throughput by reducing the number of required retransmissions, FEC shall be applied after the training sequence, regardless of frame boundaries.*

(11) *FEC calculation. The FEC coding shall be accomplished by means of a systematic fixed-length Reed- Solomon (RS)(255,249) 28-ary code.*

Note 1.— This code is capable of correcting up to three octets for data blocks of 249 octets (1992 bits). Longer transmissions must be divided up into 1992 bit transmissions and shorter transmissions must be extended by virtual fill with trailing zeros. Six RS-check octets are appended for a total block of 255 octets.

The field defining the primitive polynomial of the code shall be as follows:

p(x) = (x8 + x7 + x2 + x + 1)

The generator polynomial shall be as follows:

where:

$$\prod_{i=120}^{125} (x - \alpha^i)$$

a is a primitive element of GF(256);

GF(256) is a Galois field (GF) of size 256.

Note 2.— The Reed-Solomon codes are described in the Recommendation for Space Data System Standards Telemetry Channel Coding, by the Consultative Committee for Space Data Systems (see the IS: 23.3.4.4.3).

(12) *lengths. The six RS-check octets shall be calculated on blocks of 249 octets. Longer transmissions shall be split into blocks of 249 octets, per 23.3.4.4.3(17). Blocks of shorter length shall be extended to 249 octets by a virtual fill of trailing zeros. The virtual fill shall not be transmitted. Blocks shall be coded according to 23.3.4.4.3(13) through 23.3.4.4.3(16).*

(13) *No error correction. For blocks with 2 or fewer non-fill octets, no error correction shall be used.*

(14) *Single-byte error correction. For blocks with 3 to 30 non-fill octets, all six RS-check octets shall be generated, but only the first two shall be transmitted. The last four RS-check octets shall be treated as erasures at the decoder.*

(15) *Two-byte error correction. For blocks with 31 to 67 non-fill octets, all six RS-check octets shall be generated, but only the first four shall be transmitted. The last two RS-check octets shall be treated as erasures at the decoder.*

(16) *Three-byte error correction. For blocks with 68 or more non-fill octets, all six RS-check octets shall be generated and transmitted.*

(17) *Interleaving. To improve the performance of the FEC, an octet-based table-driven interleaver shall be used. The interleaver shall create a table having 255 octets per row a*nd c rows, where

$$c = \frac{transmission\ length\ (bits)}{1992\ (bits)}$$

where:

a) the transmission length is as defined in 23.3.4.4.3(8); and

b) *c* = the smallest integer greater than or equal to the value of the fraction.

After extending the data to an even multiple of 1992 bits, the interleaver shall write the transmission stream into the first 249 octets of each row by taking each consecutive group of

eight bits and storing them from the first column to the 249th. The first bit in each group of eight bits shall be stored in the eighth bit position; the first group of 1992 bits shall be stored in the first row, the second group of 1992 bits in the second row, etc. After the FEC is computed on each row, the FEC data (or erasures) shall be stored in columns 250 through 255. The interleaver shall then pass the data to the scrambler by reading out column by column, skipping any octet which contains erasures or all fill bits. All of the bits in an octet shall be transmitted from bit 8 to bit 1.

On reception, the de-interleaver shall calculate the number of rows and size of the last (potentially partial) row from the length field in the header. It shall only pass valid data bytes to the higher layer.

(18) *Bit scrambling*. To aid clock recovery and to stabilize the shape of the transmitted spectrum, bit scrambling shall be applied. The pseudo noise (PN) sequence shall be a 15-stage generator (see Figure 6-2) with the characteristic polynomial:

$$X^{15} + X + 1$$

The PN-sequence shall start after the frame synchronization pattern with the initial value 1101 0010 1011 001 with the left- most bit in the first stage of the register as per Figure 6-2. After processing each bit, the register shall be shifted one bit to the right. For possible encryption in the future this initial value shall be programmed. The sequence shall be added (modulo 2) to the data at the transmit side (scrambling) and to the scrambled data at the receive side (descrambling) per Table 6-3.

Note.— The concept of a PN scrambler is explained in ITU-R Recommendation S.446-4, Annex I, Section 4.3.1, Method 1 (see the IS: 23.3.4.4.3.1.2.1 to this Subpart).

23.3.4.4.3.1 MODE 2 CHANNEL SENSING

(1) *Channel busy to idle detection*. When a station receives on-channel power of at least –87 dBm for at least 5 milliseconds, then:

(a) with a likelihood of 0.9, it shall continue to consider the channel occupied if the signal level is attenuated to below -92 dBm for less than 1 millisecond; and

(b) with a likelihood of 0.9, it shall consider the channel unoccupied if the signal level is attenuated to below –92 dBm for at least 1.5 milliseconds.

Note.— The maximum link throughput available to all users is highly sensitive to the RF channel sense delay (from the time when the channel actually changes state until a station detects and acts on that change) and RF channel seizure delay (from the time when a station decides to transmit until the transmitter is sufficiently ramped up to lock out other stations). Accordingly, it is imperative that all efforts are made to reduce those times as the state-of-the-art advances.

(2) Channel idle to busy detection. With a likelihood of at least 0.9, a station shall consider the channel occupied within 1 millisecond after on-channel power rises to at least –90 dBm.

(3) The detection of an occupied channel shall occur within 0.5 milliseconds.

Note.— A higher probability of false alarm is acceptable on the idle to busy detection than the busy to idle detection because of the effects of the two different errors.

23.3.4.4.3.2 MODE 2 RECEIVER/TRANSMITTER INTERACTION

(1) *Receiver to transmitter turnaround time*. A station shall transmit the training sequence such that the centre of the first symbol of the unique word will be transmitted within 1.25 milliseconds after the result of an access attempt is successful (see Figure 6-3). The total frequency change during the transmission of the unique word shall be less than 10 Hz. After transmission of the unique word, the phase acceleration shall be less than 500 Hz per second.

(2) *Transmitter to receiver turnaround time*. The transmitter power shall be –20 dBc within 2.5 symbol periods of the middle of the final symbol of the burst. The transmitter power leakage when the transmitter is in the "off" state shall be less than –83 dBm. A station shall be capable of

receiving and demodulating with nominal performance, an incoming signal within 1.5 milliseconds after transmission of the final information symbol.

Note.— Reference DO-160D section 21, category H for antenna radiated signals.

23.3.4.4.3.3 MODE 2 PHYSICAL LAYER SYSTEM PARAMETERS

(1) *The physical layer shall implement the system parameters as defined in Table 6-4.*

(2) *Parameter P1 (minimum transmission length). Parameter P1 defines the minimum transmission length that a receiver shall be capable of demodulating without degradation of BER.*

23.3.4.4.4 Mode 3 specific physical layer

Note.— The Mode 3 specific physical layer specification includes a description of Mode 3 management (M) burst and handoff check message (H) burst uplink, M burst downlink, voice/data (V/D) burst, and bit scrambling.

(1) *Management (M) burst and handoff check message (H) burst uplink*. The M uplink burst (as contained in the Manual on VDL Mode 3 Technical Specifications) shall consist of three segments, the training sequence followed by the system data and the transmitter ramp down. The H uplink burst (as contained in the Manual on VDL Mode 3 Technical Specifications) shall consist of three segments, the training sequence followed by the handoff check message and the transmitter ramp down.

(2) *Training sequence*. Uplink M burst and H burst training sequences shall consist of two components as follows:

(a) transmitter ramp up and power stabilization; and

(b) synchronization and ambiguity resolution.

(3) *Transmitter ramp-up and power stabilization*. This shall be as defined in

Subpart 23.3.4.4.3(3).

(4) *Synchronization and ambiguity resolution*. The second component of the training sequence shall consist of the synchronization sequence, known as S_2*, as follows:

000 001 101 100 110 010 111 100 010 011 101 000 111 000

011 001 and shall be transmitted from left to right.

Note. — The sequence S_2 is very closely related to the sequence S_2 (Subpart 23.3.4.4.4(4)) . The 15 phase changes between the 16 symbols of S_2* are each exactly 180^o out of phase from the 15 phase changes associated with S_2 . This relationship can be used to simplify the process of simultaneously searching for both sequences.*

(5) *System data and handoff check message*. The non-3T configuration (as contained in the Manual on VDL Mode 3 Technical Specifications) system data shall consist of 32 transmitted symbols. The 96 transmitted bits shall include 48 bits of information and 48 parity bits, generated as 4 Golay (24, 12) code words. The 3T configuration as contained in the Manual on VDL Mode 3 Technical Specifications shall consist of 128 transmitted symbols. The 384 transmitted bits shall include 192 bits of information and 192 parity bits, generated as 16 Golay (24, 12) code words. The 3T configuration handoff check message shall consist of 40 transmitted symbols. The 120 transmitted bits shall include 60 bits of information and 60 parity bits, generated as 5 Golay (24,12) code words.

The specific definition of the Golay encoder shall be as follows:

If the 12 bit input bit sequence is written as a row vector **x**, then the 24 bit output sequence can be written as the row vector **y**, where **y = x G**, and the matrix **G** shall be given by

G =

1	1	0	1	0	1	1	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0
0	1	1	1	1	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
1	1	1	0	1	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0
0	1	1	0	0	0	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
1	1	1	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1	0	1	1	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0
1	0	0	1	1	0	0	1	1	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0

0 1 0 1 1 0 1 1 1 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0
0 0 1 0 1 1 0 1 1 1 1 0 0 0 0 0 0 0 0 0 1 0 0 0
0 0 0 1 0 1 1 0 1 1 1 1 0 0 0 0 0 0 0 0 0 1 0 0
1 1 0 1 1 1 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 1 0
1 0 1 0 1 1 1 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 1

Note. — The extended Golay code allows for the correction of any error pattern with 3 or fewer bit errors and the detection of any 4-bit error pattern.

(6) *Transmitter ramp-down.* The transmitter power shall be –20 dBc within 2.5 symbol periods of the middle of the final symbol of the burst. The transmitter power leakage when the transmitter is in the "off" state shall be less than -83 dBm.

Note. — Reference RTCA/DO-160D section 21, category H for antenna radiated signals.

(7) *Management (M) burst downlink*. The M downlink burst (as contained in the Manual on VDL Mode 3Technical Specifications) shall consist of three segments, the training sequence followed by the system data and the transmitter ramp down.

(8) *Training sequence*. The M downlink burst training sequence shall consist of two components as follows:

(a) transmitter ramp up and power stabilization; and

(b) synchronization and ambiguity resolution.

(9) *Transmitter ramp-up and power stabilization***.** This shall be as defined in 23.3.4.4.3(3).

(10) *Synchronization and ambiguity resolution*. Three separate synchronization sequences shall be used for this burst type. The standard sequence, known as S_1, shall be as follows:

000 111 001 001 010 110 000 011 100 110 011 111 010 101 100 101

and shall be transmitted from left to right. The special sequence used to identify poll responses shall be as defined in 23.3.4.4.3(4).

The special sequence used to identify net entry requests (S_1*) shall use the following sequence:

000 001 111 111 100 000 110 101 010 000 101 001 100 011

010 011 and shall be transmitted from left to right.

Note. — The sequence S_1 is very closely related to the sequence S_1. The 15 phase changes between the 16 symbols of S_1* are each exactly 180^o out of phase from the 15 phase changes associated with S_1. This relationship can be used to simplify the process of simultaneously searching for both sequences.*

(11) *System data*. The system data segment shall consist of 16 transmitted symbols. The 48 transmitted bits shall be encoded as 24 bits of system data and 24 bits of parity bits generated as two consecutive (24, 12) Golay code words. The encoding of the (24, 12) Golay code words shall be as defined in 23.3.4.4.4(5)

(12) *Transmitter ramp-down*. This shall be as defined in 23.3.4.4.4(6).

(13) *Voice or data (V/D) burst*. The V/D burst (as contained in the Manual on VDL Mode 3 Technical Specifications) shall consist of four segments: the training sequence followed by the header, the user information segment and the transmitter ramp down. The same V/D burst format shall be used for both uplink and downlink.

(14) *Training sequence*. V/D burst training sequence shall consist of two components as follows:

(a) transmitter ramp-up and power stabilization; and

(b) synchronization and ambiguity resolution.

(15) *Transmitter ramp-up and power stabilization*. This shall be as specified in 23.3.4.4.3(3).

(16) *Synchronization and ambiguity resolution*. The second component of the training sequence shall consist of the synchronization sequence, known as S_2, as follows:

000 111 011 010 000 100 001 010 100 101 011 110 001

110 101 111 and shall be transmitted from left to right.

(17) *Header*. The header segment shall consist of 8 transmitted symbols. The 24 transmitted bits shall be encoded as 12 bits of header information and 12 parity bits, generated as a single (24, 12) Golay code word. The encoding of the (24, 12) Golay code word shall be as defined in 23.3.4.4.4(5).

(18) *User information*. The user information segment shall consist of 192 3-bit symbols. When transmitting voice, FEC shall be applied to the analysis output of the vocoder specified in 6.8. The vocoder shall provide satisfactory performance in a BER environment of 10^{-3} (with a design goal of 10^{-2}). The overall bit rate of the vocoder *including FEC* is 4 800 bits/s (except when in the truncated mode in which the bit rate is 4 000 bits/s).

(19) When transmitting user data, the 576 bits shall be encoded as a single Reed-Solomon (72, 62) 2^8–ary code word. For user data input to the Reed-Solomon encoder of length less than 496 bits, input data shall be padded with zeroes at the end to a full length of 496 bits. The field defining the primitive polynomial of the code shall be as described in 23.3.4.4.3(11). The generator polynomial shall be as follows:

$$\prod_{i=120}^{129} (x - \alpha^i)$$

Note.— The Reed-Solomon (72, 62) code is capable of correcting up to five 2^8-ary (code word) symbol errors in the received word.

(20) *Transmitter ramp-down*. This shall be as defined in 23.3.4.4.4.1.3.

(21) *Interleaving*. There shall be no interleaving in Mode 3 operation.

(22) *Bit scrambling.* Under Mode 3 operation, bit scrambling, as specified in 23.3.4.4.3(18) shall be performed on each burst, starting after the training sequence. The scrambling sequence shall be reinitialized on each burst effectively providing a constant overlay for each of the Mode 3 fixed length bursts.

(23) *Receiver/transmitter interaction.* The switching times in this subsection will be defined as the time between the middle of the last information symbol of one burst and the middle of the first symbol of the synchronization sequence of the subsequent burst.

Note.— This nominal time will be shortened by considerations such as the finite width of each symbol due to Nyquist filtering and the ramp up and power stabilization sequence. Such alternative definitions could yield switching times up to 8 symbol periods shorter.

(24) *Receiver to transmitter switching time.* An aircraft radio shall be capable of switching from reception to transmission within 17 symbol periods. This time can be relaxed to 33 symbol periods for aircraft radios which do not implement functions requiring discrete addressing.

Note 1.— The shortest R/T switching time for an aircraft radio occurs when the reception of an uplink M channel beacon is followed by a V/D transmission in the same slot. In certain instances where aircraft radios do not implement functions requiring discrete addressing, the R/T switching time can be increased since the last two Golay words of the uplink M channel beacon need not be read.

Note 2.— The minimum turnaround time assumes that in configurations 3V1D, 2V1D, and 3T (as contained in Section 5.5.2.4 of the Manual on VDL Mode 3 Technical Specifications), the aircraft radios will be provided with software that will prevent them from transmitting a downlink M channel message in a slot following the reception of a voice message from another aircraft with a long time delay.

(25) *Transmitter to receiver switching time.* An aircraft radio shall be capable of switching from transmission to reception within 32 symbol periods.

Note.— The worst case T/R switching time for an aircraft radio occurs

when it transmits a downlink M channel message and receives a V/D message in the same slot.

23.3.4.4.4.1 FRINGE COVERAGE INDICATION

Indication of near edge-of-coverage shall be provided to the VDL Mode 3 aircraft.

23.3.4.5 LINK LAYER PROTOCOLS AND SERVICES

23.3.4.5.1 GENERAL INFORMATION

(1) *Functionality*. The VDL link layer shall provide the following sublayer functions:

(a) media access control (MAC) sublayer, which requires the use of the carrier sense multiple access (CSMA) algorithm for Mode 2 or TDMA for Mode 3;

(b) a data link service (DLS) sublayer:

(a) for Mode 2, the DLS sublayer provides connection-oriented point-to-point links using data link entities (DLE) and connectionless broadcast link over the MAC sublayer; and

(i) for Mode 3, the DLS sublayer provides acknowledged connectionless point-to-point and point-to-multipoint links over a MAC sublayer that guarantees sequencing; and

(ii) a VDL management entity (VME), which establishes and maintains DLEs between the aircraft and the ground-based systems using link management entities (LME).

23.3.4.5.1.1 SERVICE

(1) Connection-oriented. The VDL Mode 2 link layer shall provide a reliable point-to-point service using a connection-oriented DLS

sublayer.

(2) Connectionless. The VDL Mode 2 and 3 link layers shall provide an unacknowledged broadcast service using a connectionless DLS sublayer.

(3) Acknowledged connectionless. The VDL Mode 3 link layer shall provide an acknowledged point-to-point service using a connectionless DLS sublayer that relies upon the MAC sublayer to guarantee sequencing.

23.3.4.5.2 MAC SUBLAYER

The MAC sublayer shall provide for the transparent acquisition of the shared communications path. It makes invisible to the DLS sublayer the way in which supporting communications resources are utilized to achieve this.

Note. — Specific MAC services and procedures for VDL Modes 2 and 3 are contained in the Manuals on VDL Mode 2 and VDL Mode 3 Technical Specifications.

23.3.4.5.3 DATA LINK SERVICE SUBLAYER

(1) For Mode 2, the DLS shall support bit-oriented simplex air-ground communications using the aviation VHF link control (AVLC) protocol.

Note. — Specific data link services, parameters and protocol definitions for VDL Mode 2 are contained in the Manual on VDL Mode 2 Technical Specifications.

(2) For Mode 3, the DLS shall support bit-oriented, priority based, simplex air-ground communications using the acknowledged connectionless data link (A-CLDL) protocol.

Note. — Specific data link services, parameters and protocol definitions for VDL Mode 3 are contained in the Manual on VDL Mode 3 Technical Specifications.

23.3.4.5.4 VDL MANAGEMENT ENTITY

Services. The VME shall provide link establishment, maintenance and disconnection services as well as support parameter modification. Specific VME services, parameter formats and procedures for Modes 2 and 3 are contained in the Manuals on VDL Mode 2 and Mode 3 Technical Specifications.

23.3.4.6 SUBNETWORK LAYER PROTOCOLS AND SERVICES

23.3.4.6.1 ARCHITECTURE FOR MODE 2

The subnetwork layer protocol used across the VHF air-ground subnetwork for VDL Mode 2 is referred to formally as a subnetwork access protocol (SNAcP) and shall conform to ISO 8208, except as contained in the Manual on VDL Mode 2 Technical Specifications. The SNAcP is contained within the Manual on VDL Mode 2 Technical Specifications as the subnetwork protocol. If there are any differences between the Manual on VDL Mode 2 Technical Specifications and the cited specifications, the Manual on VDL Mode 2 Technical Specifications shall have precedence. On the air-ground interface, the aircraft subnetwork entity shall act as a DTE and the ground subnetwork entity shall act as a DCE.

Note. — Specific subnetwork layer protocol access points, services, packet formats, parameters and procedures for VDL Mode 2 are contained in the Manual on VDL Mode 2 Technical Specifications.

23.3.4.6.2 ARCHITECTURE FOR MODE 3

The subnetwork layer used across the VHF air-ground subnetwork for VDL Mode 3 provides the flexibility to simultaneously support multiple subnetwork protocols. The currently defined options are to support ISO 8473 connectionless network protocol and to support ISO 8208, both as contained in the Manual on VDL Mode 3 Technical Specifications. The Manual on VDL Mode 3 Technical Specifications shall have precedence with respect to any differences with the cited specifications. For the ISO 8208 interface, both the air and ground subnetwork entities shall act as DCEs.

Note. — Specific subnetwork layer protocol access points, services, packet formats, parameters and procedures for VDL Mode 3 are contained in the Manual on VDL Mode 3 Technical Specifications.

23.3.4.7 THE VDL MOBILE SUBNETWORK DEPENDENT CONVERGENCE FUNCTION (SNDCF)

23.3.4.7.1 VDL MODE 2 SNDCF

(1) *Introduction*. The VDL Mode 2 mobile SNDCF shall be the standard mobile SNDCF.

(2) *New function*. The VDL Mode 2 mobile SNDCF shall support maintaining context (e.g. compression tables) across subnetwork calls. The SNDCF shall use the same context (e.g. compression tables) across all SVCs negotiated to a DTE, when negotiated with the same parameters. The SNDCF shall support at least 2 SVCs sharing a context.

Note 1.— Because handoffs can be expected to reorder packets, certain compression algorithms do not lend themselves to use over VDL Mode 2. Further, implementors of dictionary-based compression algorithms must be sensitive to the problem of updates arriving on either the old or newly established call.

Note 2.— The encoding of the Call User Data field is described in Doc 9705 except with modifications as contained in the Manual on VDL Mode 2 Technical Specifications.

23.3.4.7.2 VDL Mode 3 SNDCF

The VDL Mode 3 shall support one or more of the defined SNDCFs. The first is the standard ISO 8208 SNDCF as defined in Doc 9705. This is a connection-oriented SNDCF. The second type of SNDCF supported by VDL Mode 3 is denoted frame-based SNDCF. The details of this connectionless oriented SNDCF are contained in the Manual on VDL Mode 3 Technical Specifications, including network layer interface, support for broadcast and unicast network packets, and ATN router support.

Note. — The framed-based SNDCF is termed such because it uses the

VDL Mode 3 frames without the need for an additional protocol (viz. ISO 8208 SNDCF) to transfer network packets. The frame-based SNDCF achieves independence from the network protocol by identifying the payload of each frame. Upon receipt of a frame, the payload is examined and control is passed to the protocol identified.

23.3.4.8 VOICE UNIT FOR MODE 3

23.3.4.8.1 SERVICES

(1) The voice unit shall provide for a simplex, "push-to-talk" audio and signalling interface between the user and the VDL. Two separate mutually exclusive voice circuit types shall be supported:

(a) Dedicated circuits: This shall provide service to a specific user group on an exclusive basis with no sharing of the circuit with other users outside the group. Access shall be based on a "listen-before-push-to-talk" discipline.

(b) Demand assigned circuits: This shall provide voice circuit access which is arbitrated by the ground station in response to an access request received from the aircraft station. This type of operation shall allow dynamic sharing of the channel resource increasing trunking efficiency.

(2) *Priority access*. The voice unit operation shall support a priority override access for authorized ground users.

(3) *Message source identification*. The voice unit operation shall support notification to the user of the source of a received message (i.e. whether the message originated from an air or ground station).

(4) *Coded squelch*. The voice unit shall support a coded squelch operation that offers some degree of rejection of undesired co-channel voice messages based on the burst time of arrival.

23.3.4.8.2 SPEECH ENCODING, PARAMETERS AND PROCEDURES

(1) The VDL Mode 3 shall use the advanced multiband excitation (AMBE) 4.8 kbits/s encoding/decoding algorithm, version number

AMBE-ATC-10, developed by Digital Voice Systems, Incorporated (DVSI) for voice communications.

Note 1.— Information on technical characteristics of the 4.8 kbits/s AMBE algorithm is contained in AMBE-ATC-10 Low Level Description, obtainable from DVSI.

Note 2.— The 4.8 kbits/s AMBE encoding/decoding technology described in the document is subject to DVSI patent rights and copyrights. Manufacturers must enter into a license agreement with DVSI prior to obtaining a detailed description of the algorithm before incorporation in equipment operating in the VDL Mode 3 service. By letter to ICAO dated 29 October 1999, DVSI confirmed its commitment to license the technology for the manufacture and sale of aeronautical equipment under reasonable terms and conditions, negotiated on a non-discriminatory basis.

(2) Speech encoding definition, voice unit parameters, and procedure descriptions for VDL Mode 3 Voice Unit operation are contained in the Manual on VDL Mode 3 Technical Specifications.

23.3.4.9 VDL MODE 4

A Mode 4 station shall conform to the requirements defined in 23.3.4.1.2(3), 23.3.10.1.2.5(1), 23.3.4.2.1(1), 23.3.10.1.2.4(1), 23.3.4.2.4, 23.3.4.3(1), 23.3.4.3.1(1), 23.3.4.3.2, 23.3.4.3.3(1), 23.3.4.3.3(2), 23.3.4.3.3(3), 23.3.4.3.3.1(1) and 23.3.4.9.

23.3.4.9.1 VDL MODE 4 RADIO CHANNELS

23.3.4.9.1.1 VDL MODE 4 STATION FREQUENCY RANGE

(1) *Transmitter/receiver tuning range.* A VDL Mode 4 transmitter/receiver shall be capable of tuning to any of the 25 kHz channels from 112 MHz to 137 MHz.

Note. — Operational conditions or certain applications may require the equipment to be operated in a narrower frequency range.

(2) *Simultaneous reception.* A VDL Mode 4 station shall be capable of

receiving two channels simultaneously.

(3) *A VDL Mode 4 station shall be capable of receiving additional channels simultaneously as required by operational services.*

23.3.4.9.1.2 GLOBAL SIGNALLING CHANNELS

VDL Mode 4 stations shall use two assigned frequencies as global signalling channels (GSC), to support user communications and link management functions.

Note. — Additional channels may be defined in a local domain and notified to mobile users by broadcast from ground stations on the GSCs defined above.

23.3.4.9.2 SYSTEM CAPABILITIES

(1) *ATN compatibility.* The VDL Mode 4 system shall support ATN/IPS-compliant subnetwork services.

Note. — VDL Mode 4 provides a seamless transfer of data between ATN/IPS ground networks and ATN/IPS aircraft networks. Interoperability with ATN/OSI networks, where required, is expected to be arranged prior to implementation. VDL Modes 2 and 3 provide ATN/OSI-compliant subnetworks.

(2) *Data transparency.* The VDL Mode 4 system shall provide code-independent, byte-independent transfer of data.

(3) *Broadcast.* The VDL Mode 4 system shall provide link layer broadcast services.

(4) *Point-to-point.* The VDL Mode 4 system shall provide link layer point-to-point services.

(5) *Air-air communications.* The VDL Mode 4 system shall provide air-air communications, without ground support, as well as air-ground

communications.

(6) *Connection management*. When supporting air-ground operations, the VDL Mode 4 system shall establish and maintain a reliable communications path between the aircraft and the ground system while allowing, but not requiring, manual intervention.

(7) *Ground network transition.* A mobile VDL Mode 4 DLS station shall transition from one ground VDL Mode 4 DLS station to another as required.

(8) *Derived time capability.* VDL Mode 4 shall provide the capability for deriving time from time-of-arrival measurements of received VDL Mode 4 transmissions whenever externally derived estimates of time are unavailable.

(9) *Simplex operations.* Mobile and ground VDL Mode 4 stations shall access the physical medium operating in simplex mode.

23.3.4.9.3 COORDINATION OF CHANNEL UTILIZATION

On a regional basis, transmissions shall be scheduled relative to UTC, to ensure efficient use of shared channels and to avoid unintentional slot re-use.

23.3.4.9.4 PHYSICAL LAYER PROTOCOLS AND SERVICES

Note.— Unless otherwise stated, the requirements defined in this Subpart apply to both mobile and ground stations.

23.3.4.9.4.1 FUNCTIONS

23.3.4.9.4.1.1 TRANSMITTED POWER

Airborne installation. The effective radiated power shall be such as to provide a field strength of at least 35 microvolts per metre (minus 114.5 dBW/m^2) on the basis of free space propagation, at ranges and altitudes appropriate to the conditions pertaining to the areas over which the aircraft is operated.

23.3.4.9.4.1.2 GROUND INSTALLATION.

The effective radiated power shall be such as to provide a field strength of at least 75 microvolts per metre (minus 109 dBW/m^2) within the defined operational coverage of the facility, on the basis of free-space propagation.

23.3.4.9.4.1.2 TRANSMITTER AND RECEIVER FREQUENCY CONTROL

(1) The VDL Mode 4 physical layer shall set the transmitter or receiver frequency as commanded by the link management entity (LME). Channel selection time shall be less than 13 ms after the receipt of a command from a VSS user.

(2) *DATA RECEPTION BY RECEIVER*

(3) The receiver shall decode input signals and forward them to the higher layers for processing.

(4) *DATA TRANSMISSION BY TRANSMITTER*

(5) *Data encoding and transmission.* The physical layer shall encode the data received from the data link layer and transmit it over the RF channel. RF transmission shall take place only when permitted by the MAC.

(6) *Order of transmission.* The transmission shall consist of the following stages in the following order:

(a) transmitter power stabilization;

(b) bit synchronization;

(c) ambiguity resolution and data transmission; and

(d) transmitter decay.

Note. — The definitions of the stages are given in Subparts 23.3.4.9.4.3(1) to 23.3.4.9.4.3(4).

(7) *Automatic transmitter shutdown.* A VDL Mode 4 station shall automatically shut-down power to any final stage amplifier in the event that output power from that amplifier exceeds –30 dBm for more than 1 second. Reset to an operational mode for the affected amplifier shall require a manual operation.

Note. — This is intended to protect the shared channel resource against so-called "stuck transmitters".

23.3.4.9.4.1.3 NOTIFICATION SERVICES

(1) *Signal quality*. The operational parameters of the equipment shall be monitored at the physical layer. Signal quality analysis shall be performed in the demodulator process and in the receive process.

Note. — Processes that may be evaluated in the demodulator include bit error rate (BER), signal to noise ratio (SNR), and timing jitter. Processes that may be evaluated in the receiver include received signal level and group delay.

(2) *Arrival time*. The arrival time of each received transmission shall be measured with a two-sigma error of 5 microseconds.

(3) The receiver shall be capable of measuring the arrival time within a two-sigma error of 1 microsecond.

23.3.4.9.4.2 PROTOCOL DEFINITION FOR GFSK

(1) Modulation scheme. The modulation scheme shall be GFSK. The first bit transmitted (in the training sequence) shall be a high tone

and the transmitted tone shall be toggled before transmitting a 0 (i.e. non-return to zero inverted encoding).

(2) *Modulation rate.* Binary ones and binary zeros shall be generated with a modulation index of 0.25 ± 0.03 and a BT product of 0.28 ± 0.03, producing data transmission at a bit rate of 19 200 bits/s ± 50 ppm.

23.3.4.9.4.3 STAGES OF TRANSMISSION

(1) *Transmitter power stabilization.* The first segment of the training sequence is the transmitter power stabilization, which shall have a duration of 16 symbol periods. The transmitter power level shall be no less than 90 per cent of the steady state power level at the end of the transmitter power stabilization segment.

(2) *Bit synchronization.* The second segment of the training sequence shall be the 24-bit binary sequence 01010101 0101 0101 0101 0101, transmitted from left to right immediately before the start of the data segment.

(3) *Ambiguity resolution and data transmission.* The transmission of the first bit of data shall start 40 bit intervals (approximately 2083.3 microseconds) ± 1 microsecond after the nominal start of transmission.

Note 1.— This is referenced to emissions at the output of the antenna.

Note 2.— Ambiguity resolution is performed by the link layer.

(4) *Transmitter decay.* The transmitted power level shall decay at least by 20 dB within 300 microseconds after completing a transmission. The transmitter power level shall be less than -90 dBm within 832 microseconds after completing a transmission.

23.3.4.9.4.4 CHANNEL SENSING

(1) *Estimation of noise floor.* A VDL Mode 4 station shall estimate the noise floor based on power measurements of the channel whenever a valid training sequence has not been detected.

(2) The algorithm used to estimate the noise floor shall be such that the

estimated noise floor shall be lower than the maximum power value measured on the channel over the last minute when the channel is regarded as idle.

Note. — The VDL Mode 4 receiver uses an energy sensing algorithm as one of the means to determine the state of the channel (idle or busy). One algorithm that can be used to estimate the noise floor is described in the Manual on VHF Digital Link (VDL) Mode 4 *(Doc 9816).*

(3) *Channel idle to busy detection.* A VDL Mode 4 station shall employ the following means to determine the channel idle to busy transition at the physical layer.

(4) *Detection of a training sequence.* The channel shall be declared busy if a VDL Mode 4 station detects a valid training sequence followed by a frame flag.

(5) *Measurement of channel power.* Regardless of the ability of the demodulator to detect a valid training sequence, a VDL Mode 4 station shall consider the channel busy with at least a 95 per cent probability within 1 ms after on- channel power rises to the equivalent of at least four times the estimated noise floor for at least 0.5 milliseconds.

23.3.4.9.4.5 CHANNEL BUSY TO IDLE DETECTION

(1) A VDL Mode 4 station shall employ the following means to determine the channel busy to idle transition.

(2) *Measurement of transmission length.* When the training sequence has been detected, the channel busy state shall be held for a period of time at least equal to 5 milliseconds and subsequently allowed to transition to the idle state based on measurement of channel power.

(3) *Measurement of channel power.* When not otherwise held in the channel busy state, a VDL Mode 4 station shall consider the channel idle with at least a 95 per cent probability if on-channel power falls below the equivalent of twice the estimated noise floor for at least 0.9 milliseconds.

23.3.4.9.4.6 RECEIVER/TRANSMITTER INTERACTION

(1) *Receiver to transmitter turnaround time.* A VDL Mode 4 station shall be capable of beginning the transmission of the transmitter

power stabilization sequence within 16 microseconds after terminating the receiver function.

(2) *Frequency change during transmission. The phase acceleration of the carrier from the start of the synchronization sequence to the data end flag shall be less than 300 Hz per second.*

(3) *Transmitter to receiver turnaround time. A VDL Mode 4 station shall be capable of receiving and demodulating with nominal performance an incoming* signal within 1 ms after completing a transmission.

Note. — Nominal performance is defined as a bit error rate (BER) of 10^{-4}.

23.3.4.9.4.7 PHYSICAL LAYER SYSTEM PARAMETERS

23.3.4.9.4.7.1 PARAMETER P1 (MINIMUM TRANSMISSION LENGTH)

(1) A receiver shall be capable of demodulating a transmission of minimum length P1 without degradation of BER.

(2) The value of P1 shall be 19 200 bits.

23.3.4.9.4.7.2 PARAMETER P2 (NOMINAL CO-CHANNEL INTERFERENCE PERFORMANCE)

(1) The parameter P2 shall be the nominal co-channel interference at which a receiver shall be capable of demodulating without degradation in BER.

(2) The value of P2 shall be 12 dB.

23.3.4.9.4.8 FM BROADCAST INTERFERENCE IMMUNITY PERFORMANCE FOR VDL MODE 4 RECEIVING SYSTEMS

(1) A VDL Mode 4 station shall conform to the requirements defined in Subpart 23.3.4.3.3.1 when operating in the band 117.975–137 MHz.

(2) A VDL Mode 4 station shall conform to the requirements defined

below when operating in the band 108-117.975 MHz.

(3) The VDL Mode 4 receiving system shall meet the requirements specified in 23.3.4.3.3(1) in the presence of two- signal, third-order intermodulation products caused by VHF FM broadcast signals having levels in accordance with the following:

$$2N_1 + N_2 + 72 \leq 0$$

for VHF FM sound broadcasting signals in the range 107.7–108.0 MHz

and

$$2N_1 + N_2 + 3\left\{24 - 20\log\frac{\Delta f}{0.4}\right\} \leq 0$$

for VHF FM sound broadcasting signals below 107.7 MHz,

where the frequencies of the two VHF FM sound broadcasting signals produce, within the receiver, a two-signal, third-order intermodulation product on the desired VDL Mode 4 frequency.

N_1 and N_2 are the levels (dBm) of the two VHF FM sound broadcasting signals at the VDL Mode 4 receiver input. Neither level shall exceed the desensitization criteria set forth in 23.3.4.9.4.8(4).

$\Delta f = 108.1 - f_1$, where f_1 is the frequency of N_1, the VHF FM sound broadcasting signal closer to 108.1 MHz.

Note.— The FM intermodulation immunity requirements are not applied to a VDL Mode 4 channel operating below 108.1 MHz, and hence frequencies below 108.1 MHz are not intended for general assignments.

(4) The VDL Mode 4 receiving system shall not be desensitized in the presence of VHF FM broadcast signals having levels in accordance with Table 6-5.

23.3.4.9.5 LINK LAYER

Note. — Details on link layer functions are contained in the Manual on VHF Digital Link (VDL) Mode 4 *(Doc 9816).*

23.3.4.9.6 SUBNETWORK LAYER AND SNDCF

Note. — Details on subnetwork layer functions and SNDCF are contained in the Manual on VHF Digital Link (VDL) Mode 4 *(Doc 9816).*

23.3.4.9.7 ADS-B APPLICATIONS

Note.— Details on ADS-B application functions are contained in the Manual on VHF Digital Link (VDL) Mode 4 *(Doc 9816).*

Table 6-1. Modes 2 and 3 data encoding

X_k	Y_k	Z_k	$\Delta\phi_k$
0	0	0	0 π / 4
0	0	1	1 π / 4
0	1	1	2 π / 4
0	1	0	3 π / 4
1	1	0	4 π / 4
1	1	1	5 π / 4
1	0	1	6 π / 4
1	0	0	7 π / 4

Table 6-2. Modes 2 and 3 modulation stability

VDL Mode	Aircraft Modulation Stability	Ground Modulation Stability
Mode 2	± 0.0050 per cent	± 0.0050 per cent
Mode 3	± 0.0005 per cent	± 0.0002 per cent

Table 6-3. Scrambler functions

Function	Data in	Data out
scrambling	clean data	scrambled data
descrambling	scrambled data	clean data

Table 6-4. Physical services system parameters

Symbol	Parameter name	Mode 2 value
P1	Minimum transmission length	131071 bits

Table 6-5. VDL Mode 4 Operating on frequencies between 112.0 – 117.975 MHz

Frequency (MHz)	Maximum level of unwanted signal at receiver input (dBm)
88–104	+15
106	+10
107	+5
107.9	0

Note.— The relationship is linear between adjacent points designated by the above frequencies.

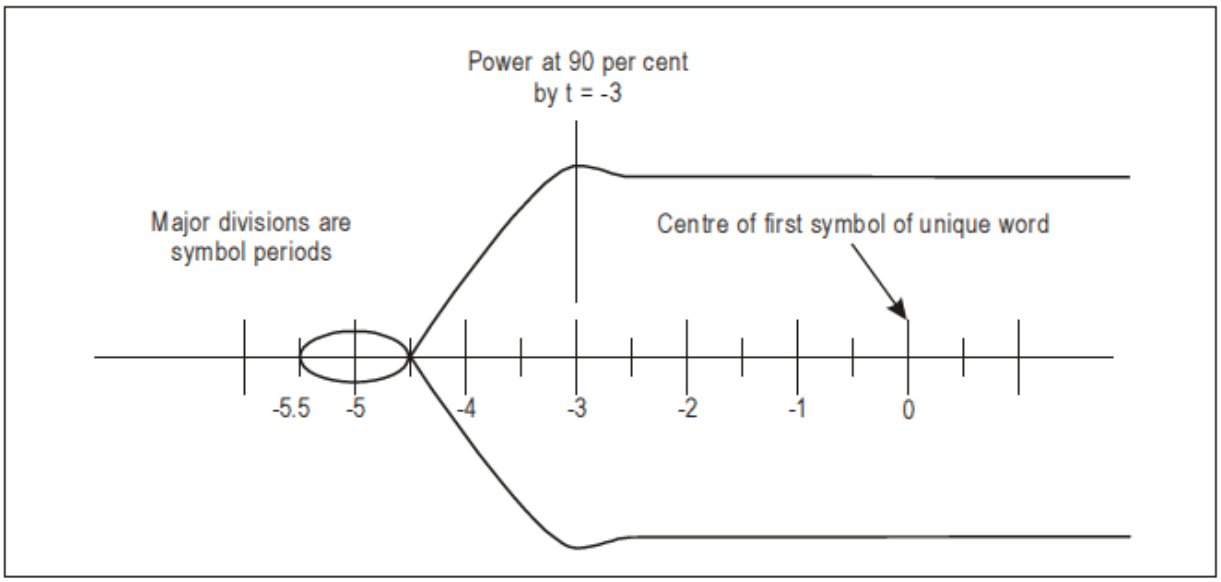


Figure 6-1. Transmitter power stabilization

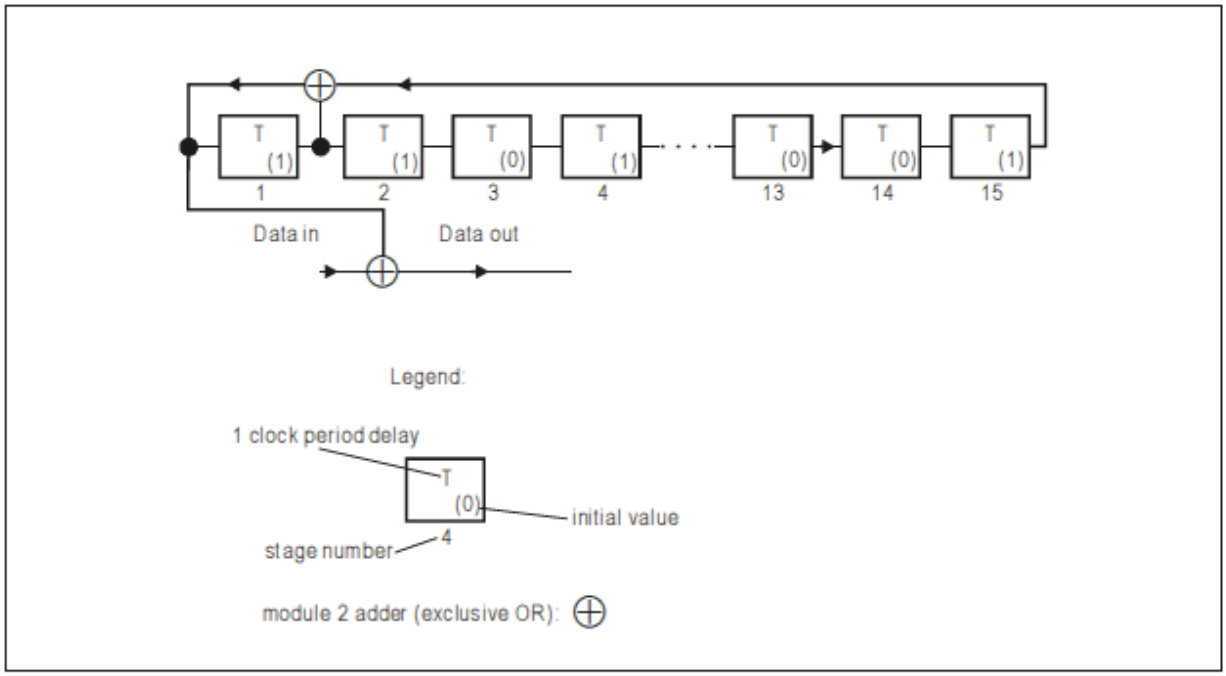


Figure 6-2. PN-generator for bit scrambling sequence

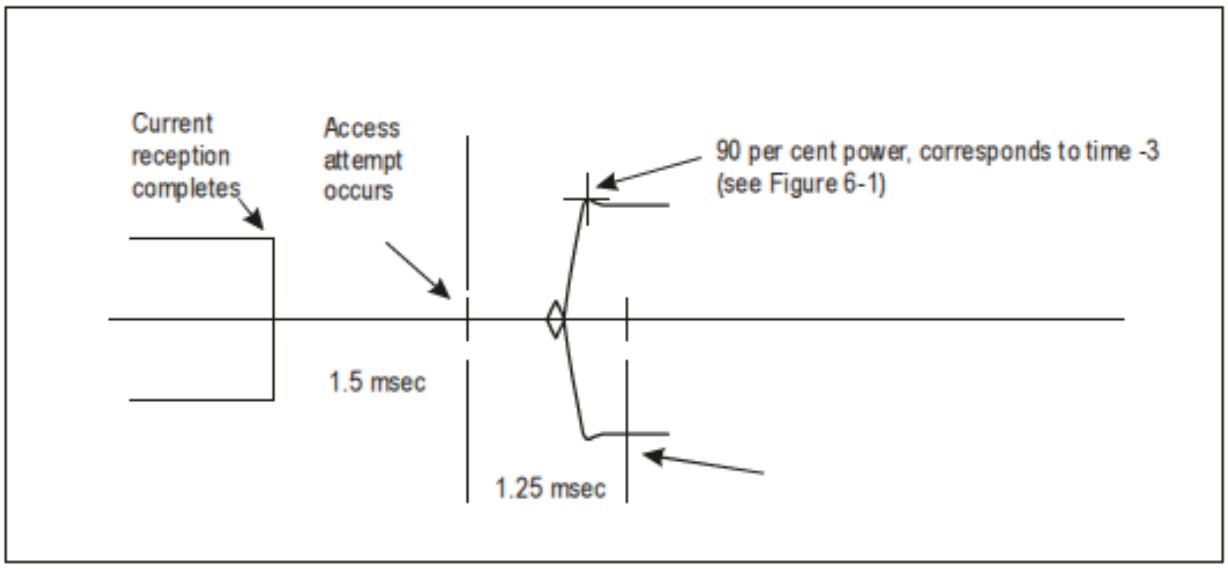


Figure 6-3. Receive to Transmit turnaround time

23.3.5 AERONAUTICAL MOBILE AIRPORT COMMUNICATIONS SYSTEM (AEROMACS)

23.3.5.1 DEFINITIONS

Adaptive modulation means a system's ability to communicate with another system using multiple burst profiles and a system's ability to subsequently communicate with multiple systems using different burst profiles.

Aerodrome means a defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft.

Aeronautical Mobile Airport Communications System (AeroMACS) means a high-capacity data link supporting mobile and fixed communications on the aerodrome surface.

AeroMACS downlink (DL) means the transmission direction from the base station (BS) to the mobile station (MS).

AeroMACS uplink (UL) means the transmission direction from the mobile station (MS) to the base station (BS).

AeroMACS handover means the process in which a mobile station (MS) migrates from the air-interface provided by one base station (BS) to the air-interface provided by another BS. A break-before-make AeroMACS handover is where service with the target BS starts after a disconnection of service with the previous serving BS.

Base station (BS) means the generalized equipment set providing connectivity, management and control of the mobile station (MS).

Bit error rate (BER) means the number of bit errors in a sample divided by the total number of bits in the sample, generally averaged over many such samples.

Burst profile means set of parameters that describe the uplink or downlink transmission properties associated with an interval usage code. Each profile contains parameters such as modulation type, forward error correction (FEC) type, preamble length, guard times, etc.

Convolutional turbo codes (CTC) means type of forward error correction (FEC) code.

Data transit delay means accordance with ISO 8348, the average value of the statistical distribution of data delays. This delay represents the subnetwork delay and does not include the connection establishment delay.

Domain means a set of end systems and intermediate systems that operate according to the same routing procedures and that is wholly contained within a single administrative domain.

Forward error correction means the process of adding redundant information to the transmitted signal in a manner which allows correction, at the receiver, of errors incurred in the transmission.

Frequency assignment means a logical assignment of centre frequency and channel bandwidth programmed to the base station (BS).

Mobile station (MS) means a station in the mobile service intended to be used while in motion or during halts at unspecified points. An MS is always a subscriber station (SS).

Partial usage sub-channelization (PUSC)means a technique in which the orthogonal frequency division multiplexing (OFDM) symbol subcarriers are divided and permuted among a subset of sub-channels for transmission, providing partial frequency diversity.

Residual error rate means the ratio of incorrect, lost and duplicate subnetwork service data units (SNSDUs) to the total number of SNSDUs that were sent.

Service data unit (SDU) means a unit of data transferred between adjacent layer entities, which is encapsulated within a protocol data unit (PDU) for transfer to a peer layer.

Service flow means a unidirectional flow of media access control layer (MAC) service data units (SDUs) on a connection that is providing a particular quality of service (QoS).

Subscriber station (SS) means a generalized equipment set providing

connectivity between subscriber equipment and a base station (BS).

Subnetwork entry time means the time from when the mobile station starts the scanning for BS transmission, until the network link establishes the connection, and the first network user "protocol data unit" can be sent.

Subnetwork service data unit (SNSDU) means an amount of subnetwork user data, the identity of which is preserved from one end of a subnetwork connection to the other.

Time division duplex (TDD) means a duplex scheme where uplink and downlink transmissions occur at different times but may share the same frequency.

23.3.5.2 INTRODUCTION

Note 1.— Aeronautical mobile airport communications system (AeroMACS) is a high-capacity data link supporting mobile and fixed communications, related to the safety and regularity of flight, on the aerodrome surface.

Note 2.— AeroMACS is derived from the IEEE 802.16-2009 mobile standards. AeroMACS profile document (RTCA DO345 and EUROCAE ED 222) lists all features from these standards which are mandatory, not applicable or optional. AeroMACS profile differentiates between base station and mobile station functionality and contains, for each feature, a reference to the applicable standards.

23.3.5.3 GENERAL

(1) AeroMACS shall conform to the requirements of this Part.

(2) AeroMACS shall only transmit when on the surface of an aerodrome.

(3) AeroMACS shall support aeronautical mobile (route) service (AM(R) S) communications.

(4) AeroMACS shall process messages according to their associated priority.

(5) AeroMACS shall support multiple levels of message priority.

(6) AeroMACS shall support point to point communication.

(7) AeroMACS shall support multicast and broadcast communication services.

(8) AeroMACS shall support internet protocol (IP) packet data services.

(9) AeroMACS shall provide mechanisms to transport ATN/IPS and ATN/OSI (over IP) based messaging.

(10) AeroMACS shall support voice services.

Note. — The Manual on the Aeronautical Telecommunication Network (ATN) using Internet Protocol Suite (IPS) Standards and Protocols *(Doc 9896) provides information on voice service over IP.*

(11) AeroMACS shall support multiple service flows simultaneously.

(12) AeroMACS shall support adaptive modulation and coding.

(13) AeroMACS shall support handover between different AeroMACS BSs during aircraft movement or on degradation of connection with current BS.

(14) AeroMACS shall keep total accumulated interference levels with limits defined by the International Telecommunication Union — Radiocommunication Sector (ITU-R) as required by national or international rules on frequency assignment planning and implementation.

(15) AeroMACS shall support a flexible implementation architecture to permit link and network layer functions to be located in different or same physical entities.

23.3.5.4 RADIO FREQUENCY (RF) CHARACTERISTICS

23.3.5.4.1 GENERAL RADIO CHARACTERISTICS

(1) AeroMACS shall operate in time division duplex (TDD) mode.

(2) AeroMACS shall operate with a 5 MHz channel bandwidth.

(3) AeroMACS MS antenna polarization shall be vertical.

(4) AeroMACS BS antenna polarization shall have a vertical component.

(5) AeroMACS shall operate without guard bands between adjacent AeroMACS channels.

(6) AeroMACS shall operate according to the orthogonal frequency division multiple access method.

(7) AeroMACS shall support both segmented partial usage sub-channelization (PUSC) and PUSC with all carriers as subcarrier permutation methods.

23.3.5.4.2 FREQUENCY BANDS

(1) AeroMACS equipment shall operate in the band from 5030 MHz to 5150 MHz in channels of 5 MHz bandwidth.

Note 1.— Some States may, on the basis of national regulations, have additional allocations to support AeroMACS. Information on the technical characteristics and operational performance of AeroMACS is contained in the AeroMACS Minimum Operational Performance Specification (MOPS) (*EUROCAE ED-223 / RTCA DO-346) and* AeroMACS Minimum Aviation System Performance Standard (MASPS) *(EUROCAE ED-227).*

Note 2.— The last centre frequency of 5145 MHz is selected as the reference frequency for the numbering of AeroMACS channels. AeroMACS nominal centre frequencies are numbered downward from the reference frequency in 5 MHz steps.

(2) The mobile equipment shall operate at centre frequencies offset from the preferred frequencies, with an offset of 250 kHz step size.

Note. — The nominal centre frequencies are the preferred centre frequencies for AeroMACS operations. However, the base stations shall have the capability to deviate from the preferred centre frequencies to satisfy potential national spectrum authority implementation issues (i.e. to allow AeroMACS operations without receiving or causing interference to other systems operating in the band such as MLS and AMT).

23.3.5.4.3 RADIATED POWER

(1) The maximum mobile station equivalent isotropic radiated power (EIRP) shall not exceed 30 dBm.

(2) The maximum base station EIRP in a sector shall not exceed 39.4 dBm.

(3) In order to meet ITU requirements, the total base station EIRP in a sector shall be decreased from that peak, considering the antenna characteristics, at elevations above the horizon. Further information is provided in the guidance material.

Note 1.— EIRP — defined as antenna gain in a specified elevation direction plus the average AeroMACS transmitter power. While the instantaneous peak power from a given transmitter may exceed that level when all of the subcarriers randomly align in phase, when the large number of transmitters assumed in the analysis is taken into account, average power is the appropriate metric.

Note 2.— If a sector contains multiple transmit antennas (e.g., multiple input multiple output (MIMO) antenna), the specified power limit is the sum of the powers from each antenna.

23.3.5.4.4 MINIMUM RECEIVER SENSITIVITY

(1) AeroMACS receiver sensitivity shall comply with Table 7-1, AeroMACS receiver sensitivity values.

Note 1.— The computation of the sensitivity level for AeroMACS is described in the Aeronautical Mobile Airport Communications System (AeroMACS) Manual *(Doc 10044).*

Note 2.— AeroMACS receiver would be 2 dB more sensitive than indicated if Convolutional Turbo Codes (CTC) is used.

Note 3.— The sensitivity level is defined as the power level measured at the receiver input when the bit error rate (BER) is equal to 1 × 10-6 and all active subcarriers are transmitted in the channel. In general, the requisite input power depends on the number of active subcarriers of the transmission.

Note 4.— The values in Table 7-1 assume a receiver noise figure of 8 dB.

Note 5.— The sensitivity values in Table 7-1 assume absence of any source of interference except for thermal and receiver noise.

Table 7-1. AeroMACS receiver sensitivity values

Modulation scheme using convolutional codes (CC) encoding scheme	Rep. Factor	MS Sensitivity	BS Sensitivity
64 QAM 3/4	1	-74.3 dBm	-74.5 dBm
64 QAM 2/3	1	-76.3 dBm	-76.5 dBm
16 QAM 3/4	1	-80.3 dBm	-80.5 dBm
16 QAM 1/2	1	-83.8 dBm	-84.0 dBm
QPSK 3/4	1	-86.3 dBm	-86.5 dBm
QPSK 1/2	1	-89.3 dBm	-89.5 dBm
QPSK 1/2 with repetition 2	2	-92.3 dBm	-92.5 dBm

Note.— A 64 QAM transmission is optional for MS.

23.3.5.4.5 SPECTRAL MASK AND EMISSIONS

(1) The power spectral density of the emissions when all active subcarriers are transmitted in the channel shall be attenuated below the maximum power spectral density as follows:

(a) on any frequency removed from the assigned frequency between 50 and 55 per cent of the authorized bandwidth: 26 + 145 log (per cent of BW/50) dB;

(b) on any frequency removed from the assigned frequency between 55 and 100 per cent of the authorized bandwidth: 32 + 31 log (per cent of (BW)/55) dB;

(c) on any frequency removed from the assigned frequency between 100 and 150 per cent of the authorized bandwidth: 40 +57 log (per cent of (BW)/100) dB; and

(d) on any frequency removed from the assigned frequency beyond 150 per cent of the authorized bandwidth: 50 dB.

Note. — The power spectral density at a given frequency is the power within a bandwidth equal to 100 kHz centred at this frequency, divided by this measurement bandwidth. It is made clear that the measurement of the power spectral density shall encompass the energy over at least one frame period.

(2) AeroMACS shall implement power control.

(3) AeroMACS minimum rejection for adjacent (+/–5MHz) channel, measured at BER=10-6 level for a victim signal power 3 dB higher than the receiver sensitivity, shall be 10 dB for 16 QAM 3/4.

(4) AeroMACS minimum rejection for adjacent (+/–5MHz) channel, measured at BER=10-6 level for a victim signal power 3 dB higher than the receiver sensitivity, shall be 4 dB for 64 QAM 3/4.

(5) AeroMACS minimum rejection for second adjacent (+/–10MHz) channel and beyond, measured at BER=10-6 level for a victim signal power 3 dB higher than the receiver sensitivity, shall be 29 dB for 16 QAM 3/4.

(6) AeroMACS minimum rejection for second adjacent (+/–10MHz) channel and beyond, measured at BER=10-6 level for a victim signal power 3 dB higher than the receiver sensitivity, shall be 23 dB for 64 QAM 3/4.

Note.— For additional clarification to the requirements stated in paragraphs(3) to (6) , refer to IEEE 802.16-2009 section 8.4.14.2.

23.3.5.4.6 FREQUENCY TOLERANCE

(1) AeroMACS BS transmitter frequency tolerance shall be better than +/- 2×10^{6} of nominal channel frequency.

(2) AeroMACS MS transmitter centre frequency shall be locked to that of the BS transmission centre frequency with a tolerance better than 2 per cent of the subcarrier spacing.

(3) AeroMACS MS shall track the frequency of the BS and shall defer any transmission if synchronization is lost or exceeds the tolerances given above.

23.3.5.5 PERFORMANCE REQUIREMENTS

23.3.5.5.1 AEROMACS COMMUNICATIONS SERVICE PROVIDER

(1) The maximum unplanned service outage duration on a per aerodrome basis shall be 6 minutes.

(2) The maximum accumulated unplanned service outage time on a per aerodrome basis shall be 240 minutes/year.

(3) The maximum number of unplanned service outages shall not exceed 40 per year per aerodrome.

Note. — The requirements given in paragraphs (1) to (3) refer to the overall service provision by the AeroMACS communication service provider on the aerodrome surface. This may include other media which can provide alternate communication paths in the event of an AeroMACS failure.

(4) Connection resilience. The probability that a transaction will be completed once started shall be at least 0.999 for AeroMACS over any ~~one~~anyone-hour interval.

Note. — Connection releases resulting from AeroMACS handover between base stations, log-off or circuit pre-emption are excluded from this specification.

23.3.5.5.2 DOPPLER SHIFT

AeroMACS shall operate with a Doppler shift induced by the movement of the MS up to a radial speed of 92.6 km (50 NM) per hour, relative to the BS.

23.3.5.5.3 DELAY

(1) Subnetwork entry time shall be less than 90 seconds.

(2) The from-MS data transit delay (95^{th} percentile) for the highest priority data service, shall be less than or equal to 1.4 seconds over a window of 1 hour or 600 SDUs, whichever is longer.

(3) The to-MS data transit delay (95^{th} percentile) for the highest priority data service, shall be less than or equal to 1.4 seconds over a window of 1 hour or 600 SDUs, whichever is longer.

23.3.5.5.4 INTEGRITY

(1) AeroMACS BS and MS shall support mechanisms to detect and correct corrupt SNSDUs.

(2) AeroMACS BS and MS shall only process SNSDUs addressed to themselves.

(3) The residual error rate, to/from MS shall be less than or equal to 5×10^{-8} per SNSDU.

Note. — There are no integrity requirements for SNSDU residual rate to the BS and MS as the requirement is entirely satisfied by the end-to-end systems in the aircraft and air traffic service provider.

(4) The maximum bit error rate shall not exceed 10^{-6} after CTC-FEC, if the received signal is equal to or greater than the minimum sensitivity level for the modulations scheme used, as given in Table 7-1.

23.3.5.5.5 SECURITY

(1) AeroMACS shall provide a capability to protect the integrity of messages in transit.

Note.— The capability includes cryptographic mechanisms to provide integrity of messages in transit.

(2) AeroMACS shall provide a capability to protect the availability of the system.

Note.— The capability includes measures to ensure that the system and its capacity are available for authorized uses during unauthorized events.

(3) AeroMACS shall provide a capability to protect the confidentiality of messages in transit.

Note.— The capability includes cryptographic mechanisms to provide encryption/decryption of messages.

(4) AeroMACS shall provide an authentication capability.

Note.— The capability includes cryptographic mechanisms to provide peer entity

authentication, mutual peer entity authentication, and data origin authentication.

(5) AeroMACS shall provide a capability to ensure the authenticity of messages in transit.

Note.— The capability includes cryptographic mechanisms to provide authenticity of messages in transit.

(6) AeroMACS shall provide a capability to authorize the permitted actions of users of the system.

Note. — The capability includes mechanisms to explicitly authorize the actions of authenticated users. Actions that are not explicitly authorized are denied.

(7) If AeroMACS provide interfaces to multiple domains, AeroMACS shall provide capability to prevent intrusion from lower integrity domain to higher integrity domain.

23.3.5.5.6 SYSTEM INTERFACES

(1) AeroMACS shall provide data service interface to the system users.

(2) AeroMACS shall support notification of the status of communications.

Note. — This requirement could support notification of the loss of communications (such as join and leave events).

23.3.5.5.7 APPLICATION REQUIREMENTS

(1) AeroMACS shall support multiple classes of services to provide appropriate service levels to applications.

(2) If there is a resource contention, AeroMACS shall pre-empt services with a lower priority than those given in 23.2.5.2 of Subpart 2 of Part 23.

23.3.6 AFTN NETWORK

23.3.6.1 DEFINITIONS

Data signalling rate means data signalling rate refers to the passage of information per unit of time and is expressed in bits/second.

Data signalling rate is given by the formula:

$$\sum_{i=1}^{i=m} \frac{1}{T_i} \log_2 n_i$$

where m is the number of parallel channels, T_i is the minimum interval for the ith channel expressed in seconds, n_i is the number of significant conditions of the modulation in the ith channel.

Note 1.—

a) *For a single channel (serial transmission) it reduces to* $(1/T)\log_2 n$; *with a two-condition modulation* (n = 2), *it is* 1/T.

b) *For a parallel transmission with equal minimum intervals and equal number of significant conditions on each channel, it is* $m(1/T)\log_2 n$ (m(1/T) *in case of a two-condition modulation).*

Note 2.— In the above definition, the term "parallel channels" is interpreted to mean: channels, each of which carries an integral part of an information unit, e.g. the parallel transmission of bits forming a character. In the case of a circuit comprising a number of channels, each of which carries information "independently", with the sole purpose of increasing the traffic handling capacity, these channels are not to be regarded as parallel channels in the context of this definition.

Degree of standardized test distortion means the degree of distortion of the restitution measured during a specific period of time when the modulation is perfect and corresponds to a specific text.

Effective margin means that margin of an individual apparatus which could be measured under actual operating conditions.

Low modulation rates means modulation rates up to and including 300 bauds.

Margin means the maximum degree of distortion of the circuit at the end of which the apparatus is situated which is compatible with the correct translation of all the signals which it may possibly receive.

Medium modulation rates means modulation rates above 300 and up to and including 3 000 bauds.

Modulation rate means the reciprocal of the unit interval measured in seconds. This rate is expressed in bauds.

Note. — Telegraph signals are characterized by intervals of time of duration equal to or longer than the shortest or unit interval. The modulation rate (formerly telegraph speed) is therefore expressed as the inverse of the value of this unit interval. If, for example, the unit interval is 20 milliseconds, the modulation rate is 50 bauds.

Synchronous operation means operation in which the time interval between code units is a constant.

23.3.6.2 TECHNICAL PROVISIONS RELATING TO TELETYPEWRITER APPARATUS AND CIRCUITS USED IN THE AFTN

(1) In international teletypewriter circuits of the AFTN, using a 5-unit code, the International Telegraph Alphabet No. 2 (see Table 8-1[**]) shall be used only to the extent prescribed in section 23.2.4.1.1 of Subpart 2 of GCAD Part 23.

(2) The modulation rate shall be determined by bilateral or multilateral agreement between administrations concerned, taking into account primarily traffic volume.

(3) The nominal duration of the transmitting cycle shall be at least 7.4 units (preferably 7.5), the stop element lasting for at least 1.4 units (preferably 1.5).

(4) The receiver shall be able to translate correctly in service the signals coming from a transmitter with a nominal transmitting cycle of 7 units.

(5) Apparatus in service shall be maintained and adjusted in such a manner that its

[**] All tables and figures are located at the end of this chapter.

net effective margin is never less than 35 per cent.

(6) The number of characters which the textual line of the page-printing apparatus may contain shall be fixed at 69.

(7) In start-stop apparatus fitted with automatic time delay switches, the disconnection of the power supply to the motor shall not take place before the lapse of at least 45 seconds after the reception of the last signal.

(8) Arrangements shall be made to avoid the mutilation of signals transmitted at the head of a message and received on start-stop reperforating apparatus.

(9) If the reperforating apparatus is provided with local means for feeding the paper, not more than one mutilated signal shall be tolerated.

(10) Complete circuits shall be so engineered and maintained that their degree of standardized test distortion does not exceed 28 per cent on the standardized text:

THE QUICK BROWN FOX JUMPS OVER THE LAZY DOG

or

VOYEZ LE BRICK GEANT QUE JEXAMINE PRES DU WHARF

(11) The degree of isochronous distortion on the standardized text of each of the parts of a complete circuit shall be as low as possible, and in any case shall not exceed 10 per cent.

(12) The overall distortion in transmitting equipment used on teletypewriter channels shall not exceed 5 per cent.

(13) AFTN circuits shall be equipped with a system of continuous check of channel condition. Additionally, controlled circuit protocols shall be applied.

23.3.6.3 TERMINAL EQUIPMENT ASSOCIATED WITH AERONAUTICAL RADIOTELETYPEWRITER CHANNELS OPERATING IN THE BAND 2.5 – 30 MHz

23.3.6.3.1 SELECTION OF TYPE OF MODULATION AND CODE

(1) Frequency shift modulation (F1B) shall be employed in radioteletypewriter systems used in the aeronautical fixed service (AFS), except where the characteristics of the independent sideband (ISB) method of operation are of advantage.

Note. — F1B type of modulation is accomplished by shifting a radio frequency carrier between two frequencies representing "position A" (start signal polarity) and "position Z" (stop signal polarity) of the start-stop 5-unit telegraphic code.

23.3.6.3.2 SYSTEM CHARACTERISTICS

(1) The characteristics of signals from radioteletypewriter transmitters utilizing F1B modulation shall be as follows:

(a) Frequency shift: the lowest possible value.

(b) Frequency shift tolerance: within plus or minus 3 per cent of the nominal value of the frequency shift.

(c) Polarity: single channel circuits: the higher frequency corresponds to "position A" (start signal polarity).

(2) The variation of the mean between the radio frequencies representing respectively "position A" and "position Z" shall not exceed 100 Hz during any two-hour period.

(3) The overall distortion of the teletypewriter signal, as monitored at the output of the radio transmitter or in its immediate vicinity, shall not exceed 10 per cent.

Note. — Such distortion means the displacement in time of the transitions between elements from their proper positions, expressed as a percentage of unit element time.

(4) Radioteletypewriter receivers concerned with F1B modulation shall be capable of operating satisfactorily on signals having the characteristics set out in paragraph(1) and (2).

(5) The characteristics of multichannel transmission of teletypewriter signals over a radio circuit shall be established by agreement between the Administrations concerned.

23.3.6.4 CHARACTERISTICS OF INTERREGIONAL AFS CIRCUITS

Interregional AFS circuits being implemented or upgraded shall employ high quality telecommunications service. Modulation rate shall take into account traffic volumes expected under both normal and alternate route conditions.

23.3.6.5 TECHNICAL PROVISIONS RELATING TO ATS MESSAGE TRANSMISSION

(1) *Interconnection by direct or omnibus channels — low modulation rates — 5-unit code.*

Note.— See 23.3.6.6 for medium modulation rates.

(2) AFTN techniques (cf. 23.3.6.2) shall be used.

23.3.6.6 TECHNICAL PROVISIONS RELATING TO INTERNATIONAL GROUND-GROUND DATA INTERCHANGE AT MEDIUM AND HIGHER SIGNALLING RATES

Note. — Throughout this section in the context of coded character sets, the term "unit" means the unit of selective information and is essentially equivalent to the term "bit".

23.3.6.6.1 GENERAL

(1) In international data interchange of characters, a 7-unit coded character set providing a repertoire of 128 characters and designated as International Alphabet No. 5 (IA-5) shall be used. Compatibility with the 5-unit coded character set of International Telegraph Alphabet No. 2 (ITA-2) shall be ensured where applicable.

(2) When the provisions of paragraph(1) are applied, International Alphabet No. 5 (IA-5) contained in Table 8-2 shall be used.

(3) The serial transmission of units comprising an individual character of IA-5 shall be with the low order unit (b_1) transmitted first.

(4) When IA-5 is used, each character shall include an additional unit for parity in the eighth level position.

(5) When the provisions of paragraph (4) are applied, the sense of the character parity bit shall produce even parity in links which operate on the start-stop principle, and odd parity in links using end-to-end synchronous operations.

(6) Character-for-character conversion shall be as listed in Tables 8-3 and 8-4 for all characters which are authorized in the AFTN format for transmission on the AFS in both IA-5 and ITA-2.

(7) Characters which appear in only one code set, or which are not authorized for transmission on the AFS shall be as depicted in the code conversion tables.

23.3.6.6.2 DATA TRANSMISSION CHARACTERISTICS

(1) The data signalling rate shall be chosen from among the following:

600 bits/s	*4 800 bits/s*
1 200 bits/s	*9 600 bits/s*
2 400 bits/s	

(2) The type of transmission for each data signalling rate shall be chosen as follows:

Data signalling rate	Type of transmission
600 bits/s	*Synchronous or asynchronous serial transmission*
1 200 bits/s	*Synchronous or asynchronous serial transmission*
2 400 bits/s	*Synchronous serial transmission*
4 800 bits/s	*Synchronous serial transmission*
9 600 bits/s	*Synchronous serial transmission*

(3) The type of modulation for each data signalling rate shall be chosen as follows:

Data signalling rate	Type of modulation
600 bits/s	*Frequency*
1 200 bits/s	*Frequency*
2 400 bits/s	*Phase*
4 800 bits/s	*Phase*
9 600 bits/s	*Phase-amplitude*

Note. — This recommendation does not necessarily apply to ground-ground extensions of air-ground links used exclusively for the transfer of air-ground data, inasmuch as such circuits may be considered as part of the air-ground link.

23.3.6.6.2.1 CHARACTER STRUCTURE ON DATA LINKS

(1) Character parity shall not be used for error checking on CIDIN links. Parity appended to IA-5 coded characters per 23.3.6.6.1(4), prior to entry to the CIDIN shall be ignored. For messages exiting the CIDIN, parity shall be generated in accordance with 23.3.6.6.1(5).

(2) Characters of less than eight bits in length shall be padded out to eight bits in length before transmission over any octet-based or bit-oriented communications network. The padding bits shall occupy the higher order end of the octet, i.e. bit 8, bit 7 as required, and shall have the binary values 0.

(3) When exchanging data over CIDIN links using bit-oriented procedures, the entry centre address, exit centre addresses and destination addresses in the Transport and CIDIN Packet Headers shall be in the IA-5-character set contained in Table 8-2.

(4) When transmitting messages in AFTN format over CIDIN links using bit-oriented procedures, the messages shall be in the IA-5-character set contained in Table 8-2

23.3.6.6.3 GROUND-GROUND CHARACTER-ORIENTED DATA LINK CONTROL PROCEDURES

Note.— The provisions of this section pertain to ground-ground data interchange applications using IA-5 prescribed by 23.3.6.6.1 and which employ the ten transmission control characters (SOH, STX, ETX, EOT, ENQ, ACK, DLE, NAK,

SYN, and ETB) for data link control, over synchronous or asynchronous transmission facilities.

(1) *Descriptions.* The following descriptions shall apply to data link applications contained in this section:

(a) A master station is that station which has control of the data link at a given instant.

(b) A slave station is one that has been selected to receive a transmission from the master station.

(c) A control station is the single station on a multipoint link that is permitted to assume master status and deliver messages to one or more individually selected (non-control) tributary stations, or it is permitted to assign temporary master status to any of the other tributary stations.

23.3.6.6.3.1 MESSAGE COMPOSITION

(1) A transmission shall consist of characters from IA-5 transmitted in accordance with 23.3.6.6.1(4 and shall be either an information message or a supervisory sequence.

(2) An information message shall be used for the exchange of data and shall take one of the following forms:

1) STX ---TEXT--- ETX BCC

2) STX ---TEXT--- ETB BCC

3) SOH ---HEADING--- STX ---TEXT--- ETX BCC

4) SOH ---HEADING--- STX ---TEXT--- ETB BCC

5) SOH ---HEADING--- ETB BCC

Note 1.— $\begin{matrix} B \\ C \\ C \end{matrix}$ is a block check character (BCC).

Note 2.— In formats 2), 4), and 5) above which end with ETB, some continuation is required.

(a) A supervisory sequence shall be composed of either a single transmission control character (EOT, ENQ, ACK or NAK) or a single transmission control (ENQ) preceded by a prefix of up to 15 non-control characters, or the character DLE used in conjunction with other graphic and control characters to provide additional communication control functions.

(3) Three system categories are specified in terms of their respective circuit characteristics, terminal configurations, and message transfer procedures as follows:

(a) System category A: two-way alternate, multipoint allowing either centralized or non-centralized operation and single or multiple message-oriented information transfers without replies (but with delivery verification).

(b) System category B: two-way simultaneous, point-to-point employing message associated blocking and modulo 8 numbering of blocks and acknowledgements.

(c) System category C: two-way alternate, multipoint allowing only centralized (computer-to-terminal) operation, single or multiple message transfers with replies.

(4) In addition to the characteristics prescribed in the paragraphs that follow for both system categories A and B, other parameters that shall be accounted for in order to ensure viable, operationally reliable communications include:

(a) the number of SYN characters required to establish and maintain synchronization;

Note.— Normally the transmitting station sends three contiguous SYN characters and the receiving station detects at least two before any action is taken.

(b) the values of system time-outs for such functions as “idle line” and “no response” as well as the number of automatic retries that are to be attempted before manual intervention is signalled;

(c) the composition of prefixes within a 15 character maximum.

Note.— By agreement between the administrations concerned, it is permissible for supervisory signals to contain a station identification prefix using characters selected from columns 4 through 7 of IA-5.

(5) For multipoint implementations designed to permit only centralized (computer-to- terminal) operations, the provisions of 23.3.6.6.3.5 shall be employed.

23.3.6.6.3.2 BLOCK CHECK CHARACTER

(1) Both system category A and B shall utilize a block check character to determine the validity of a transmission.

(2) The block check character shall be composed of 7 bits plus a parity bit.

(3) Each of the first 7 bits of the block check character shall be the modulo 2 binary sum of every element in the same bit 1 to bit 7 column of the successive characters of the transmitted block.

(4) The longitudinal parity of each column of the block, including the block check character, shall be even.

(5) The sense of the parity bit of the block check character shall be the same as for the information characters (see 23.3.6.6.1(5)).

23.3.6.6.3.2.1 SUMMATION

(1) The summation to obtain the block check character shall be started by the first appearance of either SOH (start of heading) or STX (start of text).

(2) The starting character shall not be included in the summation.

(3) If an STX character appears after the summation has been started by SOH, then

the STX character shall be included in the summation as if it were a text character.

(4) With the exception of SYN (synchronous idle), all the characters which are transmitted after the start of the block check summation shall be included in the summation, including the ETB (end of transmission/block) or ETX (end of text) control character which signals that the following character is the block check character.

(5) No character, SYN or otherwise, shall be inserted between the ETB or ETX character and the block check character.

23.3.6.6.3.3 DESCRIPTION OF SYSTEM CATEGORY A

System category A is one in which a number of stations are connected by a multipoint link and one station is permanently designated as the control station which monitors the link at all times to ensure orderly operation.

23.3.6.6.3.3.1 LINK ESTABLISHMENT PROCEDURE

(1) To establish the link for transmission, the control station shall either:

(a) poll one of the tributary stations to assign it master status; or

(b) assume master status and select one or more tributary (slave) stations to receive a transmission.

(2) Polling shall be accomplished by the control station sending a polling supervisory sequence consisting of a prefix identifying a single tributary station and ending in ENQ.

(3) A tributary station detecting its assigned polling supervisory sequence shall assume master status and respond in one of two ways:

(a) if the station has a message to send, it shall initiate a selection supervisory sequence as described in paragraph (5).

(b) if the station has no message to send, it shall send EOT, and master status shall revert to the control station.

(4) If the control station detects an invalid or no response resulting from a poll, it shall terminate by sending EOT prior to resuming polling or selection.

(5) Selection shall be accomplished by the designated master station sending a selection supervisory sequence consisting of a prefix identifying a single station and ending in ENQ.

(6) A station detecting its assigned selection supervisory sequence shall assume slave status and send one of two replies:

(a) if the station is ready to receive, it shall send a prefix followed by ACK. Upon detecting this reply, the master station shall either select another station or proceed with message transfer;

(b) if the station is not ready to receive, it shall send a prefix followed by NAK and thereby relinquish slave status. If the master station receives NAK, or no reply, it shall either select another or the same tributary station or terminate;

(c) it shall be permissible for N retries ($N \geq 0$) to be made to select a station for which NAK, an invalid reply, or no response has been received.

(7) If one or more stations have been selected and have properly responded with ACK, the master station shall proceed with message transfer.

23.3.6.6.3.3.2 MESSAGE TRANSFER PROCEDURE

(1) The master station shall send a message or series of messages, with or without headings to the selected slave station(s).

(2) The transmission of a message shall:

(a) begin with:

(i) SOH if the message has a heading,

(ii) STX if the message has no heading.

(b) be continuous, ending with ETX, immediately followed by a block check character (BCC).

(3) After transmitting one or more messages, the master station shall verify successful delivery at each selected slave station.

23.3.6.6.3.3.3 DELIVERY VERIFICATION PROCEDURE

(1) The master station shall send a delivery verification supervisory sequence consisting of a prefix identifying a single slave station and ending in ENQ.

(2) A slave station detecting its assigned delivery verification supervisory sequence shall send one of two replies:

(a) if the slave station properly received all of the transmission, it shall send an optional prefix followed by ACK.

(b) if the slave station did not receive all of the transmission properly, it shall send an optional prefix followed by NAK.

(3) If the master station receives no reply or an invalid reply, it shall request a reply from the same or another slave station until all selected stations have been properly accounted for.

(4) If the master station receives a negative reply (NAK) or, after $N \geq 0$ repeat attempts, no reply, it shall repeat that transmission to the appropriate slave stations at a later opportunity.

(5) After all messages have been sent and delivery verified, the master station shall proceed with link termination.

23.3.6.6.3.3.4 LINK TERMINATION PROCEDURE

The terminate function, negating the master or slave status of all stations and returning master status to the control station, shall be accomplished by the master station transmitting EOT.

23.3.6.6.3.4 DESCRIPTION OF SYSTEM CATEGORY B

System category B is one in which two stations are on a point-to-point, full-duplex link and each station has the capability to maintain concurrent master and slave status, i.e. master status on its transmit side and slave status on its receive side and both stations can transmit simultaneously.

23.3.6.6.3.4.1 LINK ESTABLISHMENT PROCEDURE

(1) To establish the link for message transfers (from the calling to the called station), the calling station shall request the identity of the called station by sending an identification supervisory sequence consisting of a DLE character followed by a colon character, an optional prefix, and ENQ.

(2) The called station, upon detecting ENQ, shall send one of two replies:

(a) if ready to receive, it shall send a sequence consisting of a DLE followed by a colon, a prefix which includes its identity and ended by ACK0 (see 23.3.6.6.3.4.2(5)). This establishes the link for message transfers from the calling to the called station;

(b) if not ready to receive, it shall send the above sequence with the ACK0 replaced by NAK.

(3) Establishment of the link for message transfers in the opposite direction can be initiated at any time following circuit connection in a similar manner to that described above.

23.3.6.6.3.4.2 MESSAGE TRANSFER PROCEDURE

(1) System category B message transfer provides for message associated blocking with longitudinal checking and modulo 8 numbered acknowledgements.

(2) It is permissible for a transmission block to be a complete message or a portion of a message. The sending station shall initiate the transmission with SOTB N followed by:

(a) SOH if it is the beginning of a message that contains a heading;

(b) STX if it is the beginning of a message that has no heading;

(c) SOH if it is an intermediate block that continues a heading;

(d) STX if it is an intermediate block that continues a text.

Note. — SOTB N is the two-character transmission control sequence DLE = (characters 1/0, and 3/13) followed by the block number, N, where N is one of the IA-5 characters 0, 1 ... 7 (characters 3/0, 3/1 ... 3/7).

(3) A block which ends at an intermediate point within a message shall be ended with ETB; a block which ends at the end of a message shall be ended with ETX.

(4) It shall be permissible for each station to initiate and continue to send messages to the other concurrently according to the following sequence.

(a) It shall be permissible for the sending station (master side) to send blocks, containing messages or parts of messages, continuously to the receiving station (slave side) without waiting for a reply.

(b) It shall be permissible for replies, in the form of slave responses, to be transmitted by the receiving station while the sending station is sending subsequent blocks.

Note.— By use of modulo 8 numbering of blocks and replies, it shall be permissible for the sending station to send as many as seven blocks ahead of the received replies before being required to stop transmission until six or less blocks are outstanding.

(c) If a negative reply is received, the sending station (master side) shall start retransmission with the block following the last block for which the proper affirmative acknowledgement was received.

(5) Slave responses shall be according to one of the following:

(a) if a transmission block is received without error and the station is ready to receive another block, it shall send DLE, a colon, an optional prefix, and the appropriate acknowledgement ACKN (referring to the received block beginning with SOTB N, e.g. ACK0, transmitted as DLE0 is used as the affirmative reply to the block numbered SOTB0, DLE1 for SOTB1, etc.);

(b) if a transmission block is not acceptable, the receiving station shall send DLE, a colon, an optional prefix, and NAK.

(6) Slave responses shall be interleaved between message blocks and transmitted at the earliest possible time.

23.3.6.6.3.4.3 LINK TERMINATION PROCEDURE

(1) If the link has been established for message transfers in either or both directions, the sending of EOT by a station shall signal the end of message transfers in that direction. To resume message transfers after sending EOT, the link shall be re-established in that direction.

(2) EOT shall only be transmitted by a station after all outstanding slave responses have been received or otherwise accounted for.

23.3.6.6.3.4.4 CIRCUIT DISCONNECTION

On switched connections, the data links in both directions shall be terminated before the connection is cleared. In addition, the station initiating clearing of the connection shall first announce its intention to do so by transmitting the two-character sequence DLE EOT, followed by any other signals required to clear the connection.

23.3.6.6.3.5 DESCRIPTION OF SYSTEM CATEGORY C (CENTRALIZED)

System category C (centralized) is one (like system category A) in which a number of stations are connected by a multipoint link and one station is designated as

the control station but (unlike system category A) provides only for centralized (computer-to-terminal) operations where message interchange (with replies) shall be constrained to occur only between the control and a selected tributary station.

23.3.6.6.3.5.1 LINK ESTABLISHMENT PROCEDURE

(1) To establish the link for transmission the control station shall either:

(a) poll one of the tributary stations to assign it master status; or

(b) assume master status and select a tributary station to assume slave status and receive a transmission according to either of two prescribed selection procedures:

(i) selection with response (see paragraph(5)); or

(ii) fast select (see paragraph(7)).

(2) Polling is accomplished by the control station sending a polling supervisory sequence consisting of a prefix identifying a single tributary station and ending in ENQ.

(3) A tributary station detecting its assigned polling supervisory sequence shall assume master status and respond in one of two ways:

(a) if the station has a message to send, it shall initiate message transfer. The control station assumes slave status;

(b) if the station has no message to send, it shall send EOT and master status shall revert to the control station.

(4) If the control station detects an invalid or no response resulting from a poll, it shall terminate by sending EOT prior to resuming polling or selection.

(5) Selection with response is accomplished by the control station assuming master status and sending a selection supervisory sequence consisting of a prefix identifying a single tributary station and ending in ENQ.

(6) A tributary station detecting its assigned selection supervisory sequence shall assume slave status and send one of two replies:

(a) if the station is ready to receive, it shall send an optional prefix followed by ACK. Upon detecting this reply, the master station shall proceed with message transfer;

(b) if the station is not ready to receive, it shall send an optional prefix followed by NAK. Upon detecting NAK, it shall be permissible for the master station to again attempt selecting the same tributary station or initiate termination by sending EOT.

Note. — If the control station receives an invalid or no reply, it is permitted to attempt again to select the same tributary or after N *retries (*N ≥ 0*) either to exit to a recovery procedure or to initiate termination by sending EOT.*

(7) Fast select is accomplished by the control station assuming master status and sending a selection supervisory sequence, and without ending this transmission with ENQ or waiting for the selected tributary to respond, proceeding directly to message transfer.

23.3.6.6.3.5.2 MESSAGE TRANSFER PROCEDURE

(1) The station with master status shall send a single message to the station with slave status and wait for a reply.

(2) The message transmission shall:

(a) begin with:

(i) SOH if the message has a heading,

(ii) STX if the message has no heading; and

(b) be continuous, ending with ETX, immediately followed by BCC.

(3) The slave station, upon detecting ETX followed by BCC, shall send one of two replies:

(a) if the messages were accepted and the slave station is ready to receive another message, it shall send an optional prefix followed by ACK. Upon detecting ACK, the master station shall be permitted either to transmit the next message or initiate termination.

(b) if the message was not accepted and the slave station is ready to receive another message, it shall send an optional prefix followed by NAK. Upon detecting NAK, the master station may either transmit another message or initiate termination. Following the NAK reply, the next message transmitted need not be a retransmission of the message that was not accepted.

(4) If the master station receives an invalid or no reply to a message, it shall be permitted to send a delivery verification supervisory sequence consisting of an optional prefix followed by ENQ. Upon receipt of a delivery verification supervisory sequence, the slave station repeats its last reply.

(5) *N* retries ($N \geq 0$) may be made by the master station in order to get a valid slave reply. If a valid reply is not received after *N* retries, the master station exits to a recovery procedure.

23.3.6.6.3.5.3 LINK TERMINATION PROCEDURE

The station with master status shall transmit EOT to indicate that it has no more messages to transmit. EOT shall negate the master/slave status of both stations and return master status to the control station.

23.3.6.6.4 GROUND-GROUND BIT-ORIENTED DATA LINK CONTROL PROCEDURES

Note. — The provisions of this section pertain to ground-ground data interchange applications using bit-oriented data link control procedures enabling transparent, synchronous transmission that is independent of any encoding; data link control functions are accomplished by interpreting designated bit positions in the transmission envelope of a frame.

(1) The following descriptions shall apply to data link applications contained in this section:

(a) Bit-oriented data link control procedures enable transparent transmission that is independent of any encoding.

(b) A data link is the logical association of two interconnected stations, including the communication control capability of the interconnected stations.

(c) A station is a configuration of logical elements, from or to which messages are transmitted on a data link, including those elements which control the message flow on the link via communication control procedures.

(d) A combined station sends and receives both commands and responses and is responsible for control of the data link.

(e) Data communication control procedures are the means used to control and protect the orderly interchange of information between stations on a data link.

(f) A component is defined as a number of bits in a prescribed order within a sequence for the control and supervision of the data link.

(g) An octet is a group of 8 consecutive bits.

(h) A sequence is one or more components in prescribed order comprising an integral number of octets.

(i) A field is a series of a specified number of bits or specified maximum number of bits which performs the functions of data link or communications control or constitutes data to be transferred.

(j) A frame is a unit of data to be transferred over the data link, comprising one or more fields in a prescribed order.

(k) A common ICAO data interchange network (CIDIN) switching centre is that part of an automatic AFTN switching centre which provides for the entry, relay, and exit centre functions using the bit-oriented link and CIDIN network procedures specified in this section and includes the appropriate interface(s) with other parts of the AFTN and with other networks.

23.3.6.6.4.1 BIT-ORIENTED DATA LINK CONTROL PROCEDURES FOR POINT-TO-POINT, GROUND-GROUND DATA INTERCHANGE APPLICATIONS EMPLOYING SYNCHRONOUS TRANSMISSION FACILITIES

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(1) *Frame format.* Frames shall contain not less than 32 bits, excluding the opening and closing flags, and shall conform to the following format:

FLAG F	ADDRESS A	CONTROL C	INFORMATION I	FCS	FLAG F

(2) A frame shall consist of an opening flag (F), an address field (A), a control field (C), an optional information field (I), a frame check sequence (FCS), and a closing flag sequence (F), and shall be transmitted in that order.

Note. — In relation to CIDIN, the opening flag, the fields A and C, the FCS and the closing flag form together the Data Link Control Field (DLCF). The field I is denoted as the Link Data Field (LDF).

(3) The flag (F) shall be the 8-bit sequence 01111110 which delimits the beginning and ending of each frame. It shall be permissible for the closing flag of a frame to also serve as the opening flag of the next frame.

(4) The address (A) field shall consist of one octet, excluding 0 bits added to achieve transparent transmission, which shall contain the link address of the combined station.

(5) The control (C) field shall consist of one octet, excluding 0 bits added to achieve transparent transmission, and shall contain the commands, responses, and frame sequence number components for the control of the data link.

(6) The information (I) field shall contain digital data which may be presented in any code or sequence but shall not exceed a maximum of 259 octets, excluding 0 bits added to achieve transparent transmission. The I field shall always be a multiple of 8 bits in length.

(7) The frame check sequence (FCS) shall consist of two octets, excluding 0 bits added to achieve transparent transmission, and shall contain the error detecting bits.

(8) A frame check sequence (FCS) shall be included in each frame for the purpose of error checking.

(9) The error checking algorithm shall be a cyclic redundancy check (CRC).

(10) The CRC polynomial ($P(x)$) shall be

$$x^{16} + x^{12} + x^5 + 1.$$

(11) The FCS shall be a 16-bit sequence. This FCS shall be the ones' complement of the remainder, $R(x)$, obtained from the modulo 2 division of

$$x^{16}[G(x)] + x^{K}(x^{15} + x^{14} + x^{13} + \ldots + x^{2} + x^{1} + 1)$$

by the CRC polynomial, $P(x)$.

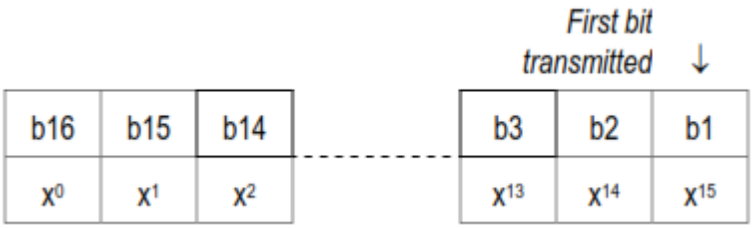
$G(x)$ shall be the contents of the frame existing between, but including neither, the final bit of the opening flag nor the first bit of the FCS, excluding bits inserted for transparent transmission.

K shall be the length of $G(x)$ (number of bits).

(12) The generation and checking of the FCS accumulation shall be as follows:

(a) the transmitting station shall initiate the FCS accumulation with the first (least significant) bit of the address (A) field and shall include all bits up to and including the last bit preceding the FCS sequence, but shall exclude all 0 bits (if any) inserted to achieve transparent transmission;

(b) upon completion of the accumulation the FCS shall be transmitted, starting with bit b1 (highest order coefficient) and proceeding in sequence to bit b16 (lowest order coefficient) as shown below;



(c) the receiving station shall carry out the cyclic redundancy check (CRC) on the content of the frame commencing with the first bit received following the opening flag, and shall include all bits up to and including the last bit preceding the closing flag, but shall exclude all 0 bits (if any) deleted according to the rules for achievement of transparency;

(d) upon completion of the FCS accumulation, the receiving station shall examine the remainder. In the absence of transmission error, the remainder shall be 1111000010111000 (x^0 through x^{15}, respectively).

(13) *Achievement of transparency.* The frame format contents (A, C, link data field, and FCS) shall be capable of containing any bit configuration.

(14) The following rules shall apply to all frame contents, except flag sequences:

(a) the transmitting station shall examine the frame contents before transmission, and shall insert a single 0 bit immediately following each sequence of 5 consecutive 1 bits;

(b) the receiving station shall examine the received frame contents for patterns consisting of 5 consecutive 1 bits immediately followed by one (or more) 0 bit(s) and shall remove the 0 bit which directly follows 5 consecutive 1 bits.

(15) *Special transmission sequences and related link states.* In addition to employing the prescribed repertoire of commands and responses to manage the interchange of data and control information, stations shall use the following conventions to signal the indicated conditions:

(a) *Abort* is the procedure by which a station in the process of sending a frame ends the frame in an unusual manner such that the receiving station shall ignore the frame. The conventions for aborting a frame shall be:

(i) transmitting at least seven, but less than fifteen, one bits (with no inserted zeros);

(ii) receiving seven one bits.

(b) Active link state. A link is in an active state when a station is transmitting a frame, an abort sequence, or interframe time fill. When the link is in the active state, the right of the transmitting station to continue transmission shall be reserved.

(c) Interframe time fill. Interframe time fill shall be accomplished by transmitting continuous flags between frames. There is no provision for time fill within a frame.

(d) Idle link state. A link is in an idle state when a continuous one condition is detected that persists for 15 bit times, or longer. Idle link time fill shall be a continuous one condition on the link.

(e) Invalid frame. An invalid frame is one that is not properly bounded by two flags or one which is shorter than 32 bits between flags.

23.3.6.6.4.1.1 MODES

(1) Operational mode. The operational mode shall be the asynchronous balanced mode (ABM).

(2) It shall be permissible for a combined station in ABM to transmit without invitation from the associated station.

(3) A combined station in ABM shall be permitted to transmit any command or response type frame except DM.

(4) Non-operational mode. The non-operational mode shall be the asynchronous disconnected mode (ADM) in which a combined station is logically disconnected from the data link.

(5) It shall be permissible for a combined station in ADM to transmit without invitation from the associated station.

(6) A combined station in ADM shall transmit only SABM, DISC, UA and DM frames. (See 23.3.6.6.4.1.1(13) for a description of the commands and responses to which these frame types refer.)

(7) A combined station in ADM shall transmit a DM when a DISC is received, and shall discard all other received command frames except SABM. If a discarded command frame has the P bit set to “1”, the combined station shall transmit a DM with the F bit set to “1”.

(8) Control field functions and parameters. Control fields contain a command or a response and sequence numbers where applicable. Three types of control fields shall be used to perform:

(a) numbered information transfer (I-frames);

(b) numbered supervisory functions (S-frames); and

(c) unnumbered control functions (U-frames).

The control field formats shall be as shown in Table 8-5. The functional frame designation associated with each type control field as well as the control field parameters employed in performing these functions shall be described in the following paragraphs.

(9) The I-frame type is used to perform information transfers. Except for some special cases it is the only format which shall be permitted to contain an information field.

(10) The S-frame type is used for supervisory commands and responses that perform link supervisory control functions such as acknowledge information frames, request transmission or retransmission of information frames, and to request a temporary suspension of transmission of I-frames. No information field shall be contained in the S-frame.

(11) The U-frame type is used for unnumbered commands and responses that provide additional link control functions. One of the U-frame responses, the frame reject (FRMR) response, shall contain an information field; all other frames of the U-frame type shall not contain an information field.

(12) The station parameters associated with the three control field types shall be as follows:

(a) *Modulus.* Each I-frame shall be sequentially numbered with a send sequence count, *N(S),* having value 0 through modulus minus one (where modulus is the modulus of the sequence numbers). The modulus shall be 8. The maximum number of sequentially numbered I-frames that a station shall have outstanding (i.e. unacknowledged) at any given time shall never exceed one less than the modulus of the sequence numbers. This restriction on the number of outstanding frames is to prevent any ambiguity in the association of transmission frames with sequence numbers during normal operation and/or error recovery.

(b) The send state variable *V*(*S*) shall denote the sequence number of the next in-sequence I-frame to be transmitted:

(i) The send state variable shall take on the value 0 through modulus minus one (modulus is the modulus of the sequence numbering and the numbers cycle through the entire range).

(ii) The value of *V*(*S*) shall be incremented by one with each successive in-sequence I-frame transmission, but shall not exceed the value of *N*(*R*) contained in the last received frame by more than the

maximum permissible number of outstanding I-frames (*k*). See i) below for the definition of *k*.

(c) Prior to transmission of an in-sequence I-frame, the value of *N*(*S*) shall be updated to equal the value of *V*(*S*).

(d) The receive state variable *V*(*R*) shall denote the sequence number of the next in-sequence I-frame to be received.

(i) *V*(*R*) shall take on the values 0 through modulus minus one.

(ii) The value of *V*(*R*) shall be incremented by one after the receipt of an error-free, in-sequence I-frame whose send sequence number *N*(*S*), equals *V*(*R*).

(e) All I-frames and S-frames shall contain *N*(*R*), the expected sequence number of the next received frame. Prior to transmission of either an I or an S type frame, the value of *N*(*R*) shall be updated to equal the current value of the receive state variable. *N*(*R*) indicates that the station transmitting the *N*(*R*) has correctly received all I-frames numbered up to and including *N*(*R*) – 1.

(f) Each station shall maintain an independent send state variable, *V*(*S*), and receive state variable, *V*(*R*), on the I-frames it sends and receives. That is, each combined station shall maintain a *V*(*S*) count on the I-frames it transmits and a *V*(*R*) count on the I-frames it has correctly received from the remote combined station.

(g) The poll (P/F) bit shall be used by a combined station to solicit (poll) a response or sequence of responses from the remote combined station.

(h) The final (P/F) bit shall be used by the remote combined station to indicate the response frame transmitted as the result of a soliciting (poll) command.

(i) The maximum number (*k*) of sequentially numbered I-frames that a station may have outstanding (i.e. unacknowledged) at any given time is a station parameter which shall never exceed the modulus.

Note.— k *is determined by station buffering limitations and shall be the subject of bilateral agreement at the time of circuit establishment.*

(13) Commands and responses. It shall be permissible for a combined station to generate either commands or responses. A command shall contain the remote station address while a response shall contain the sending station address. The

mnemonics associated with all of the commands and responses prescribed for each of the three frame types (I, S, and U) and the corresponding encoding of the control field are as shown in Table 8-6.

(14) The I-frame command provides the means for transmitting sequentially numbered frames, each of which shall be permitted to contain an information field.

(15) The S-frame commands and responses shall be used to perform numbered supervisory functions (such as acknowledgement, polling, temporary suspension of information transfer, or error recovery).

(16) The receive ready command or response (RR) shall be used by a station to:

(a) indicate that it is ready to receive an I-frame;

(b) acknowledge previously received I-frames numbered up to and including $N(R) - 1$;

(c) clear a busy condition that was initiated by the transmission of RNR.

Note. — It is permissible for a combined station to use the RR command to solicit a response from the remote combined station with the poll bit set to "1".

(17) It shall be permissible to issue a reject command or response (REJ) to request retransmission of frames starting with the I-frame numbered $N(R)$ where:

(a) I-frames numbered $N(R) - 1$ and below are acknowledged;

(b) additional I-frames pending initial transmission are to be transmitted following the retransmitted I-frame(s);

(c) only one REJ exception condition, from one given station to another station, shall be established at any given time: another REJ shall not be issued until the first REJ exception condition has been cleared;

(d) the REJ exception condition is cleared (reset) upon the receipt of an I-frame with an $N(S)$ count equal to the $N(R)$ of the REJ command/response.

(18) The receive not ready command or response (RNR) shall be used to indicate a busy condition, i.e. temporary inability to accept additional incoming I-frames, where:

(a) frames numbered up to and including $N(R) - 1$ are acknowledged;

(b) frame *N*(*R*) and any subsequent I-frames received, if any, are not acknowledged (the acceptance status of these frames shall be indicated in subsequent exchanges);

(c) the clearing of a busy condition shall be indicated by the transmission of an RR, REJ, SABM, or UA with or without the P/F bit set to "1".

(19) A station receiving an RNR frame when in the process of transmitting shall stop transmitting I-frames at the earliest possible time.

(20) Any REJ command or response which was received prior to the RNR shall be actioned before the termination of transmission.

(21) It shall be permissible for a combined station to use the RNR command with the poll bit set to "1" to obtain a supervisory frame with the final bit set to "1" from the remote combined station.

(22) It shall be permissible for the selective reject command or response (SREJ) to be used to request retransmission of the single I-frame numbered *N*(*R*) where:

(a) frames numbered up to *N*(*R*) – 1 are acknowledged; frame *N*(*R*) is not accepted; the only I-frames accepted are those received correctly and in sequence following the I-frame requested; the specific I-frame to be retransmitted is indicated by the *N*(*R*) in the SREJ command/response;

(b) the SREJ exception condition is cleared (reset) upon receipt of an I-frame with an *N*(*S*) count equal to the *N*(*R*) of the SREJ;

(c) after a station transmits a SREJ it is not permitted to transmit SREJ or REJ for an additional sequence error until the first SREJ error condition has been cleared;

(d) I-frames that have been permitted to be transmitted following the I-frame indicated by the SREJ are not retransmitted as the result of receiving a SREJ; and

(e) it is permissible for additional I-frames pending initial transmission to be transmitted following the retransmission of the specific I-frame requested by the SREJ.

(23) The U-frame commands and responses shall be used to extend the number of link control functions. Transmitted U-frames do not increment the sequence

counts at either the transmitting or receiving station:

(a) The U-frame mode-setting commands (SABM, and DISC) shall be used to place the addressed station in the appropriate response mode (ABM or ADM) where:

(i) upon acceptance of the command, the station send and receive state variables, *V*(*S*) and *V*(*R*), are set to zero;

(ii) the addressed station confirms acceptance at the earliest possible time by transmission of a single unnumbered acknowledgement, UA;

(iii) previously transmitted frames that are unacknowledged when the command is actioned remain unacknowledged;

(iv) the DISC command is used to perform a logical disconnect, i.e. to inform the addressed combined station that the transmitting combined station is suspending operation. No information field shall be permitted with the DISC command.

(b) The unnumbered acknowledge response (UA) shall be used by a combined station to acknowledge the receipt and acceptance of an unnumbered command. Received unnumbered commands are not actioned until the UA response is transmitted. No information field shall be permitted with the UA response.

(c) The frame reject response (FRMR), employing the information field described below, shall be used by a combined station in the operational mode (ABM) to report that one of the following conditions resulted from the receipt of a frame without an FCS error:

(i) a command/response that is invalid or not implemented;

(ii) a frame with an information field that exceeds the size of the buffer available;

(iii) a frame having an invalid *N*(*R*) count.

Note. — An invalid N(R) *is a count which points to an I-frame which has previously been transmitted and acknowledged or to an I-frame which has not been transmitted and is not the next sequential I-frame pending transmission.*

(d) The disconnected mode response (DM) shall be used to report a non-operational status where the station is logically disconnected from the link. No information field shall be permitted with the DM response.

Note. — The DM response shall be sent to request the remote combined station to issue a mode-setting command or, if sent in response to the reception of a mode-setting command, to inform the remote combined station that the transmitting station is still in ADM and cannot action the mode-setting command.

23.3.6.6.4.2 EXCEPTION CONDITION REPORTING AND RECOVERY

(1) This section specifies the procedures that shall be employed to effect recovery following the detection or occurrence of an exception condition at the link level. Exception conditions described are those situations that may occur as the result of transmission errors, station malfunction, or operational situations.

(2) Busy condition. A busy condition occurs when a station temporarily cannot receive or continue to receive I-frames due to internal constraints, e.g. due to buffering limitations. The busy condition shall be reported to the remote combined station by the transmission of an RNR frame with the N(R) number of the next I-frame that is expected. It shall be permissible for traffic pending transmission at the busy station to be transmitted prior to or following the RNR.

Note.— The continued existence of a busy condition must be reported by retransmission of RNR at each P/F frame exchange.

(3) Upon receipt of an RNR, a combined station in ABM shall cease transmitting I-frames at the earliest possible time by completing or aborting the frame in process. The combined station receiving an RNR shall perform a time-out operation before resuming asynchronous transmission of I-frames unless the busy condition is reported as cleared by the remote combined station. If the RNR was received as a command with the P bit set to “1”, the receiving station shall respond with an S-frame with the F bit set to “1”.

(4) The busy condition shall be cleared at the station which transmitted the RNR when the internal constraint ceases. Clearance of the busy condition shall be reported to the remote station by transmission of an RR, REJ, SABM, or UA frame (with or without the P/F bit set to “1”).

(5) N(S) sequence error. An N(S) sequence exception shall be established in the

receiving station when an I-frame that is received error free (no FCS error) contains an N(S) sequence number that is not equal to the receive variable V(R) at the receiving station. The receiving station shall not acknowledge (shall not increment its receive variable V(R)) the frame causing the sequence error, or any I-frames which may follow, until an I-frame with the correct N(S) number is received. A station that receives one or more I-frames having sequence errors, but which are otherwise error free, shall accept the control information contained in the N(R) field and the P/F bit to perform link control functions, e.g. to receive acknowledgement of previously transmitted I-frames (via the N(R)), to cause the station to respond (P bit set to "1").

(6) The means specified in 23.3.6.6.4.2(7) and 23.3.6.6.4.2(8) shall be available for initiating the retransmission of lost or errored I-frames following the occurrence of a sequence error.

(7) Where the REJ command/response is used to initiate an exception recovery following the detection of a sequence error, only one "sent REJ" exception condition, from one station to another station, shall be established at a time. A "sent REJ" exception shall be cleared when the requested I-frame is received. A station receiving REJ shall initiate sequential (re)transmission of I-frames starting with the I-frame indicated by the N(R) contained in the REJ frame.

FRMR INFORMATION FIELD BITS FOR BASIC (SABM) OPERATION

First bit transmitted

1 8	9	10 12	13	14 16	17	18	19	20	21 24
rejected basic control field	0	*V(S)*	*v*	*V(R)*	*w*	*x*	*y*	*z*	set to zero

where:

rejected basic control field is the control field of the received frame which caused the frame reject;

V(S) is the current value of the send state variable at the remote combined station reporting the error condition (bit 10 = low order bit);

V(R) is the current value of the receive state variable at the remote combined station reporting the error condition (bit 14 = low order bit);

v set to "1" indicates that the received frame which caused rejection was a response;

w set to "1" indicates that the control field received and returned in bits 1 through 8 are invalid or not implemented;

x set to "1" indicates that the control field received and returned in bits 1 through 8 was considered invalid because the frame contained an information field which is not permitted with this command. Bit *w* must be set to "1" in conjunction with this bit;

y set to "1" indicates that the information field received exceeded the maximum information field length which can be accommodated by the station reporting the error condition. This bit is mutually exclusive with bits *w* and *x* above;

z set to "1" indicates that the control field received and returned in bits 1 through 8 contained an invalid *N(R)* count. This bit is mutually exclusive with bit *w*.

(8) In the event a receiving station, due to a transmission error, does not receive (or receives and discards) a single I-frame or the last I-frame(s) in a sequence of I-frames, it shall not detect an out-of-sequence exception and, therefore, shall not transmit REJ. The station which transmitted the unacknowledged I-frame(s) shall, following the completion of a system-specified time-out period, take appropriate recovery action to determine the sequence number at which retransmission must begin.

(9) A combined station which has timed out waiting for a response shall not retransmit all unacknowledged frames immediately. The station may enquire about status with a supervisory frame.

Note 1.— If a station does retransmit all unacknowledged I-frames after a time-out, it must be prepared to receive a subsequent REJ frame with an N(R) *greater than its send variable* V(S).

Note 2.— Since contention may occur in the case of two-way alternate communications in ABM or ADM, the time-out interval employed by one combined station must be greater than that employed by the other combined station so as to permit contention to be resolved.

(10) *FCS error.* Any frame with an FCS error shall not be accepted by the receiving station and will be discarded. No action shall be taken by the receiving station as the result of that frame.

(11) *Frame reject exception condition.* A frame reject exception condition shall be established upon the receipt of an error-free frame which contains an invalid or unimplemented control field, an invalid *N(R),* or an information field which has exceeded the maximum established storage capability. If a frame reject exception condition occurs in a combined station, the station shall either:

(a) take recovery action without reporting the condition to the remote combined station; or

(b) report the condition to the remote combined station with a FRMR response. The remote station will then be expected to take recovery action; if, after waiting an appropriate time, no recovery action appears to have been taken, the combined station reporting the frame reject exception condition may take recovery action.

Recovery action for balanced operation includes the transmission of an implemented mode-setting command. Higher level functions may also be involved in the recovery.

(12) *Mode-setting contention.* A mode-setting contention situation exists when a combined station issues a mode- setting command and, before receiving an appropriate response (UA or DM), receives a mode-setting command from the remote combined station. Contention situations shall be resolved in the following manner:

(a) when the send and receive mode-setting commands are the same, each combined station shall send a UA response at the earliest respond opportunity. Each combined station shall either enter the indicated mode

immediately or defer entering the indicated mode until receiving a UA response. In the latter case, if the UA response is not received:

(i) the mode may be entered when the response timer expires; or

(ii) the mode-setting command may be reissued.

(b) when the mode-setting commands are different, each combined station shall enter ADM and issue a DM response at the earliest respond opportunity. In the case of DISC contention with a different mode-setting command, no further action is required.

(13) *Time-out functions.* Time-out functions shall be used to detect that a required or expected acknowledging action or response to a previously transmitted frame has not been received. Expiration of the time-out function shall initiate appropriate action, e.g. error recovery or reissuance of the P bit. The duration of the following time-out functions is system dependent and subject to bilateral agreement:

(a) combined stations shall provide a time-out function to determine that a response frame with F bit set to "1" to a command frame with the P bit set to "1" has not been received. The time-out function shall automatically cease upon receipt of a valid frame with the F bit set to "1";

(b) a combined station which has no P bit outstanding, and which has transmitted one or more frames for which responses are anticipated shall start a time-out function to detect the no-response condition. The time-out function shall cease when an I- or S-frame is received with the *N*(*R*) higher than the last received *N*(*R*) (actually acknowledging one or more I-frames).

23.3.6.6.5 COMMON ICAO DATA INTERCHANGE NETWORK (CIDIN)

23.3.6.6.5.1 INTRODUCTION

(1) CIDIN entry and exit centres or stations shall be used to connect application entities to the CIDIN.

Note 1.— The common ICAO data interchange network (CIDIN) is an element of the aeronautical fixed service (AFS) which uses bit-oriented procedures, store and forward techniques and packet switching techniques based on CCITT Recommendation X.25 to carry messages of specific applications of the AFS such as AFTN and operational meteorological information (OPMET).

Note 2.— The CIDIN provides a reliable common network service for the conveyance of application messages in binary or text form to air traffic service providers and aircraft operating agencies.
Note 3. — The interfacing between CIDIN and application entities is a matter for local implementation.

(2) CIDIN relay centres shall be used to forward packets between CIDIN entry and exit centres or stations which are not directly connected.

23.3.6.6.5.2 GENERAL

There shall be four protocol levels defined to control the transfer of messages between CIDIN switching centres:

(a) the data link protocol level

(b) the X.25 packet protocol level

(c) the CIDIN packet protocol level

(d) the CIDIN transport protocol level.

Note. — The relationship of the terms used is shown in Figures 8-1 and 8-2.

23.3.6.6.5.2.1 THE DATA LINK PROTOCOL LEVEL

(1) X.25 packets to be transferred between two CIDIN switching centres or a CIDIN switching centre and a packet switched data network, shall be formatted into data link frames.

(2) Each data link frame shall consist of a data link control field (DLCF), possibly followed by a link data field, and shall be terminated by a frame check sequence and flag (being the second part of the DLCF). If a link data field is present, the frame shall be denoted as an information frame.

(3) X.25 packets shall be transmitted within the link data field of information frames.

Only one packet shall be contained in the link data field.

23.3.6.6.5.2.2 THE X.25 PACKET PROTOCOL LEVEL

(1) Each CIDIN packet to be transferred on CIDIN circuits between CIDIN switching centres shall be formatted into one X.25 packet. When a packet switched data network is used, it shall be permissible to format the CIDIN packet into more than one X.25 packet.

(2) The integrity of each CIDIN packet shall be preserved by the X.25 packet protocol by mapping each CIDIN packet onto one complete X.25 packet sequence, as defined in CCITT Recommendation X.25.

(3) Each X.25 packet shall consist of an X.25 packet header, possibly followed by a user data field (UDF).

(4) The X.25 packet protocol is based on the application of virtual circuit procedures. A virtual circuit shall be defined as a logical path between two CIDIN switching centres. If a packet switched data network is used to interconnect two CIDIN switching centres, the procedure shall provide full compatibility with the procedures to be followed for virtual circuits according to CCITT Recommendation X.25.

23.3.6.6.5.2.3 THE CIDIN PACKET PROTOCOL LEVEL

(1) Each transport header and the associated segment shall be preceded by a CIDIN packet header. No further segmentation of the CIDIN message shall be used between transport protocol level and CIDIN packet protocol level. Both headers, therefore, shall be used in combination. Together they shall be referred to as the communications control field (CCF). Together with the message segment they form CIDIN packets that shall be transmitted from entry centre to exit centre(s), when necessary through one or more relay centres, as an entity.

(2) CIDIN packets of one CIDIN message shall be relayed independently via predetermined routes through the network thus allowing alternative routing on a CIDIN packet basis as necessary.

(3) The CIDIN packet header shall contain information to enable relay centres to

handle CIDIN packets in the order of priority, to transmit the CIDIN packets on the proper outgoing circuit(s) and to duplicate or multiplicate CIDIN packets when required for multiple dissemination purposes. The information shall be sufficient to apply address stripping on the exit addresses as well as on the addressee indicators of messages in AFTN format.

23.3.6.6.5.2.4 THE TRANSPORT PROTOCOL LEVEL

(1) Information exchanged over the CIDIN shall be transmitted as CIDIN messages.

(2) The length of a CIDIN message shall be defined by the CIDIN packet sequence number (CPSN). The maximum permissible length is 2^{15} packets which in effect results in no practical limitation.

(3) If the length of a CIDIN message and its transport and packet headers (as defined below) exceeds 256 octets, the message shall be divided into segments and placed in the CIDIN user data field of CIDIN packets. Each segment shall be preceded by a transport header containing information to enable the re-assembly of the CIDIN message at the exit centre(s) from individually received segments and to determine further handling of the received complete CIDIN message.

(4) All segments of one CIDIN message shall be provided with the same message identification information in the transport header. Only the CPSN and final CIDIN packet (FCP) indicator shall be different.

(5) Recovery of messages shall be performed at the transport level.

Table 8-1. International Telegraph Alphabets No. 2 and No. 3

Number of signal	*Letter case*	*Figure case*	*Impulses 5-unit code*		
			Start	*12345*	*Stop*
				International Code No. 2	
1	A	—	A	ZZAAA	Z
2	B	?	A	ZAAZZ	Z
3	C	:	A	AZZZA	Z
4	D	Note 1	A	ZAAZA	Z
5	E	3	A	ZAAAA	Z
6	F		A	ZAZZA	Z
7	G		A	AZAZZ	Z
8	H		A	AAZAZ	Z
9	I	8	A	AZZAA	Z
10	J	Attention signal	A	ZZAZA	Z
11	K	(	A	ZZZZA	Z
12	L	)	A	AZAAZ	Z
13	M	.	A	AAZZZ	Z
14	N	,	A	AAZZA	Z
15	O	9	A	AAAZZ	Z
16	P	0	A	AZZAZ	Z
17	Q	1	A	ZZZAZ	Z
18	R	4	A	AZAZA	Z
19	S	’	A	ZAZAA	Z
20	T	5	A	AAAAZ	Z
21	U	7	A	ZZZAA	Z
22	V	=	A	AZZZZ	Z
23	W	2	A	ZZAAZ	Z
24	X	/	A	ZAZZZ	Z
25	Y	6	A	ZAZAZ	Z
26	Z	+	A	ZAAAZ	Z
27	carriage return		A	AAAZA	Z
28	line feed		A	AZAAA	Z
29	letters		A	ZZZZZ	Z
30	figures		A	ZZAZZ	Z
31	space		A	AAZAA	Z
32	unperforated tape		A	AAAAA	Z
33	signal repetition				
34	signal α				
35	signal ß				

Sign	*Closed circuit*	*Double current*
A	No current	Negative current
Z	Positive current	Positive current

Table 8-2. International Alphabet No. 5 (IA-5)

(international reference version)

				b_7	0	0	0	0	1	1	1	1
				b_6	0	0	1	1	0	0	1	1
				b_5	0	1	0	1	0	1	0	1
b_4	b_3	b_2	b_1		0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	TC_7 (DLE)	SP	0	@	P	`	p
0	0	0	1	1	TC_1 (SOH)	DC_1	!	1	A	Q	a	q
0	0	1	0	2	TC_2 (STX)	DC_2	" ④	2	B	R	b	r
0	0	1	1	3	TC_3 (ETX)	DC_3	#	3	C	S	c	s
0	1	0	0	4	TC_4 (EOT)	DC_4	¤ ②	4	D	T	d	t
0	1	0	1	5	TC_5 (ENQ)	TC_8 (NAK)	%	5	E	U	e	u
0	1	1	0	6	TC_6 (ACK)	TC_9 (SYN)	&	6	F	V	f	v
0	1	1	1	7	BEL	TC_{10} (ETB)	' ④	7	G	W	g	w
1	0	0	0	8	FE_0 (BS)	CAN	(	8	H	X	h	x
1	0	0	1	9	FE_1 (HT)	EM	)	9	I	Y	i	y
1	0	1	0	10	$FE_2$① (LF)	SUB	*	:	J	Z	j	z
1	0	1	1	11	FE_3 (VT)	ESC	+	;	K	[	k	{
1	1	0	0	12	FE_4 (FF)	IS_4 (FS)	④ ,	<	L	\	l	|
1	1	0	1	13	$FE_5$① (CR)	IS_3 (GS)	–	=	M	]	m	}
1	1	1	0	14	SO	IS_2 (RS)	.	>	N	^ ④	n	¯ ③
1	1	1	1	15	SI	IS_1 (US)	/	?	O	__	o	DEL

NOTES

Note 1.—The format effectors are intended for equipment in which horizontal and vertical movements are effected separately. If equipment requires the action of CARRIAGE RETURN to be combined with a vertical movement, the format effector for that vertical movement may be used to effect the combined movement. Use of FE 2 for a combined CR and LF operation is not allowed for international transmission on AFS networks.

Note 2.—The symbol ¤ does not designate the currency of a specific country.

Note 3.—Position 7/14 is used for graphic character ¯ (OVERLINE), the graphical representation of which may vary according to national use to represent (TILDE) or another diacritical sign provided that there is no risk of confusion with another graphic character included in the table.

Note 4.—The graphic characters in position 2/2, 2/7, 2/12 and 5/14 have respectively the significance of QUOTATION MARK, APOSTROPHE, COMMA and UPWARD ARROW HEAD; however, these characters take on the significance of the diacritical signs DIAERESIS, ACUTE ACCENT, CEDILLA and CIRCUMFLEX ACCENT when they are preceded or followed by the BACKSPACE character (0/8).

Note 5.—When graphical representation of the control characters of IA-5 is required, it is permissible to use the symbols specified in International Organization for Standardization (ISO) Standard 2047-1975.

CONTROL CHARACTERS

Abbreviation	*Meaning*	*Position in the code table*
ACK	Acknowledge	0/6
BEL	Bell	0/7
BS	Backspace	0/8
CAN	Cancel	1/8
CR	Carriage return*	0/13
DC	Device control	–
DEL	Delete	7/15
DLE	Data link escape	1/0
EM	End of medium	1/9
ENQ	Enquiry	0/5
EOT	End of transmission	0/4
ESC	Escape	1/11
ETB	End of transmission block	1/7
ETX	End of text	0/3
FE	Format effector	–
FF	Form feed	0/12
FS	File separator	1/12
GS	Group separator	1/13
HT	Horizontal tabulation	0/9
IS	Information separator	–
LF	Line feed*	0/10
NAK	Negative acknowledge	1/5
NUL	Null	0/0
RS	Record separator	1/14
SI	Shift-in	0/15
SO	Shift-out	0/14
SOH	Start of heading	0/1
SP	Space	2/0
STX	Start of text	0/2
SUB	Substitute character	1/10
SYN	Synchronous idle	1/6
TC	Transmission control	–
US	Unit separator	1/15
VT	Vertical tabulation	0/11

GRAPHIC CHARACTERS

Graphic	*Note*	*Name*	*Position in the code table*
(space)		Space (*see* 7.2)	2/0
!		Exclamation mark	2/1
"	4	Quotation mark, Diaeresis	2/2
#		Number sign	2/3
¤	2	Currency sign	2/4
%		Percent sign	2/5
&		Ampersand	2/6
'	4	Apostrophe, Acute accent	2/7
(		Left parenthesis	2/8
)		Right parenthesis	2/9
*		Asterisk	2/10
+		Plus sign	2/11
,	4	Comma, Cedilla	2/12
–		Hyphen, Minus sign	2/13
.		Full stop (period)	2/14
/		Solidus	2/15
:		Colon	3/10
;		Semi-colon	3/11
<		Less-than sign	3/12
=		Equal sign	3/13
>		Greater-than sign	3/14
?		Question mark	3/15
@		Commercial 'at'	4/0
[		Left square bracket	5/11
\		Reverse solidus	5/12
]		Right square bracket	5/13
^	4	Upward arrow head, Circumflex accent	5/14
_		Underline	5/15
`		Grave accent	6/0
{		Left curly bracket	7/11
|		Vertical line	7/12
}		Right curly bracket	7/13
~	3	Overline, Tilde	7/14

* See Note 1.

DIACRITICAL SIGNS

In the character set, some printing symbols may be designed to permit their use for the composition of accented letters when necessary for general interchange of information. A sequence of three characters, comprising a letter, BACKSPACE and one of these symbols, is needed for this composition, and the symbol is then regarded as a diacritical sign. It should be noted that these symbols take on their diacritical significance only when they are preceded or followed by the BACKSPACE character: for example, the symbol corresponding to the code combination 2/7 (') normally has the significance of APOSTROPHE, but becomes the diacritical sign ACUTE ACCENT when it precedes or follows the BACKSPACE character.

NAMES, MEANINGS AND FONTS OF GRAPHIC CHARACTERS

At least one name is assigned to denote each of the graphic characters. These names are intended to reflect their customary meanings and are not intended to define or restrict the meanings of graphic characters. No particular style or font design is specified for the graphic characters.

UNIQUENESS OF CHARACTER ALLOCATION

A character allocated to a position in the table may not be placed elsewhere in the table.

FUNCTIONAL CHARACTERISTICS RELATED TO CONTROL CHARACTERS

Some definitions given below are stated in general terms and more explicit definitions of use may be needed for specific implementation of the code table on recording media or on transmission channels. These more explicit definitions and the use of these characters are the subject of ISO publications.

General designations of control characters

The general designation of control characters involves a specific class name followed by a subscript number.
They are defined as follows:

TC — *Transmission control characters* — Control characters intended to control or facilitate transmission of information over telecommunication networks.
The use of the TC characters on the general telecommunication networks is the subject of ISO publications.
The transmission control characters are:
ACK, DLE, ENQ, EOT, ETB, ETX, NAK, SOH, STX and SYN.

FE — *Format effectors* — Control characters mainly intended for the control of the layout and positioning of information on printing and/or display devices. In the definitions of specific format effectors, any reference to printing devices should be interpreted as including display devices. The definitions of format effectors use the following concept:

a) a page is composed of a number of lines of characters;

b) the characters forming a line occupy a number of positions called character positions;

c) the active position is that character position in which the character about to be processed would appear if it were to be printed. The active position normally advances one character position at a time.

The format effector characters are:
BS, CR, FF, HT, LF and VT.

DC — *Device control characters* — Control characters for the control of a local or remote ancillary device (or devices) connected to a data processing and/or telecommunication system. These control characters are not intended to control telecommunication systems; this should be achieved by the use of TCs.
Certain preferred uses of the individual DCs are given below under *Specific control characters*.

IS — *Information separators* — Control characters that are used to separate and qualify data logically. There are four such characters. They may be used either in hierarchical order or non-hierarchically; in the latter case their specific meanings depend on their applications.
When they are used hierarchically, the ascending order is:
US, RS, GS, FS.
In this case data normally delimited by a particular separator cannot be split by a higher order separator but will be considered as delimited by any higher order separator.

Specific control characters

Individual members of the classes of controls are sometimes referred to by their abbreviated class name and a subscript number (e.g. TC_5) and sometimes by a specific name indicative of their use (e.g. ENQ).

Different but related meanings may be associated with some of the control characters but in an interchange of data this normally requires agreement between the sender and the recipient.

ACK — *Acknowledge* — A transmission control character transmitted by a receiver as an affirmative response to the sender.

BEL — *Bell* — A control character that is used when there is a need to call for attention; it may control alarm or attention devices.

BS — *Backspace* — A format effector which moves the active position one character position backwards on the same line.

CAN — *Cancel* — A character, or the first character of a sequence, indicating that the data preceding it are in error. As a result these data are to be ignored. The specific meaning of this character must be defined for each application and/or between sender and recipient.

CR — *Carriage return* — A format effector which moves the active position to the first character position on the same line.

Device controls

DC_1 — A device control character which is primarily intended for turning on or starting an ancillary device. If it is not required for this purpose, it may be used to restore a device to the basic mode of operation (*see also* DC_2 and DC_3), or for any other device control function not provided by other DCs.

DC_2 — A device control character which is primarily intended for turning on or starting an ancillary device. If it is not required for this purpose, it may be used to set a device to a special mode of operation (in which case DC_1 is used to restore the device to the basic mode), or for any other device control function not provided by other DCs.

DC_3 — A device control character which is primarily intended for turning off or stopping an ancillary device. This function may be a secondary level stop, e.g. wait, pause, stand-by or halt (in which case DC_1 is used to restore normal operation). If it is not required for this purpose, it may be used for any other device control function not provided by other DCs.

DC_4 — A device control character which is primarily intended for turning off, stopping or interrupting an ancillary device. If it is not required for this purpose, it may be used for any other device control function not provided by other DCs.

Examples of use of the device controls

1) One switching
on — DC_2 off — DC_4

2) Two independent switchings
First one on — DC_2 off — DC_4
Second one on — DC_1 off — DC_3

3) Two dependent switchings
General on — DC_2 off — DC_4
Particular on — DC_1 off — DC_3

4) Input and output switching
Output on — DC_2 off — DC_4
Input on — DC_1 off — DC_3

DEL — *Delete* — A character used primarily to erase or obliterate an erroneous or unwanted character in punched tape. DEL characters may also serve to accomplish media-fill or time-fill. They may be inserted into or removed from a stream of data without affecting the information content of that stream, but then the addition or removal of these characters may affect the information layout and/or the control of equipment.

DLE — *Data link escape* — A transmission control character which will change the meaning of a limited number of contiguously following characters. It is used exclusively to provide supplementary data transmission control functions. Only graphic characters and transmission control characters can be used in DLE sequences.

EM — *End of medium* — A control character that may be used to identify the physical end of a medium, or the end of the used portion of a medium, or the end of the wanted portion of data recorded on a medium. The position of this character does not necessarily correspond to the physical end of the medium.

ENQ — *Enquiry* — A transmission control character used as a request for a response from a remote station — the response may include station identification and/or station status. When a "Who are you?" function is required on the general switched transmission network, the first use of ENQ after the connection is established shall have the meaning "Who are you?" (station identification). Subsequent use of ENQ may, or may not, include the function "Who are you?", as determined by agreement.

EOT — *End of transmission* — A transmission control character used to indicate the conclusion of the transmission of one or more texts.

ESC — *Escape* — A control character which is used to provide an additional control function. It alters the meaning of a limited number of contiguously following bit combinations which constitute the escape sequence.
Escape sequences are used to obtain additional control functions which may provide among other things graphic sets outside the standard set. Such control functions must not be used as additional transmission controls.
The use of the character ESC and of the escape sequences in conjunction with code extension techniques is the subject of an ISO Standard.

ETB — *End of transmission block* — A transmission control character used to indicate the end of a transmission block of data where data are divided into such blocks for transmission purposes.

ETX — *End of text* — A transmission control character which terminates a text.

FF — *Form feed* — A format effector which advances the active position to the same character position on a predetermined line of the next form or page.

HT — *Horizontal tabulation* — A format effector which advances the active position to the next predetermined character position on the same line.

Information separators

IS_1 (US) — A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a UNIT.

IS_2 (RS) — A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a RECORD.

IS_3 (GS) — A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a GROUP.

IS_4 (FS) — A control character used to separate and qualify data logically; its specific meaning has to be defined for each application. If this character is used in hierarchical order as specified in the general definition of IS, it delimits a data item called a FILE.

LF — *Line feed* — A format effector which advances the active position to the same character position of the next line.

NAK — *Negative acknowledge* — A transmission control character transmitted by a receiver as a negative response to the sender.

NUL — *Null* — A control character used to accomplish media-fill or time-fill. NUL characters may be inserted into or removed from a stream of data without affecting the information content of that stream, but then the addition or removal of these characters may affect the information layout and/or the control of equipment.

SI	— *Shift-in* — A control character which is used in conjunction with SHIFT-OUT and ESCAPE to extend the graphic character set of the code. It may reinstate the standard meanings of the bit combinations which follow it. The effect of this character when using code extension techniques is described in an ISO Standard.
SO	— *Shift-out* — A control character which is used in conjunction with SHIFT-IN and ESCAPE to extend the graphic character set of the code. It may alter the meaning of the bit combinations of columns 2 to 7 which follow it until a SHIFT-IN character is reached. However, the characters SPACE (2/0) and DELETE (7/15) are unaffected by SHIFT-OUT. The effect of this character when using code extension techniques is described in an ISO Standard.
SOH	— *Start of heading* — A transmission control character used as the first character of a heading of an information message.
SP	— *Space* — A character which advances the active position one character position on the same line. This character is also regarded as a non-printing graphic.
STX	— *Start of text* — A transmission control character which precedes a text and which is used to terminate a heading.
SUB	— *Substitute character* — A control character used in the place of a character that has been found to be invalid or in error. SUB is intended to be introduced by automatic means.
SYN	— *Synchronous idle* — A transmission control character used by a synchronous transmission system in the absence of any other character (idle condition) to provide a signal from which synchronism may be achieved or retained between data terminal equipment.
VT	— *Vertical tabulation* — A format effector which advances the active position to the same character position on the next predetermined line.

Table 8-3. Conversion from the International Telegraph Alphabet No. 2 (ITA-2) to the International Alphabet No. 5 (IA-5)

ITA-2 letter case of signal No.		*IA-5 column/row*		*ITA-2 figure case of signal No.*		*IA-5 column/row*	
1	A	4/1	A	1	–	2/13	–
2	B	4/2	B	2	?	3/15	?
3	C	4/3	C	3	:	3/10	:
4	D	4/4	D	4		3/15	?
5	E	4/5	E	5	3	3/3	3
6	F	4/6	F	6		3/15	?
7	G	4/7	G	7		3/15	?
8	H	4/8	H	8		3/15	?
9	I	4/9	I	9	8	3/8	8
10	J	4/10	J	10	Attention Signal *(Note 3)*	0/7	Bel
11	K	4/11	K	11	(	2/8	(
12	L	4/12	L	12	)	2/9	)
13	M	4/13	M	13	.	2/14	.
14	N	4/14	N	14	,	2/12	,
15	O	4/15	O	15	9	3/9	9
16	P	5/0	P	16	0	3/0	0
17	Q	5/1	Q	17	1	3/1	1
18	R	5/2	R	18	4	3/4	4
19	S	5/3	S	19	’	2/7	’
20	T	5/4	T	20	5	3/5	5
21	U	5/5	U	21	7	3/7	7
22	V	5/6	V	22	=	3/13	=
23	W	5/7	W	23	2	3/2	2
24	X	5/8	X	24	/	2/15	/
25	Y	5/9	Y	25	6	3/6	6
26	Z	5/10	Z	26	+	2/11	+
27	CR	0/13	CR	27	CR	0/13	CR
28	LF	0/10	LF	28	LF	0/10	LF
29	LTRS	*		29	LTRS	*	
30	FIGS	*		30	FIGS	*	
31	SP	2/0	SP	31	SP	2/0	SP
32		*		32		*	

** No conversion shall be made for these positions and the signal/character shall be removed from the data.*

Note 1.— The end-of-message signal NNNN (in letter and figure case) shall convert to ETX (0/3).

Note 2.— The start-of-message signal ZCZC (in letter and figure case) shall convert to SOH (0/1).

Note 3.— Figures case of Signal No. 10 shall only be converted upon detection of the AFTN
priority alarm which shall convert to five occurrences of BEL (0/7).

Note 4.— When converting from ITA-2, a STX (0/2) character shall be inserted once at the beginning of the next line following detection of CR LF or LF CR at the end of the Origin Line.

Note 5.— The sequence of seven signal 28 (LF) shall convert to one VT (0/11) character.

Table 8-4. Conversion from the International Alphabet No. 5 (IA-5) to the International Telegraph Alphabet No. 2 (ITA-2)

Row \ Col.	0	1	2	3	4	5	6	7
0	*	*	31FL	16F	2F	16L	2F	16L
1	Note 5	*	2F	17F	1L	17L	1L	17L
2	*	*	2F	23F	2L	18L	2L	18L
3	Note 1	*	2F	5F	3L	19L	3L	19L
4	*	*	2F	18F	4L	20L	4L	20L
5	*	*	2F	20F	5L	21L	5L	21L
6	*	*	2F	25F	6L	22L	6L	22L
7	Note 2	*	19F	21F	7L	23L	7L	23L
8	*	*	11F	9F	8L	24L	8L	24L
9	*	*	12F	15F	9L	25L	9L	25L
10	28 FL	*	2F	3F	10L	26L	10L	26L
11	Note 3	*	26F	2F	11L	2F	11L	2F
12	*	*	14F	2F	12L	2F	12L	2F
13	27FL	*	1F	22F	13L	2F	13L	2F
14	*	*	13F	2F	14L	2F	14L	2F
15	*	*	24F	2F	15L	2F	15L	*

** No conversion shall be made for these positions and the signal/character shall be removed from the data.*

Example: To find the ITA-2 signal to which the character 3/6 of IA-5 is to be converted, look at column 3, row 6.
25F means figure case of signal No. 25
(L = letter case, FL = either case designation).

Note 1.— The character 0/3 (ETX) shall convert to the ITA-2 sequence signals 14L, 14L, 14L, 14L (NNNN).

Note 2. — The signal 0/7 (BEL) shall only be converted when a sequence of 5 occurrences is detected, which shall convert to the ITA-2 sequence signals 30, 10F, 10F, 10F, 10F, 10F, 29.

Note 3. — The character sequence CR CR LF VT (0/11) ETX (0/3) shall convert to the ITA-2 sequence signals 29, 27, 27, 28, 28, 28, 28, 28, 28, 28, 28, 14L, 14L, 14L, 14L.

Note 4. — To prevent redundant generation of figure and letter characters in ITA-2 when converting from IA-5, no case designation shall be assigned to ITA-2 non-printing functions (signals No. 27, 28, 29, 30, 31).

Note 5. — The character 0/1 (SOH) shall convert to the ITA-2 sequence signals 26L, 3L, 26L, 3L (ZCZC).

Table 8-5. Control field formats

Control field format for	Control field bits							
	1	2	3	4	5	6	7	8
Information transfer (I frame)	0	*N(S)*			*P*	*N(R)*		
Supervisory commands/responses (S frame)	1	0	*S*	*S*	*P/F*	*N(R)*		
Unnumbered commands/responses	1	1	*M*	*M*	*P/F*	*M*	*M*	*M*

where:

N(S) = send sequence count (bit 2 = low order bit)
N(R) = receive sequence count (bit 6 = low order bit)
S = supervisory function bits
M = modifier function bits
P = poll bit (in commands)
F = final bit (in responses)

Table 8-6. Commands and responses

Type	*Commands*		*Responses*		*C field encoding* 1	2	3	4	5	6	7	8
Information transfer	I	(information)			0	*N(S)*			*P*	*N(R)*		
Supervisory	RR	(receive ready)	RR	(receive ready)	1	0	0	0	*P/F*	*N(R)*		
	RNR	(receive not ready)	RNR	(receive not ready)	1	0	1	0	*P/F*	*N(R)*		
	REJ	(reject)	REJ	(reject)	1	0	0	1	*P/F*	*N(R)*		
Unnumbered			DM	(disconnected mode)	1	1	1	1	*P/F*	0	0	0
	SABM	(set asynchronous balanced mode)			1	1	1	1	*P*	1	0	0
	DISC	(disconnect)			1	1	0	0	*P*	0	1	0
			UA	(unnumbered acknowledgement)	1	1	0	0	*F*	1	1	0
			FRMR	(frame reject)	1	1	1	0	*F*	0	0	1

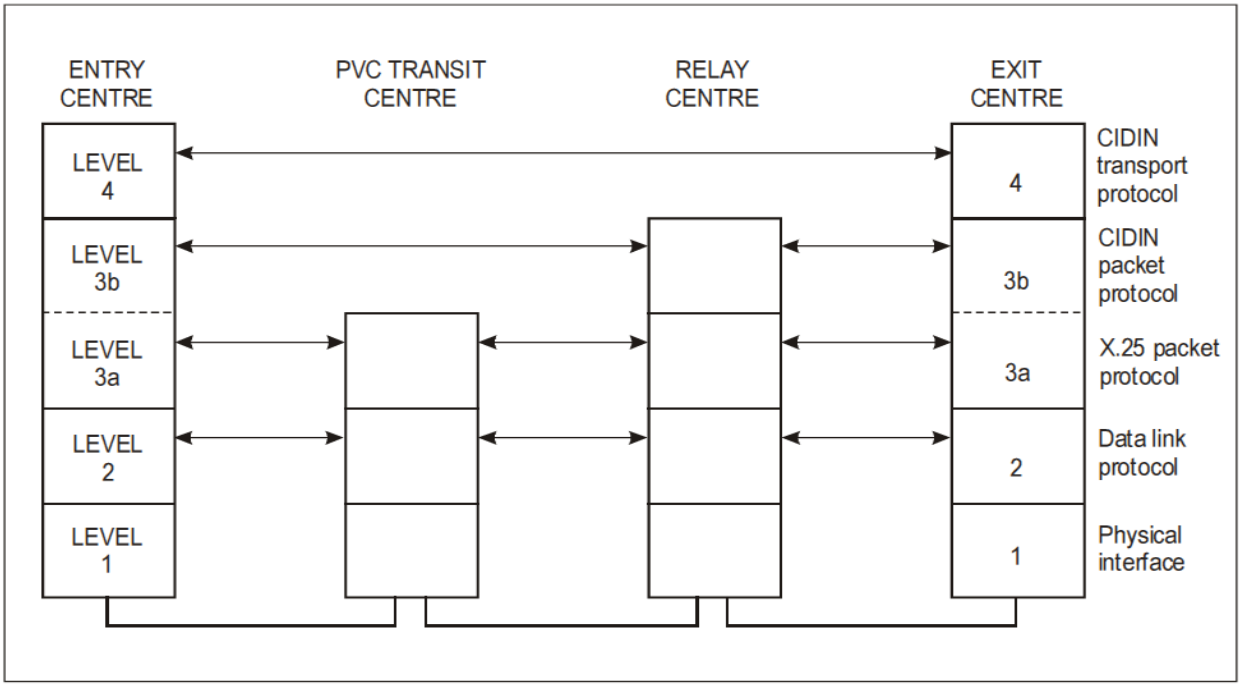


Figure 8-1. CIDIN protocol levels

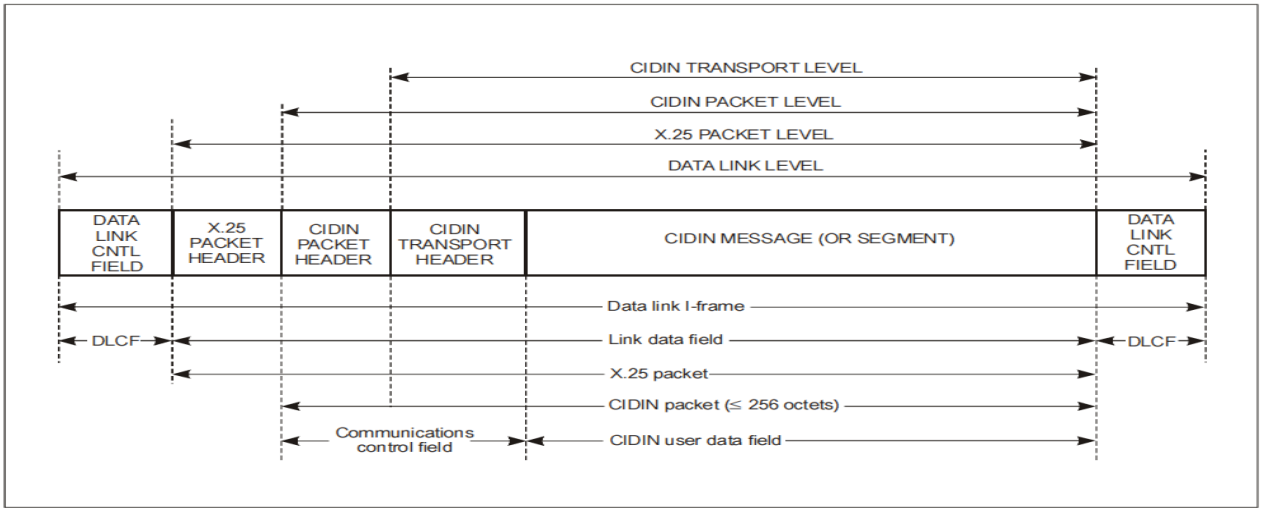


Figure 8-2. CIDIN terminology

23.3.7 AIRCRAFT ADDRESSING SYSTEM

(1) The aircraft 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 the IS: 23.3.7 to this Part.

(2) Non-aircraft transponders that are installed on aerodrome surface vehicles, obstacles or fixed Mode S target detection devices for surveillance and/or radar monitoring purposes shall be assigned 24-bit aircraft addresses.

Note.— Under such specific conditions, the term "aircraft" can be understood as "aircraft (or pseudo-aircraft) or vehicle (A/V)" where a limited set of data is generally sufficient for operational purposes.

(3) Mode S transponders used under specific conditions stated in paragraph (1) shall not have any negative impact on the performance of existing ATS surveillance systems and ACAS.

Note. – See IS:23.3.7 for the Worldwide Scheme for the Allocation, Assignment and Application of Aircraft Addresses.

23.3.8 POINT-TO-MULTIPOINT COMMUNICATIONS

23.3.8.1 SERVICE VIA SATELLITE FOR THE DISSEMINATION OF AERONAUTICAL INFORMATION

Point-to-multipoint telecommunication service via satellite to support the dissemination of aeronautical information shall be based on full-time, non pre-emptible, protected services as defined in the relevant CCITT Recommendations.

23.3.8.1.1 SERVICE VIA SATELLITE FOR THE DISSEMINATION OF WAFS PRODUCTS

System characteristics shall include the following:

(a) frequency — C-band, earth-to-satellite, 6 GHz band, satellite-to-earth, 4 GHz band;

(b) capacity with effective signalling rate of not less than 9 600 bits/s;

(c) bit error rates — better than 1 in 10^7;

(d) forward error correction; and

(e) availability 99.95 per cent.

23.3.9 HF DATA LINK

23.3.9.1 DEFINITIONS AND SYSTEM CAPABILITIES

Note. — The following Standards and Recommended Practices are specific to the high frequency data link (HFDL) and are in addition to the requirements specified in the ITU Radio Regulations (Appendix 27). The HFDL is a constituent mobile subnetwork of the aeronautical telecommunication network (ATN), operating in the aeronautical mobile (R) high frequency bands. In addition, the HFDL may provide non-ATN functions, such as direct link service (DLS). The HFDL system must enable aircraft to exchange data with ground-based users.

23.3.9.1.1 Definitions

Coded chip means a "1" or "0" output of the rate ½ or ¼ convolutional code encoder.

Designated operational coverage (DOC) area means the area in which a particular service is provided and in which the service is afforded frequency protection.

Note. — This area may, after proper coordination to ensure frequency protection, extend to areas outside the allotment areas contained in Appendix S27 to the Radio Regulations.

Direct link service (DLS) means a data communications service which makes no attempt to automatically correct errors, detected or undetected, at the link layer of the air-ground communications path. (Error control may be effected by end-user systems.)

High frequency network protocol data unit (HFNPDU) means user data packet.

Link protocol data unit (LPDU) means data unit which encapsulates a segment of an HFNPDU.

M-ary phase shift keying (M-PSK) modulation means a digital phase modulation that causes the phase of the carrier waveform to take on one of a set of M values.

Media access protocol data unit (MPDU) means data unit which encapsulates one or more LPDUs.

M-PSK symbol means one of the M possible phase shifts of the M-PSK modulated carrier representing a group of $\log_2 M$ coded chips.

Peak envelope power (PEP) means the peak power of the modulated signal supplied by the transmitter to the antenna transmission line.

Physical layer protocol data unit (PPDU) means data unit passed to the physical layer for transmission, or decoded by the physical layer after reception.

Quality of service (QOS) means the information relating to data transfer characteristics used by various communications protocols to achieve various levels of performance for network users.

Reliable link service (RLS) means data communications service provided by the subnetwork which automatically provides for error control over its link through error detection and requested retransmission of signal units found to be in error.

Squitter protocol data unit (SPDU) means data packet which is broadcast every 32 seconds by an HFDL ground station on each of its operating frequencies, and which contains link management information.

23.3.9.2 HF DATA LINK SYSTEM

23.3.9.2.1 SYSTEM ARCHITECTURE

The HFDL system shall consist of one or more ground and aircraft station subsystems, which implement the HFDL protocol (see 23.3.9.3). The HFDL system shall also include a ground management subsystem (see 23.3.9.4).

23.3.9.2.1.1 AIRCRAFT AND GROUND STATION SUBSYSTEMS

The HFDL aircraft station subsystem and the HFDL ground station subsystem

shall include the following functions:

(a) HF transmission and reception;

(b) data modulation and demodulation; and

(c) HFDL protocol implementation and frequency selection.

23.3.9.2.2 OPERATIONAL COVERAGE

Frequency assignments for HFDL shall be protected throughout their designated operational coverage (DOC) area.

Note 1.— DOC areas may be different from current MWARAs or RDARAs as defined in Appendix 27 to the ITU Radio Regulations.

Note 2.— Additional coordination with ITU is required in cases where DOC areas are not in conformity with the allotment areas specified in the ITU Radio Regulations.

23.3.9.2.3 REQUIREMENTS FOR CARRIAGE OF HFDL EQUIPMENT

Requirements for mandatory carriage of HFDL equipment shall be made on the basis of regional air navigation agreements that specify the airspace of operation and the implementation timescale.

23.3.9.2.3.1 NOTICE

The agreement above shall provide advance notice of at least two years for the mandatory carriage of airborne systems.

23.3.9.2.4 GROUND STATION NETWORKING

HFDL ground station subsystems shall interconnect through a common ground management subsystem.

Note. — This provides a distributed subnetwork, with a subnetwork point of attachment (SNPA), depending on the method of implementation, which allows

for the maintenance of virtual circuit connections as aircraft stations transition between designated operational coverage areas. The distribution may be multi-regional or worldwide.

23.3.9.2.5 GROUND STATION SYNCHRONIZATION

Synchronization of HFDL ground station subsystems shall be to within ±25 ms of UTC. For any station not operating within ±25 ms of UTC, appropriate notification shall be made to all aircraft and ground station subsystems to allow for continued system operation.

23.3.9.2.6 QUALITY OF SERVICE

23.3.9.2.6.1 RESIDUAL PACKET ERROR RATE

The undetected error rate for a network user packet which contains between 1 and 128 octets of user data shall be equal to or less than 1 in 10^6.

23.3.9.2.6.2 SPEED OF SERVICE

Transit and transfer delays for network user packets (128 octets) with priorities defined in Part I, Subpart 23.3.4, Table 4-26 for message priorities 7 through 14, shall not exceed the values of Table 11-1*.

Note.- All tables and figures are located at the end of this Section.

23.3.9.3 HF DATA LINK PROTOCOL

The HFDL protocol shall consist of a physical layer, a link layer, and a subnetwork layer, as specified below.

Note.— The HFDL protocol is a layered protocol and is compatible with the open systems interconnection (OSI) reference model. It permits the HFDL to function as an aeronautical telecommunication network (ATN)-compatible subnetwork. The details of the protocol are described in the Manual on HF Data Link *(Doc 9741).*

*

23.3.9.3.1 PHYSICAL LAYER RF CHARACTERISTICS

The aircraft and ground stations shall access the physical medium operating in simplex mode.

23.3.9.3.1.1 FREQUENCY BANDS

HFDL installations shall be capable of operating at any single sideband (SSB) carrier (reference) frequency available to the aeronautical mobile (R) service in the band 2.8 to 22 MHz, and in compliance with the relevant provisions of the Radio Regulations.

23.3.9.3.1.2 CHANNELS

Channel utilization shall be in conformity with the table of carrier (reference) frequencies of Appendix 27 to the ITU Radio Regulations.

23.3.9.3.1.3 TUNING

The equipment shall be capable of operating on integral multiples of 1 kHz.

23.3.9.3.1.4 SIDEBAND

The sideband used for transmission shall be on the higher side of its carrier (reference) frequency.

23.3.9.3.1.5 MODULATION

HFDL shall employ M-ary phase shift keying (M-PSK) to modulate the radio frequency carrier at the assigned frequency. The symbol rate shall be 1 800 symbols per second ±10 parts per million (i.e. 0.018 symbols per second). The value of M and the information data rate shall be as specified in Table 11-2.

23.3.9.3.1.5.1 M-PSK CARRIER

The M-PSK carrier expressed mathematically shall be defined as:

$s(t) = A\Sigma(p(t-kT)\cos[2\pi f_0 t + \varphi(k)])$, k =

0, 1 . . . , N-1 where:

N = number of M-PSK symbols in transmitted physical layer protocol data unit (PPDU)

s(t) = analog waveform or signal at time t

A = peak amplitude

f_0 = SSB carrier (reference) + 1 440 Hz T= M-PSK symbol period (1/1 800 s)

φ (k) = phase of kth M-PSK symbol

p(t-kT) = pulse shape of kth M-PSK symbol at time t.

Note.— The number of M-PSK symbols sent, N, defines the length (duration = NT seconds) of the PPDU. These parameters are defined in the Manual on HF Data Link *(Doc 9741).*

23.3.9.3.1.5.2 PULSE SHAPE

The pulse shape, p(t), shall determine the spectral distribution of the transmitted signal. The Fourier transform of the pulse shape, P(f), shall be defined by:

$P(f) = 1$, if $0 < |f| < (1 - b)/2T$

$P(f) = \cos\{\pi(2|f|T - 1 + b)/4b\}$, if $(1 - b)/2T < |f| < (1 + b)/2T$

$P(f) = 0$, if $|f| > (1 + b)/2T$

where the spectral roll-off parameter, b = 0.31, has been chosen so that the –20 dB points of the signal are at SSB carrier (reference) + 290 Hz and SSB carrier (reference) + 2 590 Hz and the peak-to-average power ratio of the waveform is less than 5 dB.

23.3.9.3.1.6 TRANSMITTER STABILITY

The basic frequency stability of the transmitting function shall be better than:

(a) ±20 Hz for HFDL aircraft station subsystems; and

(b) ±10 Hz for HFDL ground station subsystems.

23.3.9.3.1.7 RECEIVER STABILITY

The basic frequency stability of the receiving function shall be such that, with the transmitting function stability specified in 23.3.9.3.1.6, the overall frequency difference between ground and airborne functions achieved in service does not exceed 70 Hz.

23.3.9.3.1.8 PROTECTION

A 15 dB desired to undesired (D/U) signal ratio shall apply for the protection of co-channel assignments for HFDL as follows:

(a) data versus data;

(b) data versus voice; and

(c) voice versus data.

23.3.9.3.1.9 CLASS OF EMISSION

The class of emission shall be 2K80J2DEN.

23.3.9.3.1.10 ASSIGNED FREQUENCY

The HFDL assigned frequency shall be 1 400 Hz higher than the SSB carrier (reference) frequency.

Note.— By convention, the HFDL assigned frequency is offset from the SSB carrier (reference) frequency by 1400 Hz. The HFDL M-PSK carrier of the digital

modulation is offset from the SSB carrier (reference) frequency by 1440 Hz. The digital modulation is fully contained within the same overall channel bandwidth as the voice signal and complies with the provisions of Appendix 27 to the ITU Radio Regulations.

23.3.9.3.1.11 EMISSION LIMITS

For HFDL aircraft and ground station transmitters, the peak envelope power (P_p) of any emission on any discrete frequency shall be less than the peak envelope power (P_p) of the transmitter in accordance with the following (see Figure 11-1):

(a) on any frequency between 1.5 kHz and 4.5 kHz lower than the HFDL assigned frequency, and on any frequency between 1.5 kHz and 4.5 kHz higher than the HFDL assigned frequency: at least 30 dB;

(b) on any frequency between 4.5 kHz and 7.5 kHz lower than the HFDL assigned frequency, and on any frequency between 4.5 kHz and 7.5 kHz higher than the HFDL assigned frequency: at least 38 dB; and

(c) on any frequency lower than 7.5 kHz below the HFDL assigned frequency and on any frequency higher than 7.5 kHz above the HFDL assigned frequency:

(i) HFDL aircraft station transmitters: 43 dB;

(ii) HFDL ground station transmitters up to and including 50 W: $[43 + 10 \log_{10} P_p(W)]$ dB; and HFDL ground station transmitters more than 50 W: 60 dB.

23.3.9.3.1.12 POWER

(1) Ground station installations. The peak envelope power (P_p) supplied to the antenna transmission line shall not exceed a maximum value of 6 kW as provided for in Appendix 27 of the Radio Regulations.

(2) *Aircraft station installations*. The peak envelope power supplied to the antenna transmission line shall not exceed 400 W, except as provided for in Appendix 27/62 of the Radio Regulations.

23.3.9.3.1.13 UNDESIRED SIGNAL REJECTION

For HFDL aircraft and ground station receivers, undesired input signals shall be attenuated in accordance with the following:

(a) on any frequency between f_C and (f_C – 300 Hz), or between (f_C + 2 900 Hz) and (f_C + 3 300 Hz): at least 35 dB below the peak of the desired signal level; and

(b) on any frequency below (f_C – 300 Hz), or above (f_C + 3 300 Hz): at least 60 dB below the peak of the desired signal level,

where f_C is the carrier (reference) frequency.

23.3.9.3.1.14 RECEIVER RESPONSE TO TRANSIENTS

The receiving function shall recover from an instantaneous increase in RF power at the antenna terminal of 60 dB within 10 milliseconds. The receiving function shall recover from an instantaneous decrease in RF power at the antenna terminal of 60 dB within 25 milliseconds.

23.3.9.3.2 PHYSICAL LAYER FUNCTIONS

23.3.9.3.2.1 FUNCTIONS

The functions provided by the physical layer shall include the following:

(a) transmitter and receiver control;

(b) transmission of data; and

(c) reception of data.

23.3.9.3.2.2 TRANSMITTER AND RECEIVER CONTROL

The HFDL physical layer shall implement the transmitter/receiver switching and frequency tuning as commanded by the link layer. The physical layer shall perform transmitter keying on demand from the link layer to transmit a packet.

23.3.9.3.2.2.1 TRANSMITTER TO RECEIVER TURNAROUND TIME

The transmitted power level shall decay at least by 10 dB within 100 milliseconds after completing a transmission. An HFDL station subsystem shall be capable of receiving and demodulating, with nominal performance, an incoming signal within 200 milliseconds of the start of the subsequent receive slot.

23.3.9.3.2.2.2 RECEIVER TO TRANSMITTER TURNAROUND TIME

An HFDL station subsystem shall provide nominal output power within plus or minus 1 dB to the antenna transmission line within 200 milliseconds of the start of the transmit slot.

23.3.9.3.2.3 TRANSMISSION OF DATA

Transmission of data shall be accomplished using a time division multiple access (TDMA) technique. The HFDL data link ground station subsystems shall maintain TDMA frame and slot synchronization for the HFDL system. To ensure that slot synchronization is maintained, each HF data link modulator shall begin outputting a pre-key segment at the beginning of a time slot plus or minus 10 milliseconds.

23.3.9.3.2.3.1 TDMA STRUCTURE

Each TDMA frame shall be 32 seconds. Each TDMA frame shall be divided into thirteen equal duration slots as follows:

(a) the first slot of each TDMA frame shall be reserved for use by the HFDL ground station subsystem to broadcast link management data in SPDU packets; and

(b) the remaining slots shall be designated either as uplink slots, downlink slots reserved for specific HFDL aircraft station subsystems, or as downlink random access slots for use by all HFDL aircraft station subsystems on a contention basis. These TDMA slots shall be assigned on a dynamic basis using a combination of reservation, polling and random access assignments.

23.3.9.3.2.3.2 BROADCAST

The HFDL ground station subsystem shall broadcast a squitter protocol data unit (SPDU) every 32 seconds on each of its operating frequencies.

Note.— Details on the TDMA frame and slot structures, pre-key segment, data structures, including the SPDU, are contained in the Manual on HF Data Link *(Doc 9741).*

23.3.9.3.2.4 RECEPTION OF DATA

23.3.9.3.2.4.1 FREQUENCY SEARCH

Each HFDL aircraft station shall automatically search the assigned frequencies until it detects an operating frequency.

23.3.9.3.2.4.2 RECEPTION OF PPDUS

The HF data link receiver shall provide the means to detect, synchronize, demodulate and decode PPDUs modulated according to the waveform defined in 23.3.9.3.1.5, subject to the following distortion:

(a) the 1 440 Hz audio carrier offset by plus or minus 70 Hz;

(b) discrete and/or diffuse multipath distortion with up to 5 ms multipath spread;

(c) multipath amplitude fading with up to 2 Hz two-sided RMS Doppler spread and Rayleigh statistics; and

(d) additive Gaussian and broadband impulsive noise with varying amplitude and random arrival times.

Note.— Reference CCIR Report 549-2.

23.3.9.3.2.4.3 DECODING OF PPDUS

Upon receipt of the preamble segment the receiver shall:

(a) detect the beginning of a burst of data;

(b) measure and correct the frequency offset between the transmitter and receiver due to Doppler shift and transmitter/receiver frequency offsets;

(c) determine the data rate and interleaver settings to use during data demodulation;

(d) achieve M-PSK symbol synchronization; and

(e) train the equalizer.

23.3.9.3.2.4.4 SYNCHRONIZATION

Each HFDL aircraft station subsystem shall synchronize its slot timing to that of its corresponding ground station with respect to the reception time of the last received SPDU.

23.3.9.3.2.4.5 SPECIFIED PACKET ERROR RATE PERFORMANCE

(1) The number of HFDL media access protocol data units (MPDUs) received with one or more bit errors shall not exceed 5 per cent of the total number of MPDUs received, when using a 1.8 second interleaver and under the signal-in-space conditions shown in Table 11-3.

(2) The number of HFDL MPDUs received with one or more-bit errors shall not exceed 5 per cent of the total number of MPDUs received, when using a 1.8 second interleaver under the conditions shown in Table 11-3a.

23.3.9.3.3 LINK LAYER

The link layer shall provide control functions for the physical layer, link

management and data service protocols.

23.3.9.3.3.1 CONTROL FUNCTIONS

The link layer shall pass commands for frequency tuning, transmitter keying and transmitter/receiver switching to the physical layer.

23.3.9.3.3.2 LINK MANAGEMENT

The link layer shall manage TDMA slot assignments, log-on and log-off procedures, ground station and aircraft station TDMA synchronization, and other functions necessary, taking into account message priority, for the establishment and maintenance of communications.

23.3.9.3.3.3 DATA SERVICE PROTOCOLS

The link layer shall support a reliable link service (RLS) protocol and a direct link service (DLS) protocol.

23.3.9.3.3.3.1 *RLS*

The RLS protocol shall be used to exchange acknowledged user data packets between aircraft and ground peer link layers.

23.3.9.3.3.3.2 *DLS*

The DLS protocol shall be used to broadcast unsegmented uplink high frequency network protocol data units (HFNPDUs) and other HFNPDUs not requiring automatic retransmission by the link layer.

23.3.9.3.4 SUBNETWORK LAYER

23.3.9.3.4.1 PACKET DATA

The HFDL subnetwork layer in the HFDL aircraft station subsystem and HFDL ground station subsystem shall provide connection-oriented packet data service by establishing subnetwork connections between subnetwork service users.

23.3.9.3.4.2 CONNECTIVITY NOTIFICATION SERVICE

The HFDL subnetwork layer in the HFDL aircraft station subsystem shall provide the additional connectivity notification service by sending connectivity notification event messages to the attached ATN router.

23.3.9.3.4.2.1 CONNECTIVITY NOTIFICATION EVENT MESSAGES

The connectivity notification service shall send connectivity notification event messages to the attached ATN router through the subnetwork access function.

23.3.9.3.4.3 HFDL SUBNETWORK LAYER FUNCTIONS

The HFDL subnetwork layer in both the HFDL aircraft station subsystem and HFDL ground station subsystem shall include the following three functions:

(a) HFDL subnetwork dependent (HFSND) function;

(b) subnetwork access function; and

(c) interworking function.

23.3.9.3.4.3.1 HFSND FUNCTION

The HFSND function shall perform the HFSND protocol between each pair of HFDL aircraft station subsystems and HFDL ground station subsystems by exchanging HFNPDUs. It shall perform the HFSND protocol aircraft function in the HFDL aircraft station subsystem and the HFSND protocol ground function in the HFDL ground station subsystem.

23.3.9.3.4.3.2 SUBNETWORK ACCESS FUNCTION

The subnetwork access function shall perform the ISO 8208 protocol between the HFDL aircraft station subsystem or HFDL ground station subsystem and the attached routers by exchanging ISO 8208 packets. It shall perform the ISO 8208 DCE function in the HFDL aircraft station subsystem and the HFDL ground station subsystem.

23.3.9.3.4.3.3 INTERWORKING FUNCTION

The interworking function shall provide the necessary harmonization functions between the HFSND, the subnetwork access and the connectivity notification functions.

23.3.9.4 GROUND MANAGEMENT SUBSYSTEM

Note. — Details on the ground management subsystem functions and interfaces are contained in the Manual on HF Data Link *(Doc 9741).*

23.3.9.4.1 MANAGEMENT FUNCTIONS

The ground management subsystem shall perform the functions necessary to establish and maintain communications channels between the HFDL ground and aircraft station subsystems.

23.3.9.4.2 MANAGEMENT/CONTROL INFORMATION EXCHANGE

The ground management subsystem shall interface with the ground station subsystem in order to exchange control information required for frequency management, system table management, log status management, channel management, and quality of service (QOS) data collection.

Table 11-1. Transfer delays

	Direction	*Priority*	*Delay*
Transit delay	To-aircraft	7 through 14	45 s
	From-aircraft	7 through 14	60 s
Transfer delay (95 percentile)	To-aircraft	11 through 14	90 s
		7 through 10	120 s
	From-aircraft	11 through 14	150 s
		7 through 10	250 s

Table 11-2. Value of M and information data rate

M	*Information data rate (bits per second)*
2	300 or 600
4	1 200
8	1 800

Note.— When M equals the value 2, the data rate may be 300 or 600 bits per second as determined by the channel coding rate. The value of M may change from one data transmission to another depending on the data rate selected. The channel coding rate is described in the Manual on HF Data Link *(Doc 9741).*

Table 11-3. HF signal-in-space conditions

Data rate (bits per second)	*Number channel paths*	*Multipath (milliseconds)*	*Fading bandwidth per CCIR Report 5492*	*Frequency offset (Hz)*	*Signal to ratio (dB) in a 3 kHz bandwidth*	*MPDU size (octets)*
1 200	1 fixed	–	–	40	4	25
1 800	2 fading	2	1	40	16	400
1 200	2 fading	2	1	40	11.	256
600	2 fading	2	1	40	8	128
300	2 fading	2	1	40	5	64

Table 11-3a. HF signal-in-space conditions

Data rate (bits per second)	*Number channel paths*	*Multipath (milliseconds)*	*Fading bandwidth per CCIR Report 5492*	*Frequency offset (Hz)*	*Signal to ratio (dB) in a 3 kHz bandwidth*	*MPDU size (octets)*
1	2 fading	4	1	4	1	25
1	2 fading	2	2	4	11.	25

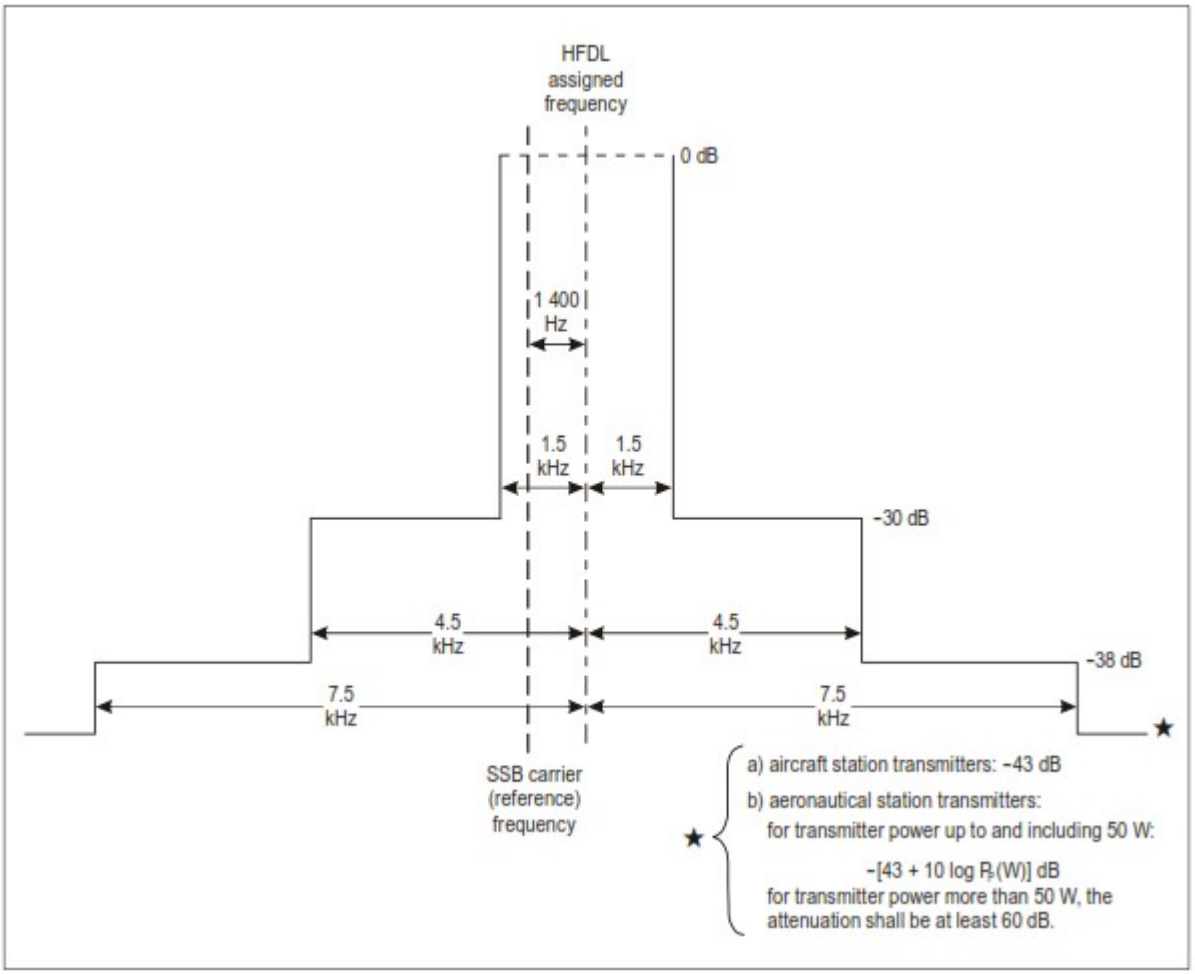


Figure 11-1. Required spectrum limits (in terms of peak power) for HFDL aircraft and ground station transmitters

23.3.10 UNIVERSAL ACCESS TRANSCEIVER (UAT)

23.3.10.1 DEFINITIONS AND OVERALL SYSTEM CHARACTERISTICS

23.3.10.1.1 Definitions

High performance receiver means a UAT receiver with enhanced selectivity to further improve the rejection of adjacent frequency DME interference see 23.3.10.3.2.2 for further details).

Optimum sampling point means the optimum sampling point of a received UAT bit stream is at the nominal centre of each bit period, when the frequency offset is either plus or minus 312.5 kHz.

Power measurement point (PMP) means a cable connects the antenna to the UAT equipment. The PMP is the end of that cable that attaches to the antenna. All power measurements are considered as being made at the PMP unless otherwise specified. The cable connecting the UAT equipment to the antenna is assumed to have 3 dB of loss.

Pseudorandom message data block means several UAT requirements state that performance will be tested using pseudorandom message data blocks. Pseudorandom message data blocks shall have statistical properties that are nearly indistinguishable from those of a true random selection of bits. For instance, each bit shall have (nearly) equal probability of being a ONE or a ZERO, independent of its neighbouring bits. There shall be a large number of such pseudorandom message data blocks for each message type (Basic ADS-B, Long ADS-B or Ground Uplink) to provide sufficient independent data for statistical performance measurements. See Section 2.3 of Part I of the *Manual on the Universal Access Transceiver (UAT)* (Doc 9861) for an example of how to provide suitable pseudorandom message data blocks

Service volume means a part of the facility coverage where the facility provides a particular service in accordance with relevant SARPs and within which the facility is afforded frequency protection.

Standard UAT receiver means a general purpose UAT receiver satisfying the minimum rejection requirements of interference from adjacent frequency distance measuring equipment (DME) (see 23.3.10.3.2.2 for further details).

Successful message reception (SMR) means the function within the UAT receiver for declaring a received message as valid for passing to an application that uses received UAT messages. See Section 4 of Part I of the *Manual on the Universal Access Transceiver (UAT)* (Doc 9861) for a detailed description of the procedure to be used by the UAT receiver for declaring successful message reception.

UAT ADS-B message means a message broadcasted once per second by each aircraft to convey state vector and other information. UAT ADS-B messages can be in one of two forms depending on the amount of information to be transmitted in a given second: the *Basic UAT ADS-B Message* or the *Long UAT ADS-B Message* (see 23.3.10.4.4.1 for definition of each). UAT ground stations can support traffic information service-broadcast (TIS-B) through transmission of individual ADS-B messages in the ADS-B segment of the UAT frame.

UAT ground uplink message means a message broadcasted by ground stations, within the ground segment of the UAT frame, to convey flight information such as text and graphical weather data, advisories, and other aeronautical information, to aircraft that are in the service volume of the ground station (see 12.4.4.2 for further details).

Universal access transceiver (UAT) means a broadcast data link operating on 978 MHz, with a modulation rate of 1.041667 Mbps.

23.3.10.1.2 UAT overall system characteristics of aircraft and ground stations

Note.— Details on technical requirements related to the implementation of UAT SARPs are contained in Part I of the Manual on the Universal Access Transceiver (UAT) *(Doc 9861). Part II of*

the Manual on the Universal Access Transceiver (UAT*) (Doc 9861) (in preparation) will provide additional guidance material.*

23.3.10.1.2.1 TRANSMISSION FREQUENCY

The transmission frequency shall be 978 MHz.

23.3.10.1.2.2 FREQUENCY STABILITY

The radio frequency of the UAT equipment shall not vary more than ±0.002 per cent (20 ppm) from the assigned frequency.

23.3.10.1.2.3 TRANSMIT POWER

23.3.10.1.2.3.1 TRANSMIT POWER LEVELS

UAT equipment shall operate at one of the power levels shown in Table 12-1*.

23.3.10.1.2.3.2 MAXIMUM POWER

The maximum equivalent isotropically radiated power (EIRP) for a UAT aircraft or ground station shall not exceed +58 dBm.

Note. — For example, the maximum EIRP listed above could result from the maximum allowable aircraft transmitter power shown in Table 12-1 with a maximum antenna gain of 4 dBi.

23.3.10.1.2.3.3 TRANSMIT MASK

The spectrum of a UAT ADS-B message transmission modulated with pseudorandom message data blocks (MDB) shall fall within the limits specified in Table 12-2 when measured in a 100 kHz bandwidth.

Note.— Figure 12-1[*] is a graphical representation of Table 12-2.

23.3.10.1.2.4 SPURIOUS EMISSIONS

Spurious emissions shall be kept at the lowest value which the state of the technique and the nature of the service permit.

Note.— Appendix 3 of the ITU Radio Regulations requires that transmitting stations shall conform to the maximum permitted power levels for spurious emissions or for unwanted emissions in the spurious domain.

23.3.10.1.2.5 POLARIZATION

The design polarization of emissions shall be vertical.

23.3.10.1.2.6 TIME/AMPLITUDE PROFILE OF UAT MESSAGE TRANSMISSION

(1) The time/amplitude profile of a UAT message transmission shall meet the following requirements, in which the *reference time* is defined as the beginning of the first bit of the synchronization sequence (see 23.3.10.4.4.1.1, 23.3.10.4.4.2.1) appearing at the output port of the equipment.

Notes. —1 All power requirements for subparagraphs "a" through "f" below apply to the PMP. For installations that support transmitter diversity, the RF power output on the non-selected antenna port shall be at least 20 dB below the level on the selected port.

Notes. —2 All power requirements for subparagraphs "a" and "f" assume a 300 kHz measurement bandwidth. All power

[**] All tables and figures are located at the end of the chapter.

requirements for subparagraphs "b", "c", "d" and "e" assume a 2 MHz measurement bandwidth.

Notes. —3 The beginning of a bit is 1/2 bit period prior to the optimum sample point.

Notes. —4 These requirements are depicted graphically in Figure 12-2.

(2) Prior to 8 bit periods before the reference time, the RF output power at the PMP shall not exceed –80 dBm.

Note.— This unwanted radiated power restriction is necessary to ensure that the UAT transmitting subsystem does not prevent closely located UAT receiving equipment on the same aircraft from meeting its requirements. It assumes that the isolation between transmitter and receiver equipment at the PMP exceeds 20 dB.

(3) Between 8 and 6 bit periods prior to the reference time, the RF output power at the PMP shall remain at least 20 dB below the minimum power requirement for the UAT equipment class.

Note.— Guidance on definition of UAT equipment classes will be provided in Part II of the Manual on the Universal Access Transceiver (UAT) *(Doc 9861) (in preparation).*

(4) During the Active state, defined as beginning at the reference time and continuing for the duration of the message, the RF output power at the PMP shall be greater than or equal to the minimum power requirement for the UAT equipment class.

(5) The RF output power at the PMP shall not exceed the maximum power for the UAT equipment class at any time during the Active state.

(6) Within 6 bit periods after the end of the Active state, the RF output power at the PMP shall be at a level at least 20 dB below the minimum power requirement for the UAT equipment class.

(7) Within 8 bit periods after the end of the Active state, the RF output power at the PMP shall fall to a level not to exceed –80

dBm.

Note.— This unwanted radiated power restriction is necessary to ensure that the transmitting subsystem does not prevent closely located UAT receiving equipment on the same aircraft from meeting its requirements. It assumes that the isolation between transmitter and receiver equipment at the PMP exceeds 20 dB.

23.3.10.1.3 Mandatory carriage requirements

Requirements for mandatory carriage of UAT equipment shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales for the carriage of equipment, including the appropriate lead time.

Note.— No changes will be required to aircraft systems or ground systems operating solely in regions not using UAT.

23.3.10.2 SYSTEM CHARACTERISTICS OF THE GROUND INSTALLATION

23.3.10.2.1 GROUND STATION TRANSMITTING FUNCTION

23.3.10.2.1.1 GROUND STATION TRANSMITTER POWER

The effective radiated power shall be such as to provide a field strength of at least 280 microvolts per metre (minus 97 dBW/m^2) within the service volume of the facility on the basis of free-space propagation.

Note. — This is determined on the basis of delivering a –91 dBm (corresponds to 200 microvolts per metre) signal level at the PMP (assuming an omnidirectional antenna). The 280 μV/m recommendation corresponds to the delivery of a -88 dBm signal level at the PMP of the receiving equipment. The 3 dB difference between –88 dBm and –91 dBm provides margin for excess path loss over free-space propagation.

23.3.10.2.2 GROUND STATION RECEIVING FUNCTION

Note. — An example ground station receiver is discussed in Section 2.5 of Part II of the Manual on the Universal Access Transceiver (UAT) *(Doc 9861), with UAT air-to-ground performance estimates consistent with use of that receiver provided in Appendix B of that manual.*

23.3.10.3 SYSTEM CHARACTERISTICS OF THE AIRCRAFT INSTALLATION

23.3.10.3.1 AIRCRAFT TRANSMITTING FUNCTION

23.3.10.3.1.1 AIRCRAFT TRANSMITTER POWER

The effective radiated power shall be such as to provide a field strength of at least 225 microvolts per metre (minus 99 dBW/m^2) on the basis of free-space propagation, at ranges and altitudes appropriate to the operational conditions pertaining to the areas over which the aircraft is operated. Transmitter power shall not exceed 54 dBm at the PMP.

Note 1.— The above field strength is determined on the basis of delivering a –93 dBm (corresponds to 160 microvolts per metre) signal level at the PMP (assuming an omnidirectional antenna). The 3 dB difference between 225 μV/m and 160 μV/m provides margin for excess path loss over free-space propagation when

receiving a long UAT ADS-B message. A 4dB margin is provided when receiving a basic UAT ADS-B message.

Note 2.—Various aircraft operations may have different air-air range requirements depending on the intended ADS-B function of the UAT equipment. Therefore different installations may operate at different power levels (see 23.3.10.1.2.3.1).

23.3.10.3.2 Receiving function

23.3.10.3.2.1 RECEIVER SENSITIVITY

23.3.10.3.2.1.1 LONG UAT ADS-B MESSAGE AS DESIRED SIGNAL

A desired signal level of –93 dBm applied at the PMP shall produce a rate of successful message reception (SMR) of 90 per cent or better under the following conditions:

(a) When the desired signal is of nominal modulation (i.e. FM deviation is 625 kHz) and at the maximum signal frequency offsets, and subject to relative Doppler shift at ±1 200 knots;

(b) When the desired signal is of maximum modulation distortion allowed in 23.3.10.4.3, at the nominal transmission frequency ±1 parts per million (ppm), and subject to relative Doppler shift at ±1 200 knots.

Note. — The receiver criteria for successful message reception of UAT ADS-B messages are provided in Section 4 of Part I of the Manual on the Universal Access Transceiver (UAT) *(Doc 9861).*

23.3.10.3.2.1.2 BASIC UAT ADS-B MESSAGE AS DESIRED SIGNAL

A desired signal level of –94 dBm applied at the PMP shall produce a rate of SMR of 90 per cent or better under the following conditions:

(a) When the desired signal is of nominal modulation (i.e. FM deviation is 625 kHz) and at the maximum signal frequency offsets, and subject to relative Doppler shift at ±1 200 knots;

(b) When the desired signal is of maximum modulation distortion allowed in 12.4.3, at the nominal transmission frequency ±1 ppm, and subject to relative Doppler shift at ±1 200 knots.

Note.— The receiver criteria for successful message reception of UAT ADS-B messages are provided in Section 4 of Part I of the Manual on the Universal Access Transceiver (UAT) *(Doc 9861).*

23.3.10.3.2.1.3 UAT GROUND UPLINK MESSAGE AS DESIRED SIGNAL

A desired signal level of –91 dBm applied at the PMP shall produce a rate of an SMR of 90 per cent or better under the following conditions:

(a) When the desired signal is of nominal modulation (i.e. FM deviation is 625 kHz) and at the maximum signal frequency offsets, and subject to relative Doppler shift at ±850 knots;

(b) When the desired signal is of maximum modulation distortion allowed in 12.4.3, at the nominal transmission frequency ±1 ppm, and subject to relative Doppler shift at ±850 knots.

Notes.—1 The receiver criteria for successful message reception of UAT ground uplink messages are provided in Section 4 of Part I of the Manual on the Universal Access Transceiver (UAT) *(Doc 9861) (in preparation).*

Notes.—2 This requirement ensures the bit rate accuracy supporting demodulation in the UAT equipment is adequate to properly receive the longer UAT ground uplink message.

23.3.10.3.2.2 RECEIVER SELECTIVITY

Notes. — 1 The undesired signal used is an unmodulated carrier applied at the frequency offset.

Notes. — 2 This requirement establishes the receiver's rejection of the off-channel energy.

Notes. — 3 It is assumed that ratios in between the specified offsets will fall near the interpolated value.

Notes. — 4 The desired signal used is a UAT ADS-B long message at -90 dBm at the PMP, to be received with a 90 per cent successful message reception rate.

Notes. — 5 The tolerable co-channel continuous wave interference power level for aircraft UAT receivers is assumed to be -101 dBm or less at the PMP.

See Section 2.4.2 of Part II of the Manual on the Universal Access Transceiver (UAT) (Doc 9861) for a discussion of when a high-performance receiver is desirable.

(1) Standard UAT receivers shall meet the selectivity characteristics given in Table 12-3.

(2) High-performance receivers shall meet the more stringent selectivity characteristics given in Table 12-4.

Note.— See Section 2.4.2 of Part II of the Manual on the Universal Access Transceiver (UAT) *(Doc 9861) for guidance material on the implementation of high-performance receivers.*

23.3.10.3.2.3 RECEIVER DESIRED SIGNAL DYNAMIC RANGE

The receiver shall achieve a successful message reception rate for long ADS-B messages of 99 per cent or better when the desired signal level is between –90 dBm and –10 dBm at the PMP in the absence of any interfering signals.

Note.— The value of –10 dBm represents 120-foot separation from an aircraft transmitter transmitting at maximum allowed

power.

23.3.10.3.2.4 RECEIVER TOLERANCE TO PULSED INTERFERENCE

Note.— All power level requirements in this section are referenced to the PMP.

(1) For Standard and High-Performance receivers the following requirements shall apply:

(a) The receiver shall be capable of achieving 99 per cent SMR of long UAT ADS-B messages when the desired signal level is between –90 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3 600 pulse pairs per second at either 12 or 30 microseconds pulse spacing at a level of –36 dBm for any 1 MHz DME channel frequency between 980 MHz and 1 213 MHz inclusive.

(b) Following a 21 microsecond pulse at a level of ZERO (0) dBm and at a frequency of 1 090 MHz, the receiver shall return to within 3 dB of the specified sensitivity level (see 23.3.10.3.2.1) within 12 microseconds.

(2) For the standard UAT receiver the following additional requirements shall apply:

(a) The receiver shall be capable of achieving 90 per cent SMR of long UAT ADS-B messages when the desired signal level is between –87 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3 600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –56 dBm and a frequency of 979 MHz.

(b) The receiver shall be capable of achieving 90 per cent SMR of long UAT ADS-B messages when the desired signal level is between –87 dBm and –10 dBm when subjected to DME

interference under the following conditions: DME pulse pairs at a nominal rate of 3 600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –70 dBm and a frequency of 978 MHz.

(3) For the high-performance receiver the following additional requirements shall apply:

(a) The receiver shall be capable of achieving 90 per cent SMR of long UAT ADS-B messages when the desired signal level is between –87 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3 600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –43 dBm and a frequency of 979 MHz.

(b) The receiver shall be capable of achieving 90 per cent SMR of long UAT ADS-B messages when the desired signal level is between –87 dBm and –10 dBm when subjected to DME interference under the following conditions: DME pulse pairs at a nominal rate of 3 600 pulse pairs per second at a 12 microseconds pulse spacing at a level of –79 dBm and a frequency of 978 MHz.

23.3.10.4 PHYSICAL LAYER CHARACTERISTICS

23.3.10.4.1 MODULATION RATE

The modulation rate shall be 1.041 667 Mbps with a tolerance for aircraft transmitters of ±20 ppm and a tolerance for ground transmitters of ±2 ppm.

Note.— The tolerance on the modulation rate is consistent with the requirement on modulation distortion (see 23.3.10.4.3).

23.3.10.4.2 Modulation type

(1) Data shall be modulated onto the carrier using binary continuous phase frequency shift keying. The modulation index, *h*, shall be no less than 0.6;

(2) A binary ONE (1) shall be indicated by a shift up in frequency from the nominal carrier frequency and a binary ZERO (0) by a shift down from the nominal carrier frequency.

Notes.— 1. Filtering of the transmitted signal (at base band and/or after frequency modulation) will be required to meet the spectral containment requirement of 23.3.10.1.2.3.3. This filtering may cause the deviation to exceed these values at points other than the optimum sampling points.

Notes.— 2. Because of the filtering of the transmitted signal, the received frequency offset varies continuously between the nominal values of ±312.5 kHz (and beyond), and the optimal sampling point may not be easily identified. This point can be defined in terms of the so-called "eye diagram" of the received signal. The ideal eye diagram is a superposition of samples of the (undistorted) post detection waveform shifted by multiples of the bit period (0.96 microseconds). The optimum sampling point is the point during the bit period at which the opening of the eye diagram (i.e. the minimum separation between positive and negative frequency offsets at very high signal-to-noise ratios) is maximized. An example "eye diagram" can be seen in Figure 12-3. The timing of the points where the lines converge defines the "optimum sampling point". Figure 12-4 shows an eye pattern that has been partially closed by modulation distortion.

23.3.10.4.3 MODULATION DISTORTION

(1) For aircraft transmitters, the minimum vertical opening of the eye diagram of the transmitted signal (measured at the optimum sampling points) shall be no less than 560 kHz when measured over an entire long UAT ADS-B message containing pseudorandom message data blocks.

(2) For ground transmitters, the minimum vertical opening of the eye diagram of the transmitted signal (measured at the optimum sampling points) shall be no less than 560 kHz when measured over an entire UAT ground uplink message containing pseudorandom message data blocks.

(3) For aircraft transmitters, the minimum horizontal opening of the eye diagram of the transmitted signal (measured at 978 MHz) shall be no less than 0.624 microseconds (0.65 symbol periods) when measured over an entire long UAT ADS-B message containing pseudorandom message data blocks.

(4) For ground transmitters, the minimum horizontal opening of the eye diagram of the transmitted signal (measured at 978 MHz) shall be no less than 0.624 microseconds (0.65 symbol periods) when measured over an entire UAT ground uplink message containing pseudorandom message data blocks.

Notes.—1. Section 23.3.10.4.4 defines the UAT ADS-B message types.

Notes.—2. The ideal eye diagram is a superposition of samples of the (undistorted) post detection waveform shifted by multiples of the bit period (0.96 microseconds).

23.3.10.4.4 BROADCAST MESSAGE CHARACTERISTICS

The UAT system shall support two different message types: the UAT ADS-B message and the UAT ground uplink message.

23.3.10.4.4.1 UAT ADS-B MESSAGE

The Active portion (see 23.3.10.1.2.6) of a UAT ADS-B message shall contain the following elements, in the following order:

(a) Bit synchronization
(b) Message data block
(c) FEC parity.

23.3.10.4.4.1.1 BIT SYNCHRONIZATION

The first element of the Active portion of the UAT ADS-B message shall be a 36-bit synchronization sequence. For the UAT ADS-B messages the sequence shall be:

111010101100110111 0

110100100111000 10

with

the left-most bit

transmitted first.

23.3.10.4.4.1.2 THE MESSAGE DATA BLOCK

The second element of the Active portion of the UAT ADS-B message shall be the message data block. There shall be two lengths of UAT ADS-B message data blocks supported. The basic UAT ADS-B message shall have a 144-bit message data block and the long UAT ADS-B message shall have a 272-bit message data block.

Note.— The format, encoding and transmission order of the message data block element is provided in Section 2.1 of Part I of the Manual on the Universal Access Transceiver (UAT) *(Doc 9861).*

23.3.10.4.4.1.3 FEC PARITY

The third and final element of the Active portion of the UAT ADS-B message shall be the FEC parity.

23.3.10.4.4.1.4 CODE TYPE

The FEC parity generation shall be based on a systematic Reed-Solomon (RS) 256-ary code with 8-bit code word symbols. FEC parity generation shall be per the following code:

(a) **Basic UAT ADS-B message**: Parity shall be a RS (30, 18) code.

Note. — This results in 12 bytes (code symbols) of parity capable of correcting up to 6 symbol errors per block.

(b) **Long UAT ADS-B message**: Parity shall be a RS (48, 34) code.

Note.— This results in 14 bytes (code symbols) of parity capable of correcting up to 7 symbol errors per block.

For either message length the primitive polynomial of the code shall be as follows:

$$p(x) = x^8 + x^7 + x^2 + x + 1$$

The generator polynomial shall be as follows:

$$\prod_{i=120}^{P}(x-\alpha^i)$$

where:

P = 131 for RS (30, 18) code,

P = 133 for RS (48, 34) code, and

α is a primitive element of a Galois field of size 256 (i.e. GF(256)).

23.3.10.4.4.1.3.2 TRANSMISSION ORDER OF FEC PARITY

FEC parity bytes shall be ordered most significant to least significant in terms of the polynomial coefficients they represent. The ordering of bits within each byte shall be most significant to least significant. FEC parity bytes shall follow the message data block.

23.3.10.4.4.2 UAT GROUND UPLINK MESSAGE

The Active portion of a UAT ground uplink message shall contain the following elements, in the following order:

(a) Bit synchronization
(b) Interleaved message data block and FEC parity.

23.3.10.4.4.2.1 BIT SYNCHRONIZATION

The first element of the Active portion of the UAT ground uplink message shall be a 36-bit synchronization sequence. For the UAT ground uplink message the sequence shall be:

000101010011001000100101

101100011101

with the left-most bit transmitted first.

23.3.10.4.4.2.2 INTERLEAVED MESSAGE DATA BLOCK AND FEC PARITY

23.3.10.4.4.2.2.1 MESSAGE DATA BLOCK (BEFORE INTERLEAVING AND AFTER DE-INTERLEAVING)

The UAT ground uplink message shall have 3 456 bits of message data block. These bits are divided into 6 groups of 576 bits. FEC is applied to each group as described in 23.3.10.4.4.2.2.2.

Note.— Further details on the format, encoding and transmission order of the UAT ground uplink message data block are provided in Section 2.2 of Part I of the Manual on the Universal Access Transceiver (UAT) *(Doc 9861).*

23.3.10.4.4.2.2.2 FEC PARITY (BEFORE INTERLEAVING AND AFTER DE-INTERLEAVING)

23.3.10.4.4.2.2.2.1 CODE TYPE

The FEC parity generation shall be based on a systematic RS 256-ary code with 8-bit code word symbols. FEC parity generation for each of the six blocks shall be a RS (92,72) code.

Notes.—1. Section 23.3.10.4.4.2.2.3 provides details on the interleaving procedure.

Notes.—2. This results in 20 bytes (symbols) of parity capable of correcting up to 10 symbol errors per block. The additional use of interleaving for the UAT ground uplink message allows additional robustness against burst errors.

The primitive polynomial of the code is as follows:

$$p(x) = x^8 + x^7 + x^2 + x + 1$$

The generator polynomial is as follows:

$$\prod_{i=120}^{P} (x - \alpha^i)$$

where:

P = 139, and

α is a primitive element of a Galois field of size 256 (i.e. GF(256)).

23.3.10.4.4.2.2.2.2 TRANSMISSION ORDER OF FEC PARITY

FEC parity bytes are ordered most significant to least significant in terms of the polynomial coefficients they represent. The ordering of bits within each byte shall be most significant to least significant. FEC parity bytes shall follow the message data block.

23.3.10.4.4.2.2.3 INTERLEAVING PROCEDURE

UAT ground uplink messages shall be interleaved and transmitted by the ground station, as listed below:

(a) **Interleaving procedure**: The interleaved message data block and FEC parity consists of 6 interleaved Reed- Solomon blocks. The interleaver is represented by a 6×92 matrix, where each entry is a RS 8-bit symbol. Each row comprises a single RS (92,72) block as shown in Table 12-5. In this table, block numbers prior to interleaving are represented as “A” through “F”. The information is ordered for transmission column by column, starting at the upper left corner of the matrix.

(b) **Transmission order**: The bytes are then transmitted in the following order:

1,73,145,217,289,361,2,74,146,218,290,362,3,. . .,C /20,D/20,E/20,F/20.

Note.— On reception these bytes need to be de-interleaved so that the RS blocks can be reassembled prior to error correction decoding.

Table 12-1. Transmitter power levels

Transmitter type	*Minimum power at PMP*	*Maximum power at PMP*	*Intended minimum air-to-air ranges*
Aircraft (Low)	7 watts (+38.5 dBm)	18 watts (+42.5 dBm)	20 NM
Aircraft (Medium)	16 watts (+42 dBm)	40 watts (+46 dBm)	40 NM
Aircraft (High)	100 watts (+50 dBm)	250 watts (+54 dBm)	120 NM
Ground Station	Specified by the service provider to meet local requirements within the constraint of 12.1.2.3.2.		

Notes.—

1. *The three levels listed for the avionics are available to support applications with varying range requirements. See the discussion of UAT aircraft Equipage Classes in Section 2.4.2 of Part II of the* Manual on the Universal Access Transceiver (UAT) *(Doc 9861) (in preparation).*

2. *The intended minimum air-to-air ranges are for high-density air traffic environments. Larger air-to-air ranges will be achieved in low-density air traffic environments.*

Table 12-2. UAT transmit spectrum

Frequency offset from centre	*Required attenuation from maximum power level (dB as measured at the PMP)*
All frequencies in the range 0 – 0.5 MHz	0
All frequencies in the range 0.5 – 1.0 MHz	Based on linear* interpolation between these points
1.0 MHz	18
All frequencies in the range 1.0 – 2.25 MHz	Based on linear* interpolation between these points
2.25 MHz	50
All frequencies in the range 2.25 – 3.25 MHz	Based on linear* interpolation between these points
3.25 MHz	60

** based on attenuation in dB and a linear frequency scale*

Table 12-3. Standard UAT receiver rejection ratios

Frequency offset from centre	*Minimum rejection ratio (Undesired/desired level in dB)*
–1.0 MHz	10
+1.0 MHz	15
(±) 2.0 MHz	50
(±) 10.0 MHz	60

Note.— It is assumed that ratios in between the specified offsets will fall near the interpolated value.

Table 12-4. High-performance receiver rejection ratios

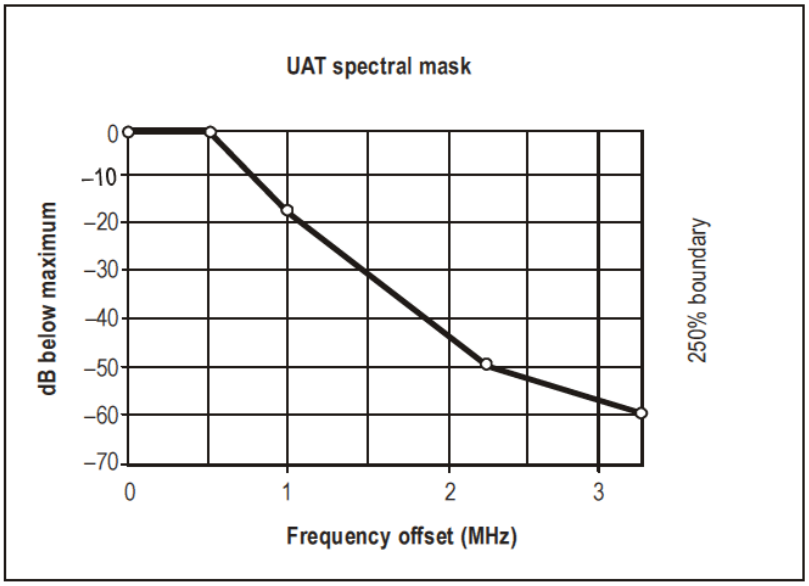
Frequency offset from centre	*Minimum rejection ratio (Undesired/desired level in dB)*
–1.0 MHz	30
+1.0 MHz	40
(±) 2.0 MHz	50
(±) 10.0 MHz	60

Table 12-5. Ground uplink interleaver matrix

RS Block	*MDB Byte #*						*FEC Parity (Block/Byte #)*			
A	1	2	3	...	71	72	A/1	...	A/19	A/20
B	73	74	75	...	143	144	B/1	...	B/19	B/20
C	145	146	147	...	215	216	C/1	...	C/19	C/20
D	217	218	219	...	287	288	D/1	...	D/19	D/20
E	289	290	291	...	359	360	E/1	...	E/19	E/20
F	361	362	363	...	431	432	F/1	...	F/19	F/20

Note.— In Table 12-5, message data block Byte #1 through #72 are the 72 bytes (8 bits each) of message data block information carried in the first RS (92,72) block. FEC parity A/1 through A/20 are the 20 bytes of FEC parity associated with that block (A).

FIGURES FOR CHAPTER 12



Notes.—

1. *99 per cent of the power of the UAT spectrum is contained in 1.3 MHz (±0.65 MHz). This is roughly equivalent to the 20 dB bandwidth.*

2. *Spurious emissions requirements begin at ±250 per cent of the 1.3 MHz value, therefore the transmit mask requirement extends to ±3.25 MHz.*

Figure 12-1. UAT transmit spectrum

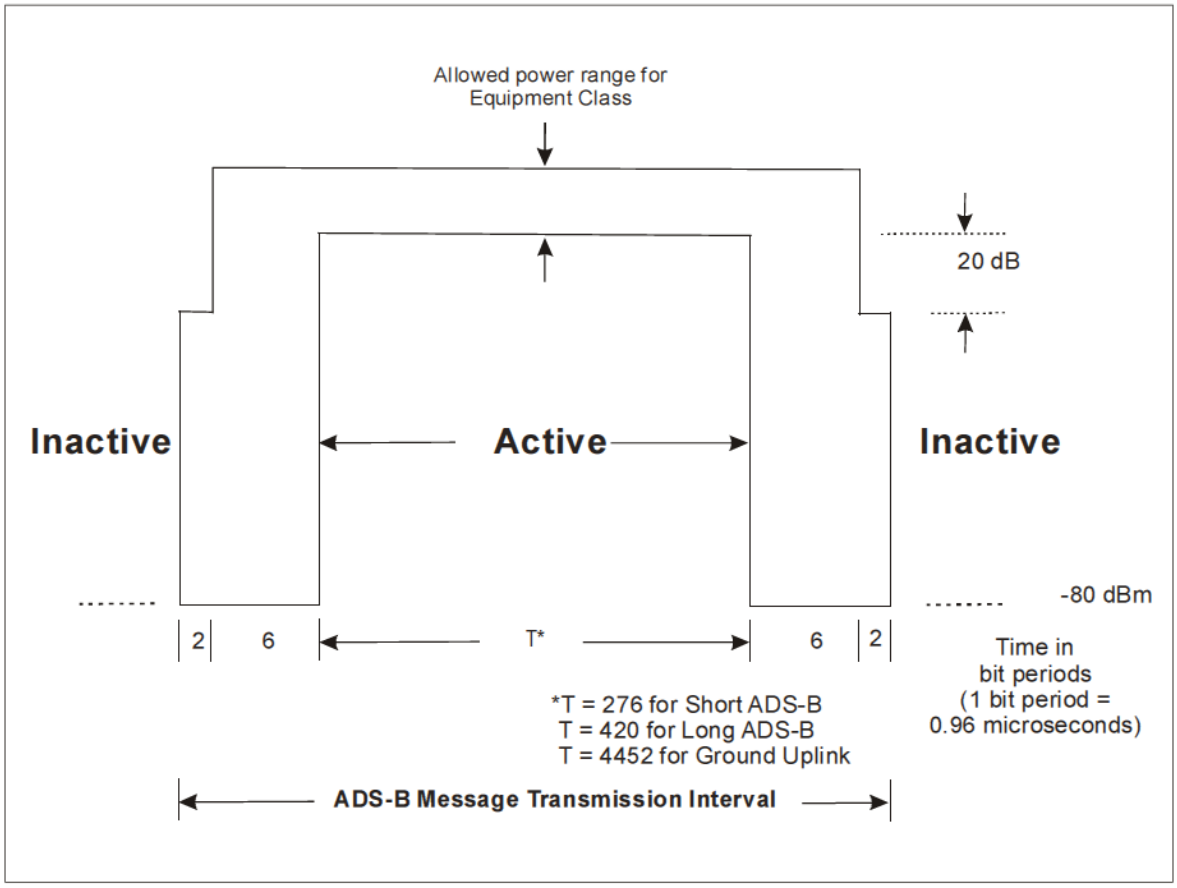


Figure 12-2. Time/amplitude profile of UAT message transmission

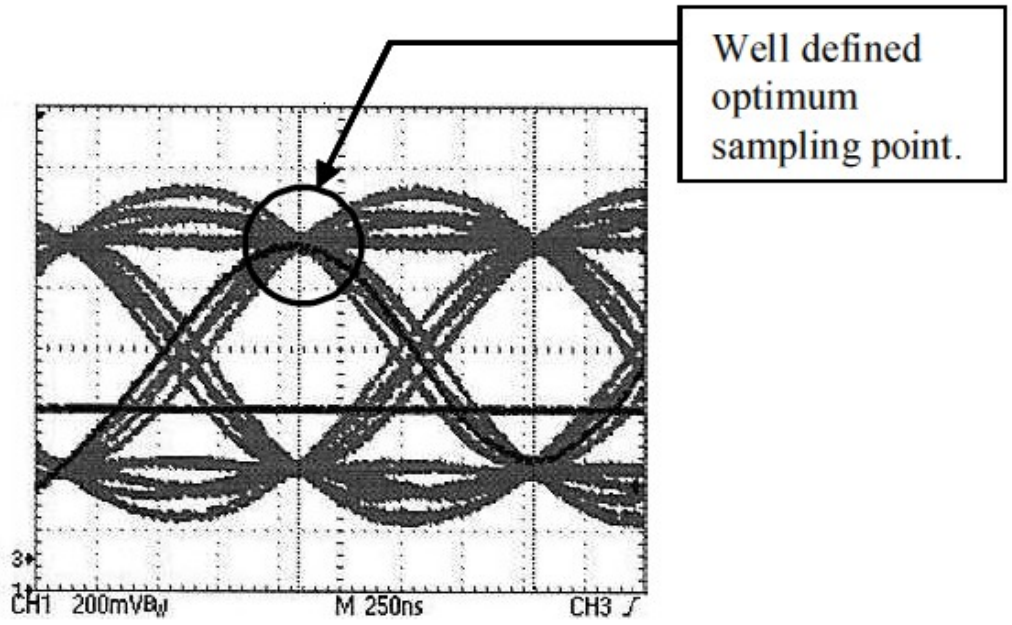


Figure 12-3. Ideal eye diagram

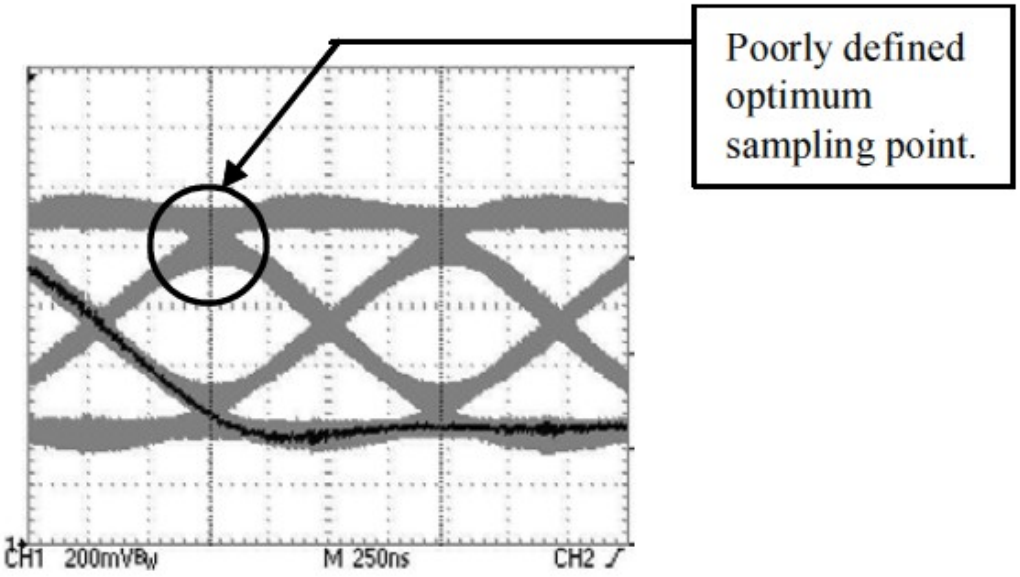


Figure 12-4. Distorted eye diagram

PART II – VOICE COMMUNICATION SYSTEMS

23.3.11 AERONAUTICAL MOBILE SERVICE

23.3.11.1 AIR-GROUND VHF COMMUNICATION SYSTEM CHARACTERISTICS

Note. — In the following text the channel spacing for 8.33 kHz channel assignments is defined as 25 kHz divided by 3 which is 8.3333 ... kHz.

The characteristics of the air-ground VHF communication system used in the International Aeronautical Mobile Service shall be in conformity with the following specifications:

(a) Radiotelephone emissions shall be double sideband (DSB) amplitude modulated (AM) carriers. The designation of emission is A3E, as specified in the ITU Radio Regulations.
(b) Spurious emissions shall be kept at the lowest value which the state of technique and the nature of the service permit.

Note. — Appendix S3 to the ITU Radio Regulations specifies the levels of spurious emissions to which transmitters must conform.

(c) The radio frequencies used shall be selected from the radio frequencies in the band 117.975 – 137 MHz. The separation between assignable frequencies (channel spacing) and frequency tolerances applicable to elements of the system shall be as specified in Subpart 23.5 (Aeronautical Radio Frequency Spectrum Utilization).

Note. — The band 117.975 – 132 MHz was allocated to the Aeronautical Mobile (R) Service in the ITU Radio Regulations (1947). By subsequent revisions at ITU World Administrative Radio Conferences the bands 132 – 136 MHz and 136 – 137 MHz were added under conditions which differ for ITU Regions, or for specified countries or combinations of countries (see RRs S5.203, S5.203A and S5.203B for additional allocations in the band 136 – 137 MHz, and S5.201 for the band 132 – 136 MHz).

(d)The design polarization of emissions shall be vertical.

23.3.11.2 SYSTEM CHARACTERISTICS OF THE GROUND INSTALLATION

23.3.11.2.1 TRANSMITTING FUNCTION

(1) Frequency stability**.** The radio frequency of operation shall not vary more than plus or minus 0.005 per cent from the assigned frequency. Where 25 kHz channel spacing is introduced in accordance with Subpart 5, the radio frequency of operation shall not vary more than plus or minus 0.002 per cent from the assigned frequency. Where 8.33 kHz channel spacing is introduced in accordance with Subpart 5, the radio frequency of operation shall not vary more than plus or minus 0.0001 per cent from the assigned frequency.

Note. — The above frequency stability requirements will not be sufficient for offset carrier systems using 25 kHz channel spacing or higher.

(2) Offset carrier systems in 25 kHz, 50 kHz and 100 kHz channel spaced environments. The stability of individual carriers of an offset carrier system shall be such as to prevent first-order heterodyne frequencies of less than 4 kHz and, additionally, the maximum frequency excursion of the outer carrier frequencies from the assigned carrier frequency shall not exceed 8 kHz. Offset carrier systems shall not be used on 8.33 kHz spaced channels.

23.3.11.2.1.1 POWER

(1) On a high percentage of occasions, the effective radiated power shall be such as to provide a field strength of a least 75 microvolts per metre (minus 109 dBW/m2) within the defined operational coverage of the facility, on the basis of free space propagation.

Note. — The above frequency stability requirements will not be sufficient for offset carrier systems using 25 kHz channel spacing or higher.

(2) Modulation. A peak modulation factor of at least 0.85 shall be achievable.

(3) Means shall be provided to maintain the average modulation factor at the highest practicable value without overmodulation.

23.3.11.2.2 RECEIVING FUNCTION

(1) Frequency stability. Where 8.33 kHz channel spacing is introduced in accordance with Part 23.5, the radio frequency of operation shall not vary more than plus or minus 0.0001 per cent from the assigned frequency.

(2) Sensitivity. After due allowance has been made for feeder loss and antenna polar diagram variation, the sensiti-vity of the receiving function shall be such as to provide on a high percentage of occasions an audio output signal with a wanted/unwanted ratio of 15 dB, with a 50 per cent amplitude modulated (A3E) radio signal having a field strength of 20 microvolts per metre (minus 120 dBW/m^2) or more.

(3) Effective acceptance bandwidth. When tuned to a channel having a width of 25 kHz, 50 kHz or 100 kHz, the receiving system shall provide an adequate and intelligible audio output when the signal specified at paragraph (2) above has a carrier frequency within plus or minus 0.005 per cent of the assigned frequency. When tuned to a channel having a width of 8.33 kHz, the receiving system shall provide an adequate and intelligible audio output when the signal specified at paragraph (2) above has a carrier frequency within plus or minus 0.0005 per cent of the assigned frequency.

(4) Adjacent channel rejection. The receiving system shall ensure an effective rejection of 60 dB or more at the next assignable channel.

23.3.11.2.3 SYSTEM CHARACTERISTICS OF THE AIRBORNE INSTALLATION

23.3.11.2.3.1 TRANSMITTING FUNCTION

(1) Frequency stability. The radio frequency of operation shall not vary more than plus or minus 0.005 per cent from the assigned frequency. Where 25 kHz channel spacing is introduced, the radio frequency of operation shall not vary more than plus or minus 0.003 per cent from the assigned frequency. Where 8.33 kHz channel spacing is introduced, the radio frequency of operation shall not vary more than plus or minus 0.0005 per cent from the assigned frequency.

(2) Power. On a high percentage of occasions, the effective radiated power shall be such as to provide a field strength of at least 20 microvolts per metre (minus 120 dBW/m2) on the basis of free space propagation, at ranges and altitudes appropriate to the operational conditions pertaining to the areas over which the aircraft is operated.

(3) Adjacent channel power. The amount of power from a 8.33 kHz airborne transmitter under all operating conditions when measured over a 7 kHz channel bandwidth centred on the first 8.33 kHz adjacent channel shall not exceed -45 dB below the transmitter carrier power. The above adjacent channel power shall take into account the typical voice spectrum.

(4) Modulation. A peak modulation factor of at least 0.85 shall be achievable.

(5) Means shall be provided to maintain the average modulation factor at the highest practicable value without overmodulation.

23.3.11.2.3.2 RECEIVING FUNCTION

Frequency stability. Where 8.33 kHz channel spacing is introduced in accordance with Subpart 23.5, the radio frequency of operation shall not vary more than plus or minus 0.0005 per cent from the assigned frequency.

23.3.11.2.3.2.1 SENSITIVITY

(1) After due allowance has been made for aircraft feeder mismatch, attenuation loss and antenna polar diagram variation, the sensitivity of the receiving function shall be such as to provide on a high percentage of occasions an audio output signal with a wanted/unwanted ratio of 15 dB, with a 50 per cent amplitude modulated (A3E) radio signal having a field strength of 75 microvolts per metre (minus 109 dBW/m2).

(2) Effective acceptance bandwidth for 100 kHz, 50 kHz and 25 kHz channel spacing receiving installations. When tuned to a channel designated in Subpart 5 as having a width of 25 kHz, 50 kHz or 100 kHz, the receiving function shall ensure an effective acceptance bandwidth as follows:

(a) in areas where offset carrier systems are employed, the receiving function shall provide an adequate audio output when the signal specified at paragraph (1) has a carrier frequency within 8 kHz of the assigned frequency.

(b) in areas where offset carrier systems are not employed, the receiving function shall provide an adequate audio output when the signal specified at paragraph (1) has a carrier frequency of plus or minus 0.005 percent of the assigned frequency.

(c) Effective acceptance bandwidth for 8.33 kHz channel spacing receiving installations. When tuned to a channel designated in part 23.5, as having a width of 8.33 kHz, the receiving function shall provide an adequate audio output when the signal specified at paragraph (1) above has a carrier frequency within plus or minus 0.0005 per cent of the assigned frequency.

(3) Adjacent channel rejection. The receiving function shall ensure an effective adjacent channel rejection as follows:

(a) 8.33 kHz channels: 60 dB or more at plus or minus 8.33 kHz with respect to the assigned frequency, and 40 dB or more at plus or minus 6.5 kHz;

(b) 25 kHz channel spacing environment: 50 dB or more at

plus or minus 25 kHz with respect to the assigned frequency and 40 dB or more at plus or minus 17 kHz;

(c) 50 kHz channel spacing environment: 50 dB or more at plus or minus 50 kHz with respect to the assigned frequency and 40 dB or more at plus or minus 35 kHz;

(d) 100 kHz channel spacing environment: 50 dB or more at plus or minus 100 kHz with respect to the assigned frequency.

(4) Whenever practicable, the receiving system shall ensure an effective adjacent channel rejection characteristic of 60 dB or more at plus or minus 25 kHz, 50 kHz and 100 kHz from the assigned frequency for receiving systems intended to operate in channel spacing environments of 25 kHz, 50 kHz and 100 kHz respectively.

(5) In the case of receivers complying with paragraph (2) above used in areas where offset carrier systems are in force, the characteristics of the receiver shall be such that:

(a) the audio frequency response precludes harmful levels of audio heterodynes resulting from the reception of two or more offset carrier frequencies.

(b) the receiver muting circuits, if provided, operate satisfactorily in the presence of audio heterodynes resulting from the reception of two or more offset carrier frequencies.

23.3.11.2.3.2.2 VDL -INTERFERENCE IMMUNITY PERFORMANCE

(1) For equipment intended to be used in independent operations of services applying DSB-AM and VDL technology on board the same aircraft, the receiving function shall provide an adequate and intelligible audio output with a desired signal field strength of not more than 150 microvolts per metre (minus 102 dBW/m^2) and with an undesired VDL signal field strength of at least 50 dB above the desired field strength on any assignable channel 100 kHz or more away from the assigned channel of the desired signal.

Note.— This level of VDL interference immunity performance provides a receiver performance consistent with the influence of the VDL RF spectrum mask as specified in Subpart 3, Part I, 23.3.6.3.4

with an effective transmitter/receiver isolation of 68 dB. Better transmitter and receiver performance could result in less isolation required.

(2) The receiving function of all new installations intended to be used in independent operations of services applying DSB-AM and VDL technology on board the same aircraft shall meet the provisions of paragraph (1).

(3) The receiving function of all installations intended to be used in independent operations of services applying DSB-AM and VDL technology on board the same aircraft shall meet the provisions of paragraph (1), subject to the conditions of paragraph (4)

(4) Requirements for mandatory compliance of the provisions of paragraph (3) shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation time scales.

(5) The agreement indicated in paragraph (4)shall provide at least two years' notice of mandatory compliance of airborne systems.

23.3.11.2.4 INTERFERENCE IMMUNITY PERFORMANCE

(1) The VHF communications receiving system shall provide satisfactory performance in the presence of two signal, third-order inter-modulation products caused by VHF FM broadcast signals having levels at the receiver input of minus 5 dBm.

(2) The VHF communications receiving system shall not be desensitized in the presence of VHF FM broadcast signals having levels at the receiver input of minus 5 dBm.

(3) Installations of airborne VHF communications receiving systems shall meet the provisions of paragraph (1) and paragraph (2) above.

(4) Airborne VHF communications receiving systems meeting the immunity performance Standards of paragraphs (1) and (2) above

shall be placed into operation at the earliest possible date.

23.3.11.2.5 SINGLE SIDEBAND (SSB) HF COMMUNICATION SYSTEM CHARACTERISTICS FOR USE IN THE AERONAUTICAL MOBILE SERVICE

The characteristics of the air-ground HF SSB system, where used in the Aeronautical Mobile Service, shall be in conformity with the following specifications.

23.3.11.2.6 FREQUENCY RANGE

(1) HF SSB installations shall be capable of operation at any SSB carrier (reference) frequency available to the Aeronautical Mobile (R) Service in the band 2.8 MHz to 22 MHz and necessary to meet the approved assignment plan for the region(s) in which the system is intended to operate, and in compliance with the relevant provisions of the Radio Regulations.

(2) The equipment shall be capable of operating on integral multiples of 1 kHz.

23.3.11.3 SIDEBAND SELECTION

The sideband transmitted shall be that on the higher frequency side of its carrier (reference) frequency.

23.3.11.4 CARRIER (REFERENCE) FREQUENCY

Channel utilization shall be in conformity with the table of carrier (reference) frequencies at 27/16 and the ITU Allotment Plan at 27/186 to 27/207 inclusive (or frequencies established on the basis of 27/21, as may be appropriate) of Appendix S27.

23.3.11.5 CLASSES OF EMISSION AND CARRIER SUPPRESSION

(1) The system shall utilize the suppressed carrier class of emission J3E (also J7B and J9B as applicable). When SELCAL is employed

as specified in Chapter 3 of Part II, the installation shall utilize class H2B emission.

(2) Aeronautical stations and aircraft stations shall have the appropriate class(es) of emission prescribed in 23.3.11.5(1) above.

(3) Aeronautical stations and aircraft stations equipped for single sideband operations shall also be equipped to transmit class H3E emission where required to be compatible with reception by double sideband equipment.

(4) For stations directly involved in co-ordinated search and rescue operations using the frequencies 3 023 kHz and 5 680 kHz, the class of emission J3E shall be used; however, since maritime mobile and land mobile receiving services may be involved, A3E and H3E classes of emission may be used.

(5) No new DSB equipment shall be installed.

(6) Aircraft station transmitters shall be capable of at least 26 dB carrier suppression with respect to peak envelope power (P_p) for classes of emission J3E, J7B or J9B.

(7) Aeronautical station transmitters shall be capable of 40 dB carrier suppression with respect to peak envelope power (P_p) for classes of emission J3E, J7B or J9B.

23.3.11.6 AUDIO FREQUENCY BANDWIDTH

(1) For radiotelephone emissions the audio frequencies shall be limited to between 300 and 2 700 Hz and the occupied bandwidth of other authorized emissions shall not exceed the upper limit of J3E emissions. In specifying these limits, however, no restriction in their extension shall be implied in so far as emissions other than J3E are concerned, provided that the limits of unwanted emissions are met (see 23.3.11.5(7) below).

(2) For other authorized classes of emission the modulation frequencies shall be such that the required spectrum limit of 23.3.11.5(7) below will be met.

23.3.11.7 FREQUENCY TOLERANCE

(1) The basic frequency stability of the transmitting function for classes of emission J3E, J7B or J9B shall be such that the difference between the actual carrier of the transmission and the carrier (reference) frequency shall not exceed:

-20 Hz for airborne installations;

-10 Hz for ground installations.

(2) The basic frequency stability of the receiving function shall be such that, with the transmitting function stabilities specified in paragraph (1) above, the over-all frequency difference between ground and airborne functions achieved in service and including Doppler shift, does not exceed 45 Hz. However, a greater frequency difference shall be permitted in the case of supersonic aircraft.

23.3.11.8 SPECTRUM LIMITS

(1) For aircraft station transmitter types and for aeronautical station transmitters first installed before 1st February 1983 and using single sideband classes of emission H2B, H3E, J3E, J7B or J9B the mean power of any emission on any discrete frequency shall be less than the mean power (P_m) of the transmitter in accordance with the following:

(a) on any frequency removed by 2 kHz or more up to 6 kHz from the assigned frequency: at least 25 dB;
(b) on any frequency removed by 6 kHz or more up to 10 kHz from the assigned frequency: at least 35 dB;

(c) on any frequency removed from the assigned frequency by 10 kHz or more:

(i)aircraft station transmitters: 40 dB;

(ii)aeronautical station transmitters:

$\{43 + 10\log_{10}P_m(W)\}dB$

(2) For aircraft station transmitters first installed after 1 February 1983 and for aeronautical station transmitters in use as of 1

February 1983 and using single sideband classes of emission H2B, H3E, J3E, J7B or J9B, the peak envelope power (P_p) of any emission on any discrete frequency shall be less than the peak envelope power (P_p) of the transmitter in accordance with the following:

(a) on any frequency removed by 1.5 kHz or more up to 4.5 kHz from the assigned frequency: at least 30dB;

(b) on any frequency removed by 4.5 kHz or more up to 7.5 kHz from the assigned frequency: at least 38dB;

(c) on any frequency removed from the assigned frequency by 7.5 kHz or more:

(i)aircraft station transmitters: 43 dB;

(ii)aeronautical station transmitters: for transmitter power up to and including 50 W:

$\{43 + 10\log_{10}P_p(W)\}dB$

For transmitter power more than 50 W: 60 dB.

23.3.11.9 POWER

(1) Aeronautical station installations. Except as permitted by the relevant provisions of Appendix S27 to the ITU Radio Regulations, the peak envelope power (P_p) supplied to the antenna transmission line for H2B, H3E, J3E, J7B or J9B classes of emissions shall not exceed a maximum value of 6 kW.

(2) Aircraft station installations. The peak envelope power supplied to the antenna transmission line for H2B, H3E, J3E, J7B or J9B classes of emission shall not exceed 400 W except as provided for in Appendix S27 of the ITU Radio Regulations as follows:

(a) S27/68 It is recognized that the power employed by aircraft transmitters may, in practice, exceed the limits specified in No. 27/60. However, the use of such increased power (which normally shall not exceed 600 W Pp) shall not cause harmful interference to stations using frequencies in accordance with

the technical principles on which the Allotment Plan is based.

(b) S27/60 Unless otherwise specified in IS 23.3.11, the peak envelope powers supplied to the antenna transmission line shall not exceed the maximum values indicated in the table below; the corresponding peak effective radiated powers being assumed to be equal to two-thirds of these values:

Class of emission	*Stations*	*Max. peak envelope power (P_p)*
H2B, J3E, J7B, J9B, A3E*, H3E* (100% modulation)	Aeronautical stations	6 kW
	Aircraft stations	400 W
Other emission such as A1A, F1B	Aeronautical stations	1.5 kW
	Aircraft stations	100 W

* A3E and H3E to be used only on 3 023 kHz and 5 680 kHz.

(3) Method of operation. Single channel simplex shall be employed.

23.3.11.10 SELCAL SYSTEM

(1) Where a SELCAL system is installed, the following system characteristics shall be applied:

a) Transmitted code. Each transmitted code shall be made up of two consecutive tone pulses, with each pulse containing two simultaneously transmitted tones. The pulses shall be of 1.0 plus or minus 0.25 seconds duration, separated by an interval of 0.2 plus or minus 0.1 second.

b) Frequency stability. The frequency of transmitted tones shall be held to plus or minus 0.15 per cent tolerance to ensure proper operation of the airborne decoder.

c) Distortion. The overall audio distortion present on the transmitted RF signal shall not exceed 15 per cent.

d) Level stability. The RF signal transmitted by the ground radio station shall contain, within 3 dB, equal amounts of the two modulating tones.

(e) Modulation envelope. The combination of tones shall result in a modulation envelope having a nominal modulation percentage as high as possible and not less than 60 per cent.

(2) The transmitted codes shall be made up of various combinations of the tones listed in Table 3-1. They are designated by colour and letter or number as indicated:

Table 3-1. SELCAL tones designated by colour and letter or number
(applicable as of 3 November 2022)

Red A	312.6
Red B	346.7
Red C	384.6
Red D	426.6
Red E	473.2
Red F	524.8
Red G	582.1
Red H	645.7
Red J	716.1
Red K	794.3
Red L	881.0
Red M	977.2

Red P	1 083.9
Red Q	1 202.3
Red R	1 333.5
Red S	1 479.1
Red T	329.2
Red U	365.2
Red V	405.0
Red W	449.3
Red X	498.3
Red Y	552.7
Red Z	613.1
Red 1	680.0
Red 2	754.2
Red 3	836.6
Red 4	927.9
Red 5	1029.2
Red 6	1141.6
Red 7	1266.2
Red 8	1404.4
Red 9	1557.8

Note 1.— The frequencies of the tones are spaced by Log^{-1} 0.0225 to avoid the possibility of harmonic combinations.

Note 2.— In accordance with the application principles developed by the Sixth Session of the Communications Division, the only codes at present used internationally are selected from the red group.

Note. - Guidance material on the use of SELCAL systems is contained in the Attachment on Part II.

(3) Aeronautical stations which are required to communicate with SELCAL-equipped aircraft shall have SELCAL encoders that support all tones in accordance with Table 3-1.

(4) SELCAL codes using the tones Red T through Red 9 as given in Table 3-1 shall only be assigned to SELCAL-equipped aircraft with the capability of receiving

these tones.

23.3.12 AERONAUTICAL VOICE COMMUNICATIONS

23.3.12.1 TECHNICAL PROVISIONS RELATING TO INTERNATIONAL AERONAUTICAL SPEECH CIRCUIT SWITCHING AND SIGNALLING FOR GROUND-GROUND APPLICATIONS

Note 1.— Detailed specifications and guidance material on the implementation of aeronautical Voice over Internet Protocol (VoIP) communications for ground-ground applications are contained in the Manual on the Aeronautical Telecommunication Network (ATN) using Internet Protocol Suite (IPS) Standards and Protocols (Doc 9896). Aeronautical VoIP communications for ground-ground applications include inter-ATS unit telephony and radio air-ground applications on the ground component between the ATS unit and the air-ground control radio station, which is responsible for handling communications pertaining to the operation and control of aircraft in a given area.

Note 2.— Guidance material on the implementation of the speech circuits supported by air traffic services (ATS) ground-ground voice switching and signalling is contained in the Manual on Air Traffic Services (ATS) Ground-Ground Voice Switching and Signalling (Doc 9804).

(1) The use of circuit switching and signalling to provide speech circuits to interconnect ATS units not interconnected by dedicated circuits shall be by agreement between the Administrations concerned.

(2) The application of aeronautical speech circuit switching and signalling shall be made on the basis of regional air navigation agreements.

(3) The ATC communication requirements defined in 24.6.2 shall be met by implementation of one or more of the following basic three call types:

(a) instantaneous access;

(b) direct access; and

(c) indirect access.

(4) In addition to the ability to make basic telephone calls, the following functions

shall be provided in order to meet the requirements set out in Part 24:

(a) means of indicating the calling/called party identity;

(b) means of initiating urgent/priority calls; and

(c) conference capabilities.

(5) The characteristics of the circuits used in aeronautical speech circuit switching and signalling shall conform to appropriate ISO/IEC international standards and ITU-T recommendations.

(6) Digital signalling systems shall be used wherever their use can be justified in terms of any of the following:

(a)improved quality of service;
(b) improved user facilities; or
(c)reduced costs where quality of service is maintained.

(7) The characteristics of supervisory tones to be used (such as ringing, busy, number unobtainable) shall conform to appropriate ITU-T recommendations.

(8) To take advantage of the benefits of interconnecting regional and national aeronautical speech networks, the international aeronautical telephone network numbering scheme shall be used.

23.3.13 EMERGENCY LOCATOR TRANSMITTER (ELT) FOR SEARCH AND RESCUE

23.3.13.1GENERAL

(1) ELTS operating on 121.5MHz will be required to meet the improved technical characteristics contained in 5.2.1.8.

(2) All installations of emergency locator transmitters operating on 406 MHz shall meet the provisions of 23.3.11.13.

(3) All installations of emergency locator transmitters operating on 121.5 MHz shall meet the provisions of 23.3.11.12.2.

(5) Emergency locator transmitters shall operate on 406 MHz and 121.5 MHz simultaneously.

(6) All emergency locator transmitters installed on or after 1 January 2002 shall operate simultaneously on 406 MHz and 121.5 MHz.

(7) The technical characteristics for the 406 MHz component of an integrated ELT shall be in accordance with 23.3.11.12.2.

(8) The technical characteristics for the 121.5 MHz component of an integrated ELT shall be in accordance with 23.3.11.13.

(9) The Authority shall register a 406 MHz ELT for all aircraft. Register information regarding the ELT shall be immediately available to search and rescue authorities. The authority shall update the register whenever necessary.

(10) ELT register information shall include the following:

(a) transmitter identification (expressed in the form of an alphanumerical code of 15 hexadecimal characters);

(b) transmitter manufacturer, model and, when available, manufacturer's serial number;

(c) number; COSPAS-SARSAT* type approval

(d) name, address (postal and e-mail) and emergency telephone number of the owner and operator;

(e) name, address (postal and e-mail) and telephone number of other emergency contacts (two, if possible) to whom the owner or the operator is known;

(f) aircraft manufacturer and type; and

(g) colour of the aircraft.

23.3.11.1.1 SPECIFICATION FOR THE 121.5 MHZ COMPONENT OF EMERGENCY LOCATOR TRANSMITTER (ELT) FOR SEARCH AND RESCUE

Note 1.— Information on technical characteristics and operational performance of 121.5 MHz ELTs is contained in RTCA Document DO-183 and European Organization for Civil Aviation Equipment (EUROCAE) Document ED.62.

Note 2.— Technical characteristics of emergency locator transmitters operating on 121.5 MHz are contained in ITU-R Recommendation M.690-1. The ITU designation for an ELT is Emergency Position — Indicating Radio Beacon (EPIRB).

23.3.11.1.2 TECHNICAL CHARACTERISTICS

(1) Emergency locator transmitters (ELT) shall operate on 121.5 MHz. The frequency tolerance shall not exceed plus or minus 0.005 per cent.

(2) The emission from an ELT under normal conditions and attitudes of the antenna shall be vertically polarized and essentially omni- directional in the horizontal plane.

(3) Over a period of 48 hours of continuous operation, at an operating temperature of minus 20°C, the peak effective radiated power (PERP) shall at no time be less than 50 mW.

(4) The type of emission shall be A3X. Any other type of modulation that meets the requirements of 23.3.12.12.3(5),23.3.12.12.3(6)and 23.3.12.12.3(7) below may be used provided that it will not prejudice precise location of the beacon by homing equipment.

(5) The carrier shall be amplitude modulated at a modulation factor of at least 0.85.

(6) The modulation applied to the carrier shall have a minimum duty cycle of 33 per cent.

(7) The emission shall have a distinctive audio characteristic achieved by amplitude modulating the carrier with an audio frequency sweeping downward over a range of not less than 700 Hz within the range 1 600 Hz to 300 Hz and with a sweep repetition rate of between 2 Hz and 4 Hz.

(8) After 1 January 2000, the emission shall include a clearly defined carrier frequency distinct from the modulation sideband components; in particular, at least 30 per cent of the power shall be contained at all times within plus or minus 30 Hz of the carrier frequency on 121.5 MHz.

23.3.11.1.3 SPECIFICATION FOR THE 406MHZ COMPONENT OF EMERGENCY LOCATOR TRANSMITTER (ELT) FOR SEARCH AND RESCUE

23.3.11.1.3.1 TECHNICAL CHARACTERISTICS

Note 1.— Transmission characteristics for 406 MHz emergency locator transmitters are contained in ITU-R M.633.

Note 2.— Information on technical characteristics and operational performance of 406 MHz ELTs is contained in RTCA Document DO-204 and European Organization for Civil Aviation Equipment (EUROCAE) Document ED-62.

(1) Emergency locator transmitters shall operate on one of the frequency channels assigned for use in the frequency band 406.0 to 406.1 MHz.

(2) The period between transmissions shall be 50 seconds plus or minus 5 per cent.

(3) Over a period of 24 hours of continuous operation at an operating temperature of -20°C, the transmitter power output shall be within the limits of 5 W plus or minus 2dB.

(4) The 406 MHz ELT shall be capable of transmitting a digital message.

23.3.11.1.3.2 TRANSMITTER IDENTIFICATION CODING

(1) Emergency locator transmitters operating on 406 MHz shall be assigned a unique coding for identification of the transmitter or aircraft on which it is carried.

(2) The emergency locator transmitter shall be coded in accordance with either the aviation user protocol or one of the serialized user protocols described in IS: 23.3.12.13(2) to this Subpart, and shall be registered with the appropriate authority.

GHANA CIVIL AVIATION
(AIR NAVIGATION SERVICES)
DIRECTIVES

PART 23 SUBPART 3 – IMPLEMENTING STANDARDS

For ease of reference, the number assigned to each implementing standard corresponds to its associated regulation. For example, IS 23.2.1 would reflect a standard required in subsection 23.3.1

IS: 23.3.4.3.2 EMERGENCY LOCATOR TRANSMITTER CODING *(*

Note. — A detailed description of beacon coding is contained in Specification for COSPAS-SARSAT 406 MHz Distress Beacons (C/S T.001). The following technical specifications are specific to emergency locator transmitters used in aviation

1. GENERAL

(1) The emergency locator transmitter (ELT) operating on 406 MHz shall have the capacity to transmit a programmed digital message which contains information related to the ELT and/or the aircraft on which it is carried.

(2) The ELT shall be uniquely coded in accordance with 1.3 and be registered with the appropriate authority.

(3) The ELT digital message shall contain either the transmitter serial number or one of the following information elements:

(a) aircraft operating agency designator and a serial number;

(b) 24-bit aircraft address;

(c) aircraft nationality and registration marks.

(4) All ELTs shall be designed for operation with the COSPAS-SARSAT* system and be type approved.

Note. — Transmission characteristics of the ELT signal can be confirmed by making use of the COSPAS-SARSAT Type Approval Standard (C/S T.007).

1. ELT CODING

(1) The ELT digital message shall contain information relating to the message format, coding protocol, country code, identification data and location data, as appropriate.

(2) For ELTs with no navigation data provided, the short message format C/S

T.001 shall be used, making use of bits 1 through 112. For ELTs with navigation data, if provided, the long message format shall be used, making use of bits 1 through 144.

3. Protected data field

(1) The protected data field consisting of bits 25 through 85 shall be protected by an error correcting code and shall be the portion of the message which shall be unique in every distress ELT.

(2) A message format flag indicated by bit 25 shall be set to "0" to indicate the short message format or set to "1" to indicate the long format for ELTs capable of providing location data.

* COSPAS = Space system for search of vessels in distress;
SARSAT = Search and rescue satellite-aided tracking.

(3) A protocol flag shall be indicated by bit 26 and shall be set to "1" for user and user location protocols, and "0" for location protocols.

(4) A country code, which indicates the State where additional data are available on the aircraft on which the ELT is carried, shall be contained in bits 27 through 36 which designate a three-digit decimal country code number expressed in binary notation.

Note. — Country codes are based on the International Telecommunication Union (ITU) country codes shown in Table 4 of Part I, Volume I of the ITU List of Call Signs and Numerical Identities.

(5) Bits 37 through 39 (user and user location protocols) or bits 37 through 40 (location protocols) shall designate one of the protocols where values "001" and "011" or "0011", "0100", "0101", and "1000" are used for aviation as shown in the examples contained in this appendix.

(6) The ELT digital message shall contain either the transmitter serial number

or an identification of the aircraft or operator as shown below.

(7) In the serial user and serial user location protocol (designated by bit 26=1 and bits 37 through 39 being “011”), the serial identification data shall be encoded in binary notation with the least significant bit on the right. Bits 40 through 42 shall indicate type of ELT serial identification data encoded where:

(a) “000” indicates ELT serial number (binary notation) is encoded in bits 44 through 63;

(b) “001” indicates aircraft operator (3 letter encoded using modified Baudot code shown in Table 5-1) and a serial number (binary notation) are encoded in bits 44 through 61 and 62 through 73, respectively;

(c) “011” indicates the 24-bit aircraft address is encoded in bits 44 through 67 and each additional ELT number (binary notation) on the same aircraft is encoded in bits 68 through 73.

Note. — States will ensure that each beacon, coded with the country code of the State, is uniquely coded and registered in a database. Unique coding of serialized coded beacons can be facilitated by including the COSPAS-SARSAT Type Approval Certificate Number which is a unique number assigned by COSPAS-SARSAT for each approved ELT model, as part of the ELT message.

(8) In the aviation user or user location protocol (designated by bit 26=1 and bits 37 through 39 being “001”), the aircraft nationality and registration marking shall be encoded in bits 40 through 81, using the modified Baudot code shown in Table 5-1 to encode seven alphanumeric characters. This data shall be right justified with the modified Baudot “space” (“100100”) being used where no character exists.

(9) Bits 84 and 85 (user or user location protocol) or bit 112 (location protocols) shall indicate any homing transmitter that may be integrated in the ELT.

(10) In standard and national location protocols, all identification and location data shall be encoded in binary notation with the least significant bit right justified. The aircraft operator designator (3 letter code) shall be encoded in 15 bits using a modified Baudot code (Table 5-1) using only the 5 right most bits per letter and dropping the left most bit which has a value of 1 for letters.

Table 5-1. Modified Baudot code

Letter	*Code MSB LSB*	*Figure*	*Code MSB LSB*
A	111000	(-)*	011000
B	110011		
C	101110		
D	110010		
E	110000	3	010000
F	110110		
G	101011		
H	100101		
I	101100		
J	111010	8	001100
K	111110		
L	101001		
M	100111		
N	100110		
O	100011	9	000011
P	101101	0	001101
Q	111101	1	011101
R	101010	4	001010
S	110100		
T	100001	5	000001
U	111100	7	011100
V	101111		
W	111001	2	011001
X	110111	/	010111
Y	110101	6	010101
Z	110001		
( )**	100100		

MSB = most significant bit least
LSB = significant bit
* = hyphen
** = space

EXAMPLES OF CODING

ELT serial number

25		27	37			40				44	64	74	85	
F	1	COUNTRY	0	1	1	T	T	T	C	SERIAL NUMBER DATA (20 BITS)	SEE NOTE 1	SEE NOTE 2	A	A

Aircraft address

25		27	37			40				44	68	74	85	
F	1	COUNTRY	0	1	1	T	T	T	C	AIRCRAFT ADDRESS (24 BITS)	SEE NOTE 3	SEE NOTE 2	A	A

Aircraft operator designator and serial number

25		27	37			40				44	62	74	85	
F	1	COUNTRY	0	1	1	T	T	T	C	OPERATOR 3-LETTER DESIGNATOR	SERIAL NUMBER 1-4096	SEE NOTE 2	A	A

Aircraft registration marking

25		27	37			40	83		85	
F	1	COUNTRY	0	0	1	AIRCRAFT REGISTRATION MARKING (UP TO 7 ALPHANUMERIC CHARACTERS) (42 BITS)	0	0	A	A

T = Beacon type TTT: = 000 indicates ELT serial number is encoded;
= 001 indicates operating agency and serial number are encoded;
= 011 indicates 24-bit aircraft address is encoded.

C = Certificate flag bit: 1 = to indicate that COSPAS-SARSAT Type Approval Certificate number is encoded in bits 74 through 83 and
0 = otherwise

F = Format flag: 0 = Short Message
1 = Long Message

A = Auxiliary radio-locating device: 00 = no auxiliary radio-locating device

01 = 121.5 MHz
11 = other auxiliary radio-locating device

Note 1.— 10 bits, all 0s or
National use.

Note 2.— COSPAS-SARSAT Type Approval Certificate number in binary notation with the least significant bit on the right, or National use.

Note 3.— Serial number, in binary notation with the least significant bit on the right, of additional ELTs carried in the same aircraft or default to 0s when only one ELT is carried.

EXAMPLE OF CODING (USER LOCATION PROTOCOL)

25	26	←27 36→	←37 ←40 85→ 39→ 83→		←86 106→	←107 112→	←113 132→	←133 144→
1	1	10	3	44	2	21	1	12	13	12
1	1	CC	T	IDENTIFICATION DATA (AS IN ANY OF USER PROTOCOLS ABOVE)	A	21-BIT BCH ERROR CORRECTING CODE	E	LATITUDE	LONGITUDE	12-BIT BCH ERROR CORRECTING CODE
								1	7	4	1	8	4	
								N/S	DEG 0–90 (1 d)	MIN 0–56 (4m)	E/W	DEG 0–180 (1 d)	MIN 0–56 (4m)	

CC = Country Code;
E = Encoded position data source: 1 = Internal navigation device, 0 = External navigation device

EXAMPLE OF CODING (STANDARD LOCATION PROTOCOL)

25	26	←27 36→	←37 40→ | ←41 85→			←86 106 →	107 112→	←113 132→		←133 144→
61 BITS							26 BITS			
1	1	10	4	45		21	6	20		12
1	0	CC	PC	IDENTIFICATION DATA	LATITUDE LONGITUDE		SD	LATITUDE	LONGITUDE	

				24		1	9	1	10	21-BIT BCH CODE		1	15	4	1	15	4	12-BIT BCH CODE
			0011	AIRCRAFT 24 BIT ADDRESS		N = 0	LAT DEG 0–90 (1/4 d)	E = 0	LON DEG 0–180 (1/4 d)			– = 0 + = 1	MINUTES 0–30 (1 m)	SECONDS 0–56 (4 s)	– = 0 + = 1	MINUTES 0–30 (1 m)	SECONDS 0–56 (4 s)	
			0101	15	9	S = 1		W = 1										
				AIRCRAFT OPER. DESIGNATOR	SERIAL No 1–511													
			0100	10	14													
				C/STA No 1–1023	SERIAL No 1–16383													

CC = Country Code;
PC = Protocol Code 0011 indicates 24-bit aircraft address is encoded;
0101 indicates operating agency and serial number are encoded;
0100 indicates ELT serial number is encoded.
SD = Supplementary Data bits 107 – 110 = 1101;
bit 111 = Encoded Position Data Source (1 = internal; 0 = external)
bit 112: 1 = 121.5 MHz auxiliary radio locating device;
0 = other or no auxiliary radio locating device.

Note 1.— Further details on protocol coding can be found in Specification for COSPAS-SARSAT 406 MHz Distress Beacon (C/S T.001).

Note 2. — All identification and location data are to be encoded in binary notation with the least significant bit on the right except for the aircraft operator designator (3 letter code).

Note 3. — For details on BCH error correcting code see Specification for COSPAS-SARSAT 406

MHz Distress Beacon (C/S T.001).

EXAMPLE OF CODING (NATIONAL LOCATION PROTOCOL)

25	26	←27 36→	←37 40→|←41 85→											←86 106→	107 112	←113 132→								←133 144→
61 BITS PDF-1														BCH-1	26 BITS PDF-2								BCH-2
1	1	10	4	45										21	6	7			7			6	12
1	0	CC	1000	18 bits ID	27 bits LATITUDE LONGITUDE									21-BIT BCH CODE	SD	LATITUDE			LONGITUDE			NU	12-BIT BCH CODE
				18	1	7	5	1	8	5						1	2	4	1	2	4		
				NATIONAL ID NUMBER	N = 0 S = 1	DEGREES 0–90 (1d)	MINUTES 0–58 (2m)	E = 0 W = 1	DEGREES 0–180 (1d)	MINUTES 0–58 (2m)						– = 0 + = 1	MINUTES 0–3 (1m)	SECONDS 0–56 (4s)	– = 0 + = 1	MINUTES 0–3 (1m)	SECONDS 0–56 (4s)		

CC= Country Code;
ID = Identification 8-bit identification data consisting of a serial number assigned by
SD= Supplementary bits 107 – 109 = 110;
bit 110 = Additional Data Flag describing the use of bits 113 to 132:
1 = Delta position; 0 = National assignment;
bit 111 = Encoded Position Data Source: 1 = internal, 0 = external;
bit 112: 1 = 121.5 MHz auxiliary radio locating device;
0 = other or no device
NU = National use = 6 bits reserved for national use (additional beacon type identification or other uses).

Note 1.— Further details on protocol coding can be found in Specification for COSPAS-SARSAT 406 MHz Distress Beacon

(C/S T.001).

Note 2.— All identification and location data are to be encoded in binary notation with the least significant bit on the right.

Note 3.— For details on BCH error correcting code see Specification for COSPAS-SARSAT 406 MHZ Distress Beacon (C/S T.001).

ATTACHMENT TO PART I. GUIDANCE MATERIAL FOR THE VHF DIGITAL LINK (VDL)

1. GUIDANCE MATERIAL FOR THE VHF DIGITAL LINK (VDL)

Note. — The Standards and Recommended Practices (SARPs) referred to are contained in Annex 10, Volume III, Part 1, Chapter 6.

2. SYSTEM DESCRIPTION

(1) The VDL system provides an air-ground data communications link within the aeronautical telecommunications network (ATN). The VDL will operate in parallel with the other ATN air-ground subnetworks.

(2) VDL ground stations consist of a VHF radio and a computer capable of handling the VDL protocol throughout the coverage area. The VDL stations offer connectivity via a ground-based telecommunications network (e.g. X.25 based) to ATN intermediate systems which will provide access to ground-based ATN end systems.

(3) In order to communicate with the VDL ground stations, aircraft are required to be equipped with VDL avionics which will include a VHF radio and a computer capable of handling the VDL protocol. The air-ground communication wilL utilize 25 kHz channels in the VHF aeronautical mobile

(route) service band.

3. VDL PRINCIPLES

(1) Communications transfer principles

(2) Connectivity between applications running in ATN end systems (ES) using the ATN and its subnetworks including the VDL, for air-ground communication is provided by the transport layer entities in these end systems. Transport connections between airborne and ground end systems shall be maintained through controlled changes of the precise ATN intermediate systems (IS) and VDL network elements that provide this connectivity.

(3) Transport connections between ATN ES are not linked to a particular subnetwork and ISO 8473 network protocol data units transmitted by an ES can pass via any air-ground ATN compatible subnetwork (such as aeronautical mobile-satellite service (AMSS) data link, SSR Mode S data link or VDL) that meets the quality of service (QOS) requirements. A transport connection between an aircraft ES and a ground ES shall be maintained as long as there is at least one air-ground subnetwork connection between the aircraft IS and a ground IS which has connectivity to the ground ES. In order to maximize subnetwork connectivity, aircraft are expected to maintain air-ground subnetwork connections via any subnetwork(AMSS, Mode S or VDL) with which link layer connectivity can be established.

(4) The VDL subnetwork provides connectivity in the form of switched virtual circuits between ISO 8208 data terminal equipment (DTE) entities of aircraft and ground-based ATN intermediate systems. Due to the fact that VHF signals Annex 10 — Aeronautical Communications Volume III 22/11/07 ATT I-2 have only line-of-sight propagation, it is necessary for aircraft in flight to regularly establish link connections with new VDL ground stations in order to maintain VHF coverage. An established VDL virtual circuit between an aircraft DTE and a ground DTE is maintained through a controlled change to a ground station through which the ground DTE can be accessed.

(5) VDL virtual circuits may be cleared when the aircraft or

ground IS identifies a policy situation where the virtual circuit to the ground DTE is no longer necessary but this shall only happen if another VDL virtual circuit remains established. A policy situation is a situation where considerations other than coverage influence the decision to establish a connection. This could be, for example, a situation where an aircraft is within the designated operational coverage area of ground stations operated by different operators and a decision must be made with which operator to establish a connection. The case where an aircraft crosses a border between two States needs special attention. An aircraft has to establish a virtual circuit to the DTE in the IS of the State entered before clearing the virtual circuit with the DTE in the IS of the State left.

(6) The scenarios for subnetwork connection maintenance are shown in Figure ATT I-1*. If the ground stations on each side of a State border do not offer ISO 8208 connectivity to the DTEs of the IS in both States, aircraft crossing the border will have to set up a link connection to a ground station in the State entered before being able to establish a virtual circuit to the IS of that State. Only after establishment of the new link connection and virtual circuit, the aircraft will clear the virtual circuit with the DTE of the IS of the country left over the link which gave access to that IS. If the VDL aeronautical stations on both sides of the State border offer connectivity to the IS in both States, the changeover of the virtual circuits has to take place over the same link connection.

4. VDL quality of service for ATN routing

(1) The use of the VDL system for air-ground communications will depend on the routing decisions of aircraft and ground-based ATN IS. These ISs will decide on the path to be used for air-ground communications based on quality of service values requested by transmitting ESs.

(2) The IS at each end of the air-ground connections must interpret the requested QOS value and decide which of the

available connections can best be met. It is important that the level of QOS which a VDL connection is perceived as providing, is set at a level which corresponds to its true performance.

(3) In cases where the VDL is the only data link with which an aircraft has been equipped, all communications must be routed via a VDL connection and the value set for QOS to be provided by the connection must not block the communication.

(4) In other cases where aircraft are equipped with other air-ground data links (such as AMSS and SSR Mode S) there may be simultaneous parallel connections over multiple subnetworks. In these cases, the values for QOS provided by each subnetwork must be set so as to ensure that the VDL connection will be used where appropriate.

(5) It is necessary that coordination take place between aircraft operators, ground station operators and ground system operators to ensure that the right balance is achieved between different subnetworks.

5. VDL GROUND STATION NETWORK CONCEPT

5.1. Access

(1) A VDL ground station will provide access for aircraft to the ground ATN IS using the VDL protocol over a VHF channel.

* The figure is located at the end of this attachment.

(2) Institutional issues concerning VDL ground station network operators

(3) An ATS provider wishing to use VDL for air traffic service (ATS) communications needs to ensure that the VDL service is available. The ATS provider can either operate the VDL ground station network itself or arrange for the operation of the VDL stations (or VDL network) by a telecommunications service provider. It seems likely that individual States will make different arrangements for the provision of VDL service to aircraft. Operation and implementation of VDL need to be coordinated at a regional level in order to ensure

acceptable service on international routes.

(4) The use of a VDL ground station network by entities external to the ATS provider will be subject to service agreements between the ATS provider and the telecommunications service provider. These agreements set out the obligations of the two parties and need, in particular, to be specific on the quality of service provided as well as the characteristics of the user interface.

(5) It seems likely that some VDL ground station network operators will levy user charges. These are expected to be levied either on the aircraft operators and/or on the ATS providers. It is necessary to ensure that the use of VDL is feasible for those aircraft operators intended to use VDL for ATS/AOC communications.

5.2 VDL ground station equipment

(1) A VDL ground station will consist of a VHF radio and a computer which may be separate or integrated with the radio. The VDL functionality of the VHF radio equipment will be similar to that installed in aircraft.

(2) The provision of network status monitoring is an important element in the maintenance of the highest availability possible.

5.3 Ground station sitting

(1) The line of sight limitations of VHF propagation is an important factor in the siting of ground stations. It is necessary to ensure that the ground stations are installed in a manner which provides coverage throughout the designated operational coverage area (DOC).

(2) The coverage requirements for VDL depend on the applications that are intended to operate over the VDL. These applications may function, for example, when an aircraft is at en-route altitude, in a terminal area or on the ground at an airport.

(3) En-route coverage can be provided using a small number of ground stations with a large DOC (for example, the range of a VHF signal from a station at sea level and an aircraft at 37 000 ft is approximately 200 NM). Hence, it is in fact desirable that the smallest number of ground stations possible be used to provide en-route coverage in order to minimize the possibility of simultaneous uplink transmissions from ground stations which may cause message collisions on the VHF channel. The factors limiting en-route coverage will be availability of landmass and the availability of a communications link from a ground station to other ground systems.

(4) Terminal area coverage requires, in general, the installation of ground stations at all airports where VDL operation is required in order to ensure coverage throughout the terminal area.

(5) Aerodrome surface communication coverage must be provided by a ground station at the airport but, due to the physical structure of the airport, it may not be possible to guarantee coverage in all areas with a single station.

5.4 Ground station frequency engineering

(1) The choice of the VHF channel on which a ground station will operate depends on the coverage that the ground station will be required to provide. Coverage on a particular channel is provided by a collection of ground stations operating on that channel and the communications on that channel will occupy the channel for all the ground stations in a coverage area.

(2) As with VHF voice communications, VDL communications cannot be limited to propagating only within States, and frequency coordination between States will be required in the allocation of VDL frequencies. The nature of the protocol does, however, allow for frequency re-use by several ground stations within the same coverage area and hence the rules

for the assignment of frequencies are not the same as for voice communications.

(3) The carrier sense multiple access (CSMA) media access control protocol (MAC) layer used in VDL cannot exclude message collisions if some stations using a frequency channel cannot receive the transmissions of other stations, a situation known as a hidden transmitter situation. Hidden transmitters lead to simultaneous transmissions which can cause the intended receiver of one or both transmissions to be unable to decode the received signal.

(4) A frequency will be assigned to providing en-route coverage and all the en-route stations will be set to operate on this frequency. In order to minimize the probability of simultaneous transmissions on the channel by hidden transmitters in a CSMA environment, this channel may not be used for terminal area or aerodrome surface communications except in areas of very low channel loading.

(5) The VDL SARPs call for the provision of a common signalling channel (CSC) on which access to VDL service will be guaranteed in all areas where VDL Mode 2 service is available. This is especially important at airports and on the edge of VDL en-route coverage zones where aircraft are likely to establish initial VDL connectivity. Since the characteristics of Mode 1 and Mode 2 radio frequency transmissions are not compatible, the CSC cannot be used for Mode 1 communications. There is no requirement for a CSC for VDL Mode 1.

5.5 Ground station connection to intermediate systems

(1) In order to provide access to the ground systems which are connected to the aeronautical telecommunications network, a VDL ground station needs to be connected to one or more ATN IS. The purpose of a VDL ground station is to interconnect aircraft with the ground-based ATN via which communications with terrestrial ATN ES can take place.

(2) The ground-based ATN IS can be co-hosted in the VDL ground station computer in which case the VDL subnetwork virtual circuit will end in that computer. This architecture

will have an impact on the exchanges required when an aircraft establishes a VDL link with a new ground station. The exact exchange will depend on whether the ground stations contain separate IS or elements of the same distributed intermediate system.

(3) If the IS is not contained in the VDL ground station, it will be connected to the ground station by one of the following means:

(a) wide area network (WAN);

(b) local area network (LAN); and

(c) dedicated communications line.

(4) In all cases, in order to be in accordance with the Manual of the Aeronautical Telecommunication Network (ATN) (Doc 9578) for providing an open systems interconnection (OSI) compatible connection-oriented subnetwork service between the aircraft IS and the ground-based IS, the VDL ground station computer will be required to extend the VDL virtual circuit across the terrestrial network or link.

(5) In order to provide simultaneous virtual circuits to several terrestrial ISs, the VDL ground station computer needs to contain a VDL subnetwork entity capable of converting addresses in VDL subnetwork call requests into addresses in the ground-based network.

6. VDL AIRBORNE OPERATING CONCEPT

6.1 Avionics

VDL avionics. In order to operate in a VDL network, aircraft need to be equipped with an avionics system providing the VDL subnetwork user (ISO 8208 DTE) function. The system providing this function will also provide the subnetwork user functions for the other air-ground ATN-compatible subnetworks and the aircraft ATN intermediate system function and, hence, its development is necessary in order to provide ATN communications to multiple end-systems or

over multiple air-ground subnetworks.

6.2 VDL avionics certification

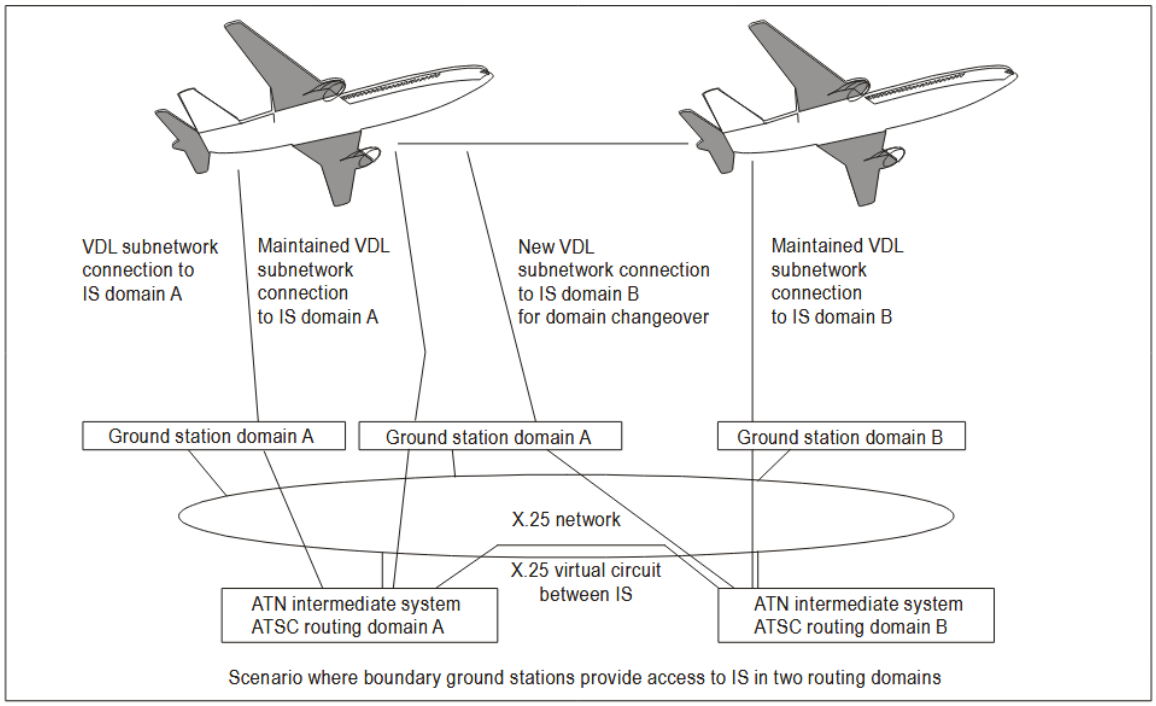
(1) The VHF digital radio may also provide for double-side band amplitude modulation (DSB-AM) voice capability for emergency back-up to VHF radios used for voice communications. It would be necessary in this case to demonstrate that the VDL functionality of the VDR does not interfere with the DSB-AM voice functionality.

(2) The VDL function in the VHF digital radio provides an air-ground data link service to the VDL subnetwork user entity of the aircraft ATN intermediate system. If the provision of a VHF subnetwork service to an ATN intermediate system were considered an essential service for a particular installation, the VDL functionality of the VDR would need to be certified as an essential function. The use of VDL for ATS communications is not, however, intended to require two aircraft radios to operate simultaneously in VDL mode.

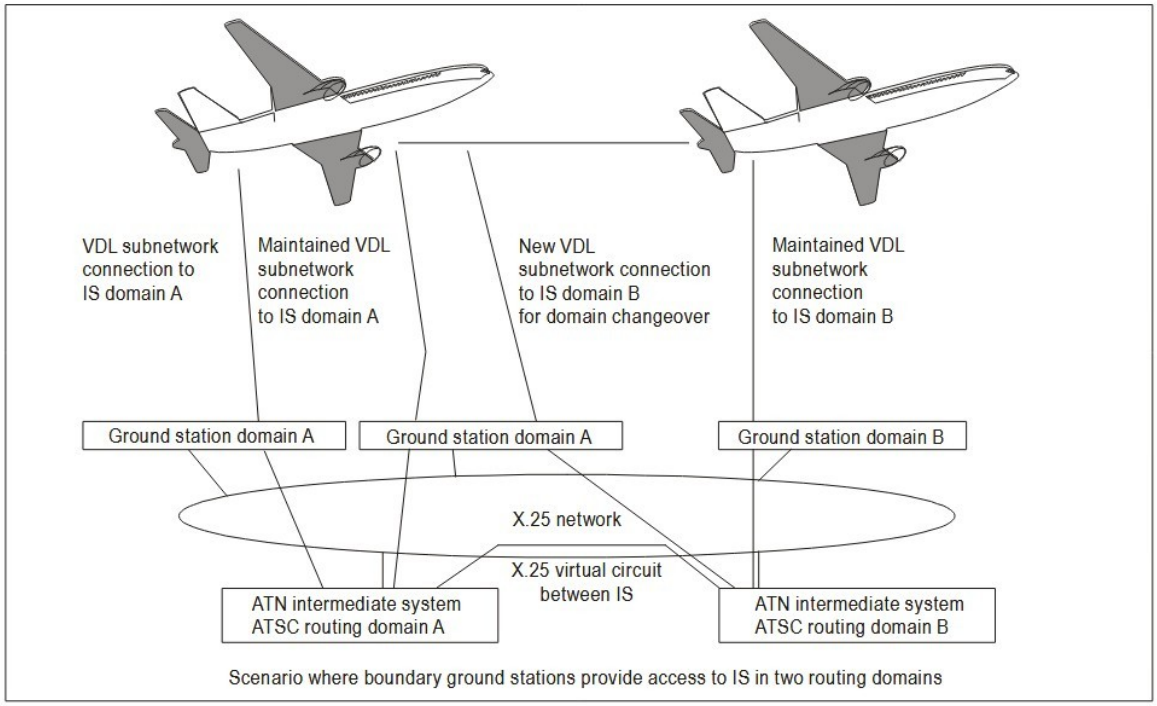
6.3 Registration of aircraft with VDL network operators

(1) For normal communications service, it is to be expected that aircraft operators will be required to register their aircraft with the network operators. In emergency or back-up situations, it must be possible for any VDL-equipped aircraft to establish connectivity over any VDL ground station network.

(2) Registration of aircraft VDL stations with VDL network operators is desirable for network management since, for example, a network operator may identify a temporary fault in the VDL communications from an aircraft and would wish to contact the operator of the aircraft in order to have the fault resolved. Registration of aircraft is also useful in planning the required ground station network capacity. Registration with a VDL ground station network operator does not necessarily imply that the aircraft operator will be charged for use of the VDL ground station network.



Scenario where boundary ground stations provide access to IS in two routing domains



Scenario where boundary ground stations provide access to IS in two routing domains

ATTACHMENT TO PART II. GUIDANCE MATERIAL FOR COMMUNICATION SYSTEMS

1. VHF COMMUNICATIONS

1.1 Audio characteristics of VHF communication equipment

(1) The aeronautical radiotelephony services represent a special case of the application of radiotelephony, in that the requirement is for the transmission of messages in such a way that fidelity of wave form is of secondary importance, emphasis being upon fidelity of basic intelligence. This means that it is not necessary to transmit those parts of the wave form which are solely concerned with individuality, accent and emphasis.

(2) The effective acceptance bandwidth for 8.33 kHz equipment is required to be at least plus and minus 3 462 Hz. This value considers the general case, i.e. air-to-ground transmissions and consists of 2 500 Hz audio bandwidth, 685 Hz for an aircraft transmitter instability of 5 ppm, 137 Hz for a ground receiver instability of 1 ppm and 140 Hz due to Doppler shift (2.2.2.4 and 2.3.2.6 of Part II refer).

(3) Offset carrier system in 25 kHz, 50 kHz and 100 kHz spaced channels

(4) The following are examples of offset carrier systems which meet the requirements of Part II, 2.2.1.1.1.

(a) 2-carrier system. Carriers shall be spaced at plus and minus 5 kHz. This requires a frequency stability of plus or minus 2 kHz (15.3 parts per million at 130 MHz).

(b) 3-carrier system. Carriers shall be spaced at zero and plus and minus 7.3 kHz. This requires a

frequency stability of plus or minus 0.65 kHz (5 parts per million at 130 MHz). The following are examples or 4- and 5-carrier systems which meet the requirements of Part II, 2.2.1.1.1.

(c) 4-carrier system. Carriers shall be spaced at plus and minus 2.5 kHz and plus and minus 7.5 kHz. This requires a frequency stability of plus or minus 0.5 kHz (3.8 parts per million at 130 MHz).

(d) 5-carrier system. Carriers shall be spaced at zero, plus and minus 4 kHz and plus and minus 8 kHz. A frequency stability in the order of plus or minus 40 Hz (0.3 parts per million at 130 MHz) is an achievable and practicable interpretation of the requirement in this case.

Note 1. — The carrier frequency spacings referred to above are with respect to the assigned channel frequency.

Note 2. — In aircraft receivers which employ a measurement of the received carrier-to-noise ratio to operate the mute, the audio heterodynes caused by the reception of two or more off-set carriers can be interpreted as noise and cause the audio output to be muted even when an adequate wanted signal is present. In order that the airborne receiving system can conform with the sensitivity recommendations contained in Part II, 2.3.2.2, the design of the receivers may need to ensure that their sensitivity is maintained at a high level when receiving off-set carrier transmissions. The use of a carrier level override is an unsatisfactory solution to this requirement, but where it is employed, setting the override level as low as possible can ameliorate the problem.

(5) Immunity performance of COM receiving systems in the presence of VHF FM broadcast interference

(6) With reference to the Note of 2.3.3.2 of Part II, the immunity performance defined there must be measured against an agreed measure of derogation of the receiving system's normal performance, and in the presence of, and under standard conditions for the input wanted

signal. This is necessary to ensure that the checking of receiving station equipment on bench test can be performed to a repeatable set of conditions, and results, and to facilitate their subsequent approval. An adequate measure of immunity performance may be obtained by the use of wanted signal of minus 87 dBm into the receiving equipment and the signal modulated with a 1 kHz tone at 30 per cent modulation depth. The signal-to-noise ratio shall not fall below 6 dB when the interfering signals specified at Part II, 2.3.3.1 and 2.3.3.2 are applied. The broadcast signals shall be selected from frequencies in the range between 87.5 and 107.9 MHz and shall be modulated with a representative broadcast type signal.

Note 1.— The signal level of minus 87 dBm assumes a combined antenna and feeder gain of 0 dB.

Note 2.— The reduction in the signal-to-noise ratio quoted above is for the purpose of standardization when checking that receiving station equipment on bench measurements meet the required immunity. In the planning of frequencies and in the assessment of protection from FM broadcast interference, a value not less than this, and in many cases higher, depending on the operational circumstances in individual cases, shall be chosen as the basis of the interference assessment.

2. SELCAL SYSTEM

(1) This material is intended to provide information and guidance relating to the operation of the SELCAL system. It is associated with the Recommended Practices contained in Part II, Chapter 3.

(a) Function. The purpose of the SELCAL system is to permit the selective calling of individual aircraft over radiotelephone channels linking the ground station with the aircraft, and is intended to operate on en-route frequencies with existing HF and VHF ground-to-air communications transmitters and receivers with a minimum of electrical and mechanical modification. The normal functioning of the ground-

to-air communications link shall be unaffected, except at such time as the selective calling function is being formed.

(b) Principles of operation. Selective calling is accomplished by the coder of the ground transmitter sending a single group of coded tone pulses to the aircraft receiver and decoder. The airborne receiver and decoder equipment is capable of receiving and interpreting, by means of an indicator, the correct code and rejecting all other codes in thepresence of random noise and interference. The ground portion of the coding device (ground selective calling unit) supplies coded information to the ground-to-air transmitter. The airborne selective calling unit is the special airborne equipment which operates with existing communications receivers on the aircraft to permit decoding of the ground-to-air signals for display on the signal indicator. The type of signal indicator can be chosen to suit operational requirements of the user and may consist of a lamp, a bell, a chime or any combination of such indicating devices.

IS: 23.3.4.4.3.1.2.1 REFERENCES

1. REFERENCES

References to Standards from the International Organization for Standardization (ISO) are as specified (including date published) below. These ISO Standards shall apply to the extent specified in the SARPs.

2. NORMATIVE REFERENCES

These SARPs reference the following ISO documents:

ISO	*Title*	12/91
646	*Information technology — ISO 7-bit coded character set for information interchange*	
Date published		
3309	*HDLC Procedures — Frame Structure, Version 3*	
12/93		
4335	*HDLC Elements of Procedures*, Version 3	
12/93		
7498	*OSI Basic Reference Model, Version 1*	
11/94		
7809	*HDLC Procedures — Consolidation of Classes of Procedures, Version 1*	3/90 2nd ed.
8208	*Information Processing Systems — Data Communications — X.25 Packet Level Protocol for Data Terminal Equipment*	12/93
8885	*HDLC Procedures — General Purpose XID Frame Information Field Content and Format*, Version [1]	
12/93		

8886.3 6/92	*OSI Data Link Service Definition*, Version 3
10039 6/91	*Local Area Networks — MAC Service Definition*, Version 1

3. BACKGROUND REFERENCES

The following documents are listed as reference material.

Originator	*Title*
ITU-R	Recommendation S.446.4, Annex I
CCSDS	*Telemetry Channel Coding, Recommendation for Space Data System Standards*, Consultative Committee for Space Date Systems, CCSDS 101.0-B-3, Blue Book

IS: 23.3.3.7 A WORLDWIDE SCHEME FOR THE ALLOCATION, ASSIGNMENT AND APPLICATION OF AIRCRAFT ADDRESSES

1. GENERAL

1.1 Global communications, navigation and surveillance systems shall use an individual aircraft address composed of 24 bits. At any one time, no address shall be assigned to more than one aircraft. The assignment of aircraft addresses requires a comprehensive scheme providing for a balanced and expandable distribution of aircraft addresses applicable worldwide.

2. DESCRIPTION OF THE SCHEME

2.1 Table 9-1 provides for blocks of consecutive addresses available to States for assignment to aircraft. Each block is defined by a fixed pattern of the first 4, 6, 9, 11, 12 or 13 bits of the 24-bit address. Thus, blocks of different sizes (1 048 576,262 144, 32 768, 8192, 4 096 and 2048 consecutive addresses, respectively) are made available.

3. MANAGEMENT OF THE SCHEME

3.1 The International Civil Aviation Organization (ICAO) shall administer the scheme so that appropriate international distribution of aircraft addresses can be maintained.

4. ALLOCATION OF AIRCRAFT ADDRESSES

4.1 Blocks of aircraft addresses shall be allocated by ICAO to the State of Registry or common mark registering authority. Address allocations to States shall be as shown in Table 9-1.

4.2 A State of Registry or common mark registering authority shall notify ICAO when allocation to that State of an additional block of addresses is required for assignment to aircraft.

~~4.3 In the future management of the scheme, advantage shall be taken of the blocks of aircraft addresses not yet allocated. These spare blocks shall be distributed on the basis of~~

~~the relevant ICAO region:~~
~~Addresses starting with bit combination 00100: AFI region Addresses starting with bit combination 00101: SAM region Addresses starting with bit combination 0101: EUR and NAT regions Addresses starting with bit combination 01100: MID region Addresses starting with bit combination 01101: ASIA region~~
~~Addresses starting with bit combination 1001: NAM and PAC regions~~
~~Addresses starting with bit combination 111011: CAR region~~
~~In addition, aircraft addresses starting with bit combinations 1011, 1101 and 1111 have been reserved for future use.~~

4.3 Any future requirement for additional aircraft addresses shall be accommodated through coordination between ICAO and the States of Registry or common mark registering authority concerned. A request for additional aircraft addresses shall only be made by a registering authority when at least 75 per cent of the number of addresses already allocated to that registering authority have been assigned to aircraft.

4.4 ICAO shall allocate blocks of aircraft addresses to non-Contracting States upon request.

5. ASSIGNMENT OF AIRCRAFT ADDRESSES

(1) ~~Using~~ During the registration process, its allocated block of addresses, the State of Registry or common mark registering authority shall assign an individual aircraft address to each suitably equipped aircraft entered on a national or international register (Table 9-1).

Note.— For an aircraft delivery, the aircraft operator is expected to inform the airframe manufacturer of an address assignment. The airframe manufacturer or other organization responsible for a delivery flight is expected to ensure installation of a correctly assigned address supplied by the State of Registry or common mark registering authority. Exceptionally, a temporary address may be supplied under the arrangements detailed in paragraph 7.

(2) Aircraft addresses shall be assigned to aircraft in accordance with the following principles:

(a) at any one time, no address shall be assigned to more than one aircraft with the exception of aerodrome surface vehicles on surface movement areas. If such exceptions are applied by the State of Registry, the vehicles which have been allocated the same address shall not operate on aerodromes separated by less than 1 000 km;

(b) only one address shall be assigned to an aircraft, irrespective of the composition of equipment on board. In the case when a removable transponder is shared by several light aviation aircraft such as balloons or gliders, it shall be possible to assign a unique address to the removable transponder. The registers 08_{16}, 20_{16}, 21_{16}, 22_{16} and 25_{16} of the removable transponder shall be correctly updated each time the removable transponder is installed in any aircraft;

(c) the address shall not be changed except under exceptional circumstances and shall not be changed during flight;

(d) when an aircraft changes its State of Registry, the new registering State shall assign the aircraft a new address from its own allocation address block, and the old aircraft address shall be returned to the allocation address block of the State that previously registered the aircraft;

(e) the address shall serve only a technical role for addressing and identification of aircraft and shall not be used to convey any specific information; and

(f) the addresses composed of 24 ZEROS or 24 ONES shall not be assigned to aircraft.

(3) *Any method used to assign aircraft addresses shall ensure efficient use of the entire address block that is allocated to that State.*

(4) Assignment of aircraft addresses to unmanned aircraft (UA)

Note — States may need to consider withholding aircraft addresses to unmanned aircraft (UA) unless certain criteria have been met. Proper and efficient utilization of available bandwidth and capacity at 1 090 MHz is a key element to ensure the safe operation of aeronautical surveillance systems, including secondary surveillance radar (SSR), automatic dependent surveillance — broadcast (ADS-B) and airborne collision avoidance systems (ACAS). A large number of UA equipped with ADS-B OUT transmitters operating at 1 090 MHz may adversely affect the operation of surveillance systems in the area. Reference is made to the guidance material contained in the Aeronautical Surveillance Manual (Doc 9924), intended to assist States when validating the utilization of 1 090 MHz.

6. ADMINISTRATION OF THE AIRCRAFT ADDRESS ASSIGNMENTS

(1) The State of Registry or common mark registering authority shall administer the allocated block of aircraft addresses so that appropriate assignment of aircraft addresses within its allocated block can be maintained.

Note. — The aircraft address is an essential element that needs to be correctly configured in an aircraft to support operation of systems and functions, such as SSR Mode S, ADS-B, datalink, collision avoidance and emergency location.

(2) States shall establish and publish an administrative procedure for requesting and assigning aircraft addresses.

Note. — An example of an effective administrative procedure, including the indication of the aircraft address in the certificate of registration, which can be used by the State of Registry or common mark registering authority, can be found in the Aeronautical Surveillance Manual (Doc 9924).

(3) The State of Registry or common mark registering authority shall put in place measures to ensure that aircraft registered under their responsibility are flying with a correct aircraft address.

Note. — Examples of such measures can be found in 2.1.7 of Appendix O of the Aeronautical Surveillance Manual (Doc 9924).

7. APPLICATION OF AIRCRAFT ADDRESSES

(1) The aircraft addresses shall be used in applications which require the routing of information to or from individual suitably equipped aircraft.

Note 1.— Examples of such applications are the aeronautical telecommunication network (ATN), SSR Mode S, ADS-B, emergency locator transmitter (ELT) and airborne collision avoidance system (ACAS).

Note 2.— This Standard does not preclude assigning the aircraft addresses for special applications associated with the general applications defined therein. An example of such a special application is the utilization of the 24-bit address in a pseudo-aeronautical earth station to monitor the aeronautical mobile-satellite service ground earth station and in the fixed Mode S transponders (reporting the on-the-ground status as specified in GCAD Part 23.5 to monitor the Mode S ground station operation. Address assignments for special applications are to be carried out in conformance with the procedure established by the State to manage the 24-bit address assignments to aircraft.

(2) An address consisting of 24 ZEROs shall not be used for any application.

8. ADMINISTRATION OF THE TEMPORARY AIRCRAFT ADDRESS ASSIGNMENTS

(1) Temporary addresses shall be assigned to aircraft in exceptional circumstances, such as when operators have been unable to obtain an address from their individual States of Registry or Common Mark Registering Authority in a timely manner. ICAO shall assign temporary addresses from the block "ICAO[1]" shown in Table 9-1.

(2) When requesting a temporary address, the aircraft operator shall supply to ICAO: aircraft identification, type and make of aircraft, name and address of the operator, and an explanation of the reason for the request.

(3) Upon issuance of the temporary address to the aircraft operators, ICAO shall inform the State of Registry of the issuance of the temporary address, reason and duration.

(4) The aircraft operator shall:

(a) inform the State of Registry of the temporary assignment and reiterate the request for a permanent address; and

(b) inform the airframe manufacturer.

(5) When the permanent aircraft address is obtained from the State of Registry, the operator shall:

(a) inform ICAO without delay;

(b) relinquish his/her temporary address; and

(c) arrange for encoding of the valid unique address within 180 calendar days.

(6) If a permanent address is not obtained within one year, the aircraft operator shall reapply for a new temporary aircraft address. Under no circumstances shall a temporary aircraft address be used by the aircraft operator for over one year.

Table 9-1. Allocation of aircraft addresses to States

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Note. — The left-hand column of the 24-bit address patterns represents the most significant bit (MSB) of the address.

State	*Number of addresses in block*					*Allocation of blocks of addresses (a dash represents a bit value equal to 0 or 1)*
	1 024	*4 096*	*32 768*	*262 144*	*1 048 576*	
Afghanistan	*	*	*			0111 00 000 000 ––– –––––––––
Albania		*				0101 00 000 001 0 –––––––––
Algeria	*					0 –––––––––
Angola				*		0000 10 100 ––– –––––––––
Antigua and Barbuda	*		*	*		0000 10 010 000 ––– –––––––––
Argentina	*	*				0000 11 001 010 0 –––––––––
Armenia		*				1110 00 ––– ––– –––––––––
Australia	*					0110 00 000 000 0 –––––––––
Austria	*		*			0111 11 ––– ––– –––––––––
Azerbaijan	*					0100 01 000 ––– –––––––––
Bahamas	*	*				0110 00 000 000 1 0 –––––––––
Bahrain	*					0000 10 101 000 ––– –––––––––
Bangladesh	*		*	*		1000 10 010 100 ––– –––––––––
Barbados	*					0111 00 000 010 ––– –––––––––
Belarus	*	*				0000 10 101 010 0 –––––––––
Belgium		*		*		0101 00 010 000 0 –––––––––
Belize		*				0100 01 001 ––– –––––––––
Benin						0000 10 101 011 0
Bhutan						
Bolivia	*	*		*		
Bosnia and Herzegovina		*				
Botswana		*				
Brazil	*					
Brunei		*				

State	*Number of addresses in block*					*Allocation of blocks of addresses*
	1	*4*	*32*	*262*	*1 048*	

| | | |

State	*Number of addresses in*					*Allocation of blocks of addresses (a dash represents a bit value equal to 0 or 1)*
	1 024	*4 096*	*32 768*	*262 144*	*1 048 576*	

| | | |

State	*Number of addresses in block*					*Allocation of blocks of addresses (a dash represents a bit value equal to 0 or 1)*
	1	*4*	*32*	*262*	*1 048*	

| | | |

State	*Number of addresses in*					*Allocation of blocks of addresses (a dash represents a bit value equal to 0 or 1)*
	1 024	*4 096*	*32 768*	*262 144*	*1 048 576*	
Other allocations			*			1 1 1 1 – – 0 0 – – 0 0 0 – – – – – – – – – – –
ICAO[1]	*					

1. ICAO administers this block for assigning temporary aircraft addresses as described in section 7.