

Figure 5-23. Control fields used in MODE S packets

SCHEDULE 5

(Regulation 52(2), (4), 53(1), (2), (3), (4), (5), (6), 54(1), 55, 56, 57, 58, 59, 60(1), (2), 61, 62(1), (2), 63, 64(1), (2), (3), (4), 65(1)(g), (2), (3))

VHF AIR GROUND DIGITAL LINK (VDL)

1. SYSTEM CHARACTERISTICS OF THE GROUND INSTALLATION FOR VHF AIR-GROUND DIGITAL LINK

1.1 Ground station transmitting function

- 1.1.1 *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 Fifteenth Schedule for 25 kHz channel spacing.*

1.2 Power

The effective radiated power shall be such as to provide a field strength of at least 75 microvolts per metre (minus 109 dBW/m²) within the defined operational coverage of the facility, on the basis of free-space propagation.

1.3 Spurious emissions

- 1.3.1 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.*

1.4 Adjacent channel emissions

- 1.4.1 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.
- 1.4.1.1 After 1st 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.
- 1.4.2 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.
- 1.4.2.1 After 1st 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.

- 1.4.2.2 After 1st 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.
- 1.4.3 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.
- 1.4.3.1 After 1st 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.
- 1.4.4 After 1st January, 2005, all VDL ground transmitters shall meet the provisions of 1.4.1.1, 1.4.2.1, 1.4.2.2 and 1.4.3.1, subject to the conditions of 1.4.5.
- 1.4.5 Requirements of mandatory compliance of the provisions of 1.4.4 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.

SCHEDULE 6

(Regulation 57, 58, 59, 60(1), (2), 61, 62(1), (2), 63, 64(1), (2), (3), (4), 65(1) (g), (2), (3))

VHF AIR GROUND DIGITAL LINK (VDL)

1. SYSTEM CHARACTERISTICS OF THE AIRCRAFT INSTALLATION FOR VHF AIR-GROUND DIGITAL LINK

1.1 *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.

1.2 *Power.* The effective radiated power shall be such as to provide a field strength of at least 20 microvolts per metre (minus 120 dBW/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.

1.3 Spurious emissions

1.3.1 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.

1.4 Adjacent channel emissions

1.4.1 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.

1.4.1.1 After 1st 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.

1.4.2 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.

1.4.2.1 After 1st 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.

1.4.2.2 After 1st 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.

1.4.3 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.

1.4.3.1 After 1st 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.

1.4.4 After 1st January, 2005, all VDL aircraft transmitters shall meet the provisions of 1.4.1.1, 1.4.2.1, 1.4.2.2 and 1.4.3.1, subject to the conditions of 1.4.5.

1.4.5 Requirements of mandatory compliance of the provisions of 1.4.4 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.

1.5 Receiving function

1.5.1 *Specified error rate.* The specified error rate for Mode 2 operation shall be the maximum corrected Bit Error Rate (BER) of 1 in 10⁴. The specified error rate for Mode 3 operation shall be the maximum uncorrected BER of 1 in 10³. The specified error rate for Mode 4 operation shall be the maximum uncorrected BER of 1 in 10⁴.

Note. — *The above physical layer BER requirements are derived from the BER requirement imposed by ATN at the sub-network interface.*

1.5.2 *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/m²).

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

1.5.3 *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.

1.5.3.1 After 1st 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 1.4 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 ICAO Handbook on Radio Frequency Spectrum Requirements for Civil Aviation including statement of Approved ICAO Policies (Doc 9718).*

1.5.3.2 After 1st January, 2005, the receiving function of all installations of VDL shall meet the provisions of 1.5.3.1, subject to the conditions of 1.5.3.3.

1.5.3.3 Requirements of mandatory compliance of the provisions of 1.5.3.2 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.

1.5.4 INTERFERENCE IMMUNITY PERFORMANCE

1.5.4.1 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.

1.5.4.2 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.

SCHEDULE 7

(Regulation 58 and 59)

VHF AIR GROUND DIGITAL LINK SYSTEMS

1. PHYSICAL LAYER PROTOCOLS AND SERVICES

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

1.1 Functions

1.1.1 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

1.1.1.1 *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.

1.1.1.2 *Digital reception by the receiver.* The receiver shall decode input signals and forward them to the higher layers for processing.

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

1.2 Modes 2 and 3 common physical layer

1.2.1 *Modulation scheme.* Modes 2 and 3 shall use differentially encoded 8 phase shift keying (D8PSK), using a raised cosine filter with $\alpha = 0.6$ (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.

1.2.1.1 *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 $\Delta\varphi_k$, that is:

$$\varphi_k = \varphi_{k-1} + \Delta\varphi_k$$

Table 6-1 Modes 2 and 3 data encoding

X_k	Y_k	Z_k	$\Delta\varphi_k$
0	0	0	$0\pi/4$
0	0	1	$1\pi/4$
0	1	1	$2\pi/4$
0	1	0	$3\pi/4$
1	1	0	$4\pi/4$
1	1	1	$5\pi/4$
1	0	1	$6\pi/4$
1	0	0	$7\pi/4$

1.2.1.2 Transmitted signal form. The phase-modulated baseband signal as defined in 1.2.1.1 shall excite the pulse shape filter.

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

where:

- h is the complex impulse response of the pulse shape filter;
- k is defined in 1.2.1.1;
- φ is defined by the equation in 1.2.1.1;
- 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 $\alpha=0.6$.

- 1.2.2 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.

Table 6-2 Mode 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

1.3 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.

- 1.3.1 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 1.3.1.2), interleave (per 1.3.1.3), prepend the training sequence (per 1.3.1.1), carry out bit scrambling (per 1.3.1.4) and finally encode and modulate the RF signal (per 1.2.1).

- 1.3.1.1 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.

1.3.1.1.1 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.

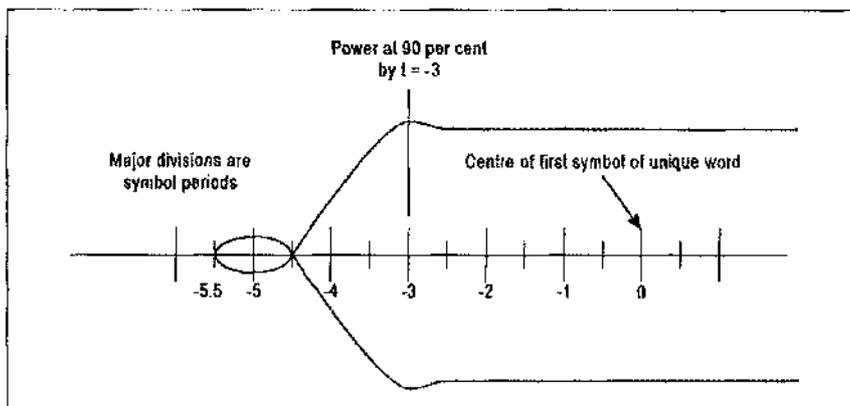


Figure 6-1 Transmitter power stabilization

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 $t = -3.5$ symbol periods.

1.3.1.1.2 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

and shall be transmitted from left to right.

1.3.1.1.3 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.

1.3.1.1.4 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

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.

1.3.1.1.5 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:

$$[P_1, \dots, P_5] = [R_1, \dots, R_3, TL_1, \dots, TL_{17}] H^T$$

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:

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

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

1.3.1.2 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.

1.3.1.2.1 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:

$$p(x) = (x^8 + x^7 + x^2 + x + 1)$$

The generator polynomial shall be as follows:

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

where:

α 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.

- 1.3.1.2.2 *Block 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 1.3.1.3. 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 1.3.1.2.3 through 1.3.1.2.3.3.
- 1.3.1.2.3 *No error correction.* For blocks with 2 or fewer non-fill octets, no error correction shall be used.
- 1.3.1.2.3.1 *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.
- 1.3.1.2.3.2 *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.
- 1.3.1.2.3.3 *Three-byte error correction.* For blocks with 68 or more non-fill octets, all six RS-check octets shall be generated and transmitted.
- 1.3.1.3 *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 and c rows, where

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

where:

- (a) the transmission length is as defined in 1.3.1.1.5; 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.

1.3.1.4 *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 leftmost 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.

Table 6-3 Scrambler function

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

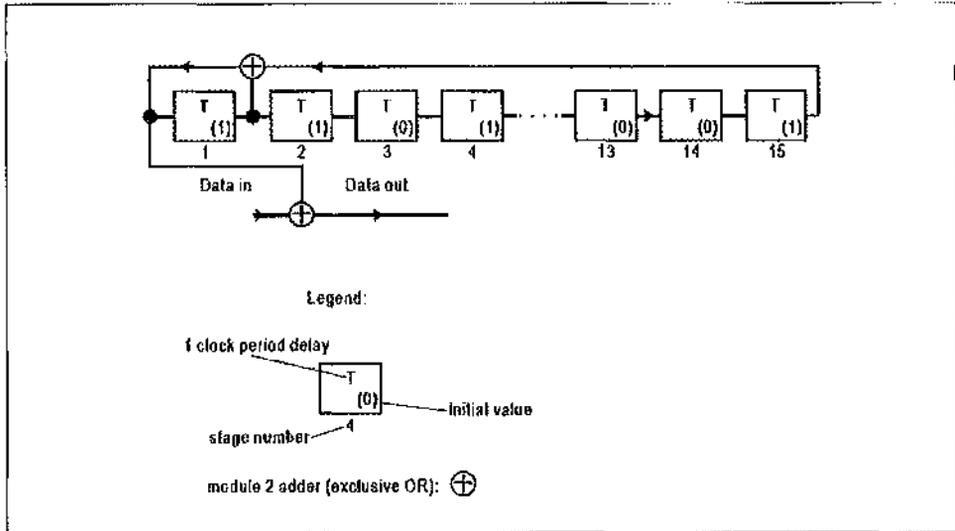


Figure 6-2 PN generator for bit scrambling

Note: The concept of a PN scrambler is explained in ITU-RS.446-4, Annex I, Section 4.3.1, Method 1).

1.3.2 MODE 2 CHANNEL SENSING

1.3.2.1 *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.

1.3.2.2 *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.

1.3.2.3 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.

1.3.3 MODE 2 RECEIVER/TRANSMITTER INTERACTION

1.3.3.1 *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.

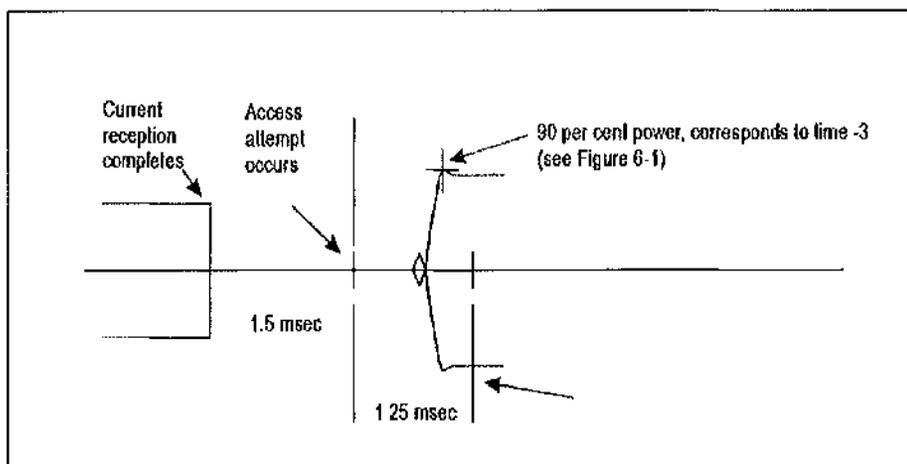


Figure 6-3 Receive to transmit turnaround time

1.3.3.2 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.

1.3.4 MODE 2 PHYSICAL LAYER SYSTEM PARAMETERS

1.3.4.1 The physical layer shall implement the system parameters as defined in Table 6-4.

Table 6-4 Physical services system parameters

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

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

1.4 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.

1.4.1 *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.

1.4.1.1 *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.

1.4.1.1.1 *Transmitter ramp-up and power stabilization.* This shall be as defined in section 1.3.1.1.1.

- 1.4.1.3 *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.

- 1.4.2 *Management (M) burst downlink.* The M downlink 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.

- 1.4.2.1 *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.

- 1.4.2.1.1 *Transmitter ramp-up and power stabilization.* This shall be as defined in 1.4.1.1.1.

- 1.4.2.1.2 *Synchronization and ambiguity resolution.* Three separate synchronization sequences shall be used for this burst type. The standard sequence, known as S1, 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 6.4.4.1.1.2.

The special sequence used to identify net entry requests (S1*) 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 S1* is very closely related to the sequence S1. The 15 phase changes between the 16 symbols of S1* are each exactly 180° out of phase from the 15 phase changes associated with S1. This relationship can be used to simplify the process of simultaneously searching for both sequences.

- 1.4.2.2 *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 should be as defined in 1.4.1.2

- 1.4.2.3 *Transmitter ramp-down.* This shall be as defined in 1.4.1.3.

1.4.3 *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.

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

- (d) transmitter ramp-up and power stabilization; and
- (e) synchronization and ambiguity resolution.

1.4.3.1.1 *Transmitter ramp-up and power stabilization.* This shall be as specified in 1.4.1.1.1.

1.4.3.1.2 *Synchronization and ambiguity resolution.* The second component of the training sequence shall consist of the synchronization sequence, known as S2, 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.

1.4.3.2 *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 1.4.1.2.

1.4.3.3 *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).

1.4.3.3.1 When transmitting user data, the 576 bits shall be encoded as a single Reed-Solomon (72, 62) 28-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 1.3.1.2.1.

The generator polynomial shall be as follows:

$$\prod_{i=1}^{120} (x - \alpha^i)$$

Note.— The Reed-Solomon (72, 62) code is capable of correcting up to five 28-ary (code word) symbol errors in the received word.

1.4.3.4 *Transmitter ramp-down.* This shall be as defined in 1.4.1.3.

1.4.4 *Interleaving.* There shall be no interleaving in Mode 3 operation.

1.4.5 *Bit scrambling.* Under Mode 3 operation, bit scrambling, as specified in 1.3.1.4 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.

1.4.6 *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.

1.4.6.1 *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 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 3VID, 2VID, 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.

1.4.6.2 *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.

1.4.7 Fringe coverage indication

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

SCHEDULE 8

(Regulation 53(1), (2), (4), (5), (6), 55, 56, 57, 58 and 59)

VHF AIR GROUND DIGITAL LINK SYSTEMS

1. LINK LAYER PROTOCOLS AND SERVICES

1.1 General information

1.1.1 *Functionality.* The VDL link layer shall provide the following sub layer functions:

- (a) media access control (MAC) sub layer, 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) sub layer:
 - 1) for Mode 2, the DLS sub layer provides connection-oriented point-to-point links using data link entities (DLE) and connectionless broadcast link over the MAC sub layer; and
 - 2) for Mode 3, the DLS sub layer provides acknowledged connectionless point-to-point and point-to-multipoint links over a MAC sub layer that guarantees sequencing; and
- (c) a VDL management entity (VME), which establishes and maintains DLLs between the aircraft and the ground-based systems using link management entities (LME).

1.1.2 SERVICE

1.1.2.1 *Connection-oriented.* The VDL Mode 2 link layer shall provide a reliable point-to-point service using a connection-oriented DLS sub layer.

1.1.2.2 *Connectionless.* The VDL Mode 2 and 3 link layers shall provide an unacknowledged broadcast service using a connectionless DLS sub layer.

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

1.2 6.5.2 MAC sub layer

1.2.1 The MAC sub layer shall provide for the transparent acquisition of the shared communications path. It makes invisible to the DLS sub layer 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.

1.3 Data link service sub layer

1.3.1 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.

- 1.3.2 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.

1.4 VDL management entity

- 1.4.1 *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.

SCHEDULE 9

(Regulation 53 (1), (2), (4), (5), (6), 55, 56, 57, 58 and 59)

VHF AIR GROUND DIGITAL LINK SYSTEMS

1. SUB NETWORK LAYER PROTOCOLS AND SERVICES

1.1 Architecture for Mode 2

- 1.1.1 The sub network layer protocol used across the VHF air-ground sub network for VDL Mode 2 is referred to formally as a sub network 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 sub network 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 sub network entity shall act as a DTE and the ground sub network entity shall act as a DCE.

Note: Specific sub network 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.

1.2 Architecture for Mode 3

- 1.2.1 The sub network layer used across the VHF air-ground sub network for VDL Mode 3 provides the flexibility to simultaneously support multiple sub network 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 sub network entities shall act as DCEs.

Note: Specific sub network 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.

SCHEDULE 10

(Regulation 57(b), 64(1), (2), (3), 65(1)(g), (2), (3))

VDL MODE 4

1. Physical layer protocols and services

Note: Unless otherwise Stated, the requirements defined in this section apply to both mobile and ground stations.

1.1 FUNCTIONS

1.1.1 TRANSMITTED POWER

1.1.1.1 *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/m²) 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.

1.1.1.2 *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/m²) within the defined operational coverage of the facility, on the basis of free-space propagation.

1.1.2 TRANSMITTER AND RECEIVER FREQUENCY CONTROL

1.1.2.1 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.

1.1.3 DATA RECEPTION BY RECEIVER

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

1.1.4 DATA TRANSMISSION BY TRANSMITTER

1.1.4.1 *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.

1.1.4.2 *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 Sections 1.2.3.1 to 1.2.3.4.

1.1.4.3 *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".

1.1.5 NOTIFICATION SERVICES

1.1.5.1 *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.

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

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

1.2 PROTOCOL DEFINITION FOR GFSK

1.2.1 *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).

1.2.2 *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.

1.2.3 STAGES OF TRANSMISSION

1.2.3.1 *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.

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

1.2.3.3 *Ambiguity resolution and data transmission.* The transmission of the first bit of data shall start 40 bit intervals (approximately $2\ 083.3$ 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.

- 1.2.3.4 *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.

1.3 CHANNEL SENSING

- 1.3.1 *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.

- 1.3.2 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 VDL Mode 4 Technical Specifications.

- 1.3.3 *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.

- 1.3.3.1 *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.

- 1.3.3.2 *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.

1.3.4 CHANNEL BUSY TO IDLE DETECTION

- 1.3.4.1 A VDL Mode 4 station shall employ the following means to determine the channel busy to idle transition.

- 1.3.4.2 *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.

- 1.3.4.3 *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.

1.4 RECEIVER/TRANSMITTER INTERACTION

- 1.4.1 *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.
- 1.4.2 *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.
- 1.4.3 *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} .

1.5 PHYSICAL LAYER SYSTEM PARAMETERS

1.5.1 PARAMETER P1 (MINIMUM TRANSMISSION LENGTH)

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

1.5.1.2 The value of P1 shall be 19 200 bits.

1.5.2 PARAMETER P2 (NOMINAL CO-CHANNEL INTERFERENCE PERFORMANCE)

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

1.5.2.2 The value of P2 shall be 12 dB

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

1.6.1 A VDL Mode 4 station shall conform to the requirements defined in section 1.5.4 when operating in the band 117.975–137 MHz

1.6.2 A VDL Mode 4 station shall conform to the requirements defined below when operating in the band 108–117.975 MHz

1.6.2.1 The VDL Mode 4 receiving system shall meet the requirements specified in 1.5.1 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.

N1 and N2 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 1.6.2.2.

$\Delta f = 108.1 - f_1$, where f_1 is the frequency of N1, 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.

1.6.2.2 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

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.

2. Link layer

Note.— Details on link layer functions are contained in the Manual on VDL Mode 4 Technical Specifications.

3. Subnetwork layer and SNDCF

Note.— Details on subnetwork layer functions and SNDCF are contained in the Manual on VDL Mode 4 Technical Specifications.

4. ADS-B applications

Note.— Details on ADS-B application functions are contained in the Manual on VDL Mode 4 Technical Specifications.

SCHEDULE 11

(Regulation 83)

1. 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".

1.1 General

- 1.1.1 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.
- 1.1.2 When the provisions of 1.1.1 are applied, International Alphabet No. 5 (IA-5) contained in Table 8-2 shall be used.
 - 1.1.2.1 The serial transmission of units comprising an individual character of IA-5 shall be with the low order unit (b¹) transmitted first.
 - 1.1.2.2 When IA-5 is used, each character shall include an additional unit for parity in the eighth level position.
 - 1.1.2.3 When the provisions of 1.1.2.2 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.
 - 1.1.2.4 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 IA-.
 - 1.1.2.5 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.

1.2 Data transmission characteristics

- 1.2.1 8.6.2.1 The data signalling rate shall be chosen from among the following:

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

- 1.2.2 The type of transmission for each data signalling rate shall be chosen as follows:

Data signalling rate	Type of transmission
1 600 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

- 1.2.3 The type of modulation for each data signalling rate shall be chosen as follows:

Data signalling rate	Type of modulation
1 600 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 standard does not necessarily apply to ground-ground extensions of air-ground links used exclusively for the transfer of air-ground data, in as much as such circuits may be considered as part of the air-ground link.

1.2.4 CHARACTER STRUCTURE ON DATA LINKS

1.2.4.1 Character parity shall not be used for error checking on CIDIN links. Parity appended to IA-5 coded characters per 1.1.2.2, prior to entry to the CIDIN shall be ignored. For messages exiting the CIDIN, parity shall be generated in accordance with 1.1.2.3 –

1.2.4.2 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.

1.2.4 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-

1.2.5 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-

1.3 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 1.1 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.

1.3.1 *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.

1.3.2 MESSAGE COMPOSITION

- (a) A transmission shall consist of characters from IA-5 transmitted in accordance with 1.1.2.2 and shall be either an information message or a supervisory sequence.
- (b) An information message used for the exchange of data shall take one of the following forms:

- | | | | | | | |
|----|---|---------------|---|------------|---|---|
| 1) | S | | E | B | | |
| | T | ---TEXT--- | T | C | | |
| | X | | X | C | | |
| | | | | | | |
| 2) | S | | E | B | | |
| | T | ---TEXT--- | T | C | | |
| | X | | B | C | | |
| | | | | | | |
| 3) | S | | S | E | B | |
| | O | ---HEADING--- | T | ---TEXT--- | T | C |
| | H | | X | | X | C |
| | | | | | | |
| 4) | S | | S | E | B | |
| | O | ---HEADING--- | T | ---TEXT--- | T | C |
| | H | | X | | B | C |
| | | | | | | |
| 5) | S | | E | B | | |
| | O | ---HEADING--- | T | C | | |
| | H | | B | C | | |

Note 1- ^B
C is a block check character (BCC)
^C

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

(c) A supervisory sequence shall be composed of either a single transmission control character (EOT, FNQ, 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.

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

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

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

1.3.3.1 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; and

(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 1A-5.

1.3.3.1 For multipoint implementations designed to permit only centralized (computer-to-terminal) operations, the provisions of 1.3.7 shall be employed.

1.3.4 BLOCK CHECK CHARACTER

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

1.3.4.2 The block check character shall be composed of 7 bits plus a parity bit.

1.3.4.3 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.

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

1.3.4.5 The sense of the parity bit of the block check character shall be the same as for the information characters (see 1.1.2.3).

1.3.4.6 SUMMATION

1.3.4.6.1 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).

1.3.4.6.2 The starting character shall not be included in the summation.

1.3.4.6.3 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.

1.3.4.6.4 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.

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

1.3.5 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.

1.3.5.1 LINK ESTABLISHMENT PROCEDURE

1.3.5.1.1 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.

1.3.5.1.2 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.

1.3.5.1.3 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 1.3.5.1.5; and
- (b) if the station has no message to send, it shall send EOT, and master status shall revert to the control station.

1.3.5.1.4 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.

1.3.5.1.5 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.

1.3.5.1.6 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; and
- (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.

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

1.3.5.2 MESSAGE TRANSFER PROCEDURE

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

1.3.5.2.2 The transmission of a message shall —

- (a) begin with:
 1. SOH if the message has a heading; and
 2. STX if the message has no heading;
- (b) be continuous, ending with ETX, immediately followed by a block check character (BCC).

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

1.3.5.3 DELIVERY VERIFICATION PROCEDURE

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

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

1.3.5.3.3 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.

1.3.5.3.4 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.

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

1.3.5.4 LINK TERMINATION PROCEDURE

1.3.5.4.1 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.

1.3.6 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.

1.3.6.1 LINK ESTABLISHMENT PROCEDURE

1.3.6.1.1 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.

1.3.6.1.2 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 1.3.6.2.5). This establishes the link for message transfers from the calling to the called station; and
- (b) if not ready to receive, it shall send the above sequence with the ACK0 replaced by NAK.

1.3.6.1.3 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.

1.3.6.2 MESSAGE TRANSFER PROCEDURE

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

1.3.6.2.2 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; and
- (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 1A-5 characters 0, 1 ... 7 (characters 3/0, 3/1 ... 3/7).

1.3.6.2.3 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.

1.3.6.2.4 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; and:

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.

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

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

1.3.6.3 LINK TERMINATION PROCEDURE

1.3.6.3.1 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.

1.3.6.3.2 EOT shall only be transmitted by a station after all outstanding slave responses have been received or otherwise accounted for.

1.3.6.4 CIRCUIT DISCONNECTION

1.3.6.4.1 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.

1.3.7 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.

1.3.7.1 LINK ESTABLISHMENT PROCEDURE

1.3.7.1.1 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:
 1. selection with response (see 1.3.7.1.5); or
 2. fast select (see 1.3.7.1.7).

- 1.3.7.1.2 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.
- 1.3.7.1.3 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; and
 - (b) if the station has no message to send, it shall send EOT and master status shall revert to the control station.
- 1.3.7.1.4 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.
- 1.3.7.1.5 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.
- 1.3.7.1.6 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; and
 - (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 ($N \geq 0$) either to exit to a recovery procedure or to initiate termination by sending EOT.

- 1.3.7.1.7 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.

1.3.7.2 MESSAGE TRANSFER PROCEDURE

- 1.3.7.2.1 The station with master status shall send a single message to the station with slave status and wait for a reply.
- 1.3.7.2.2 The message transmission shall begin with:
- (a) SOH if the message has a heading, — STX if the message has no heading; and
 - (b) be continuous, ending with ETX, immediately followed by BCC.
- 1.3.7.2.3 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; and

- (b) if the message was not accepted and the slave station is ready to receive an other 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.

1.3.7.2.4 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.

1.3.7.2.5 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.

1.3.7.3 LINK TERMINATION PROCEDURE

1.3.7.3.1 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.

1.4 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.

1.4.1 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; and
- (j) a frame is a unit of data to be transferred over the data link, comprising one or more fields in a prescribed order.

1.4.2 BIT-ORIENTED DATA LINK CONTROL PROCEDURES FOR POINT-TO-POINT, GROUND-GROUND DATA INTERCHANGE APPLICATIONS EMPLOYING SYNCHRONOUS TRANSMISSION FACILITIES

1.4.2.1 *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
-----------	--------------	--------------	------------------	-----	-----------

1.4.2.1.1 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.

1.4.2.1.1.1 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.

1.4.2.1.1.2 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.

1.4.2.1.1.3 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.

1.4.2.1.1.4 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.

1.4.2.1.1.5 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.

1.4.2.2 A frame check sequence (FCS) shall be included in each frame for the purpose of error checking.

1.4.2.2.1 The error checking algorithm shall be a cyclic redundancy check (CRC).

1.4.2.2.2 The CRC polynomial $P(x)$ shall be

$$x^{16} + x^{12} + x^5 + 1.$$

1.4.2.2.3 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

$$x^{16}[G(x)] + x^K(x^{15} + x^{14} + x^{13} + \dots + x^2 + x^1 + 1)$$

by the CRC polynomial, $P(x)$.

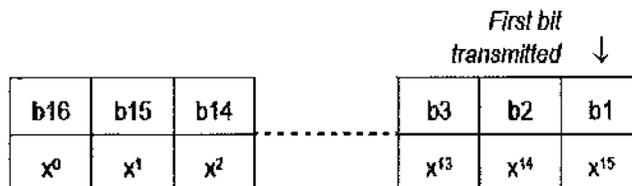
$G(x)$ shall be the contents of the frame existing between, but including neither, the final bit of the opening flag nor the first bit of the FCS, excluding bits inserted for transparent transmission.

K shall be the length of $G(x)$ (number of bits).

1.4.2.2.4 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;

First bit transmitted ↓



- (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; and
- (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).

1.4.2.3 Achievement of transparency. The frame format contents (A, C, link data field, and FCS) shall be capable of containing any bit configuration.

1.4.2.3.1 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; and
- (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.

1.4.2.4 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 -
 1. transmitting at least seven, but less than fifteen, one bits (with no inserted zeros);
 2. 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; and
- (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.

1.4.2.5 MODES

1.4.2.5.1 Operational mode. The operational mode shall be the asynchronous balanced mode (ABM).

1.4.2.5.1.1 It shall be permissible for a combined station in ABM to transmit without invitation from the associated station.

1.4.2.5.1.2 A combined station in ABM shall be permitted to transmit any command or response type frame except DM.

1.4.2.5.2 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.

1.4.2.5.2.1 It shall be permissible for a combined station in ADM to transmit without invitation from the associated station.

1.4.2.5.2.2 A combined station in ADM shall transmit only SABM, DISC, UA and DM frames. (See 1.4.2.7 for a description of the commands and responses to which these frame types refer.)

1.4.2.5.2.3 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".

1.4.2.6 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.

- 1.4.2.6.1 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.
- 1.4.2.6.2 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.
- 1.4.2.6.3 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.
- 1.4.2.6.4 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;

1. $V(R)$ shall take on the values 0 through modulus minus one.
 2. 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; and
- (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 should be the subject of bilateral agreement at the time of circuit establishment.

1.4.2.7 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.

1.4.2.7.1 The I-frame command provides the means for transmitting sequentially numbered frames, each of which shall be permitted to contain an information field.

1.4.2.7.2 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).

1.4.2.7.2.1 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 $N(R) - 1$; and
- (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".

1.4.2.7.2.2 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; and
- (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.

1.4.2.7.2.3 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); and

- (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".

1.4.2.7.2.3.1

- (a) a station receiving an RNR frame when in the process of transmitting shall stop transmitting I-frames at the earliest possible time.
- (b) any REJ command or response which was received prior to the RNR shall be actioned before the termination of transmission.
- (c) 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.

1.4.2.7.2.4 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.

1.4.2.7.3 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; and
 - 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.

1.4.3 EXCEPTION CONDITION REPORTING AND RECOVERY

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.

1.4.3.1 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.

1.4.3.1.1 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".

1.4.3.1.2 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").

1.4.3.2 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").

1.4.3.2.1 The means specified in 1.4.3.2.1.1 and 1.4.3.2.1.2 shall be available for initiating the retransmission of lost or errored I-frames following the occurrence of a sequence error.

1.4.3.2.1.1 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

<i>First bit transmitted</i>													
1	8	9	10	12	13	14	16	17	18	19	20	21	24
rejected basic control field			0	<i>V(S)</i>		<i>v</i>	<i>V(R)</i>		<i>w</i>	<i>x</i>	<i>y</i>	<i>z</i>	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*.

1.4.3.2.1.2 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.

- 1.4.3.2.1.3 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.

- 1.4.3.3 *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.

- 1.4.3.4 *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.

- 1.4.3.5 *Mode-setting contention.* A mode-setting contention situation exists when a combined station issues a modesetting 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:

- (1) 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;

(2) 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.

1.4.4 *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"; and
- (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).

TABLES FOR THE ELEVENTH SCHEDULE

Table 8-2: International Alphabet No. 5 (IA-5)

				b ₁	0	0	0	0	1	1	1	1
				b ₂	0	0	1	1	0	0	1	1
				b ₃	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	1	A	Q	a	q
0	0	1	0	2	TC ₂ (STX)	DC ₂	"	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	¤	4	D	T	d	t
0	1	0	1	5	TC ₅ (BQK)	TC ₆ (BKS)	%	5	E	U	e	u
0	1	1	0	6	TC ₈ (ACK)	TC ₉ (SYN)	&	6	F	V	f	v
0	1	1	1	7	BEL	TC ₁₀ (ETB)	'	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 (LF)	EM	}	9	I	Y	i	y
1	0	1	0	10	FE ₂ ⊙ (FF)	SUB	*	:	J	Z	j	z
1	0	1	1	11	FE ₃ (VD)	ESC	+	;	K	[k	{
1	1	0	0	12	FE ₄ (FF)	IS ₁ (FS)	⊙	<	L	l	l	
1	1	0	1	13	FE ₅ ⊙ (FN)	IS ₃ (FS)	-	=	M]	m	}
1	1	1	0	14	SO	IS ₂ (FS)	.	>	N	^	n	⊙
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
EIX	End of text	0/3
FE	Form 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	1/8
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	Apostrophic, Acute accent	2/7
(Left parenthesis	2/8
)		Right parenthesis	2/9
*		Asternisk	2/10
+		Plus sign	2/11
,	4	Comma, Cedula	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 page is composed of a number of lines of characters;
 - the characters forming a line occupy a number of positions called character positions;
 - 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. TC₀) 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

- DC₀** — 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 DC₂ and DC₃), or for any other device control function not provided by other DCs.
- DC₂** — 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 DC₀ is used to restore the device to the basic mode), or for any other device control function not provided by other DCs.
- DC₃** — 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 DC₀ 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.

DC₄ — 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 — DC₂ off — DC₄

2) Two independent switchings
First one on — DC₂ off — DC₄
Second one on — DC₁ off — DC₃

3) Two dependent switchings
General on — DC₂ off — DC₄
Particular on — DC₁ off — DC₃

4) Input and output switching
Output on — DC₂ off — DC₄
Input on — DC₁ off — DC₃

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 contiguous 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 contiguous 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

IS₁ (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.

IS₂ (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.

IS₃ (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.

IS₄ (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 8-5 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

SCHEDULE 12

(Regulation 84)

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, 12 or 14 bits of the 24-bit address. Thus, blocks of different sizes (1 048 576, 262 144, 32 768, 4 096 and 1 024 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.

4.0 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.

- 4.4 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.
- 4.5 ICAO shall allocate blocks of aircraft addresses to non-Contracting States upon request.

5.0 ASSIGNMENT OF AIRCRAFT ADDRESSES

- 5.1 Using 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.

- 5.2 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 0816, 2016, 2116, 2216 and 2516 of the removable transponders 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.
- 5.2.1 Any method used to assign aircraft addresses shall ensure efficient use of the entire address block that is allocated to Uganda.

6 APPLICATION OF AIRCRAFT ADDRESSES

- 6.1 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 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. Examples of such special applications are 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 ANS Technical Standards, Part II, Volume IV, 3.1.2.6.10.1.2) 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 Uganda to manage the 24-bit address assignments to aircraft.

- 6.2 An address consisting of 24 ZEROs shall not be used for any application.

7 ADMINISTRATION OF THE TEMPORARY AIRCRAFT ADDRESS ASSIGNMENTS

- 7.1 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 "ICAO1" shown in Table 9-1.

- 7.2 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.

7.2.1 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.

- 7.3 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.

- 7.4 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.

- 7.5 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

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	00	-----
Algeria			*			0000	10	100	---	-----	
Angola		*				0000	10	010	000	--	-----
Antigua and Barbuda	*					0000	11	001	010	00	-----
Argentina				*		1110	00	---	---	---	-----
Armenia	*					0110	00	000	000	00	-----
Australia				*		0111	11	---	---	---	-----
Austria			*			0100	01	000	---	---	-----
Azerbaijan	*					0110	00	000	000	10	-----
Bahamas		*				0000	10	101	000	---	-----
Bahrain		*				1000	10	010	100	--	-----
Bangladesh		*				0111	00	000	010	---	-----
Barbados	*					0000	10	101	010	00	-----
Belarus	*					0101	00	010	000	00	-----
Belgium			*			0100	01	001	---	---	-----
Belize	*					0000	10	101	011	00	-----
Benin	*					0000	10	010	100	00	-----
Bhutan	*					0110	10	000	000	00	-----
Bolivia		*				1110	10	010	100	--	-----
Bosnia and Herzegovina	*					0101	00	010	011	00	-----
Botswana	*					0000	00	110	000	00	-----
Brazil				*		1110	01	---	---	---	-----
Brunei Darussalam	*					1000	10	010	101	00	-----
Bulgaria			*			0100	01	010	---	---	-----
Burkina Faso		*				0000	10	011	100	--	-----
Burundi		*				0000	00	110	010	--	-----
Cambodia		*				0111	00	001	110	---	-----
Cameroon		*				0000	00	110	100	--	-----
Canada				*		1100	00	---	---	---	-----
Cape Verde	*					0000	10	010	110	00	-----
Central African Republic		*				0000	01	101	100	--	-----
Chad		*				0000	10	000	100	--	-----
Chile		*				1110	10	000	000	--	-----
China				*		0111	10	---	---	---	-----
Colombia		*				0000	10	101	100	--	-----
Comoros	*					0000	00	110	101	00	-----
Congo		*				0000	00	110	110	--	-----
Cook Islands	*					1001	00	000	001	00	-----
Costa Rica		*				0000	10	101	110	---	-----
Côte d'Ivoire		*				0000	00	111	000	--	-----
Croatia	*					0101	00	000	001	11	-----
Cuba		*				0000	10	110	000	---	-----
Cyprus	*					0100	11	001	000	00	-----
Czech Republic			*			0100	10	011	---	---	-----

Stato	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					
Democratic People's Republic of Korea			*			0111	00	100	---	---
Democratic Republic of the Congo		*				0000	10	001	100	---
Denmark			*			0100	01	011	---	---
Djibouti	*					0000	10	011	000	00
Dominican Republic		*				0000	11	000	100	---
Ecuador		*				1110	10	000	100	---
Egypt			*			0000	00	010	---	---
El Salvador		*				0000	10	110	010	---
Equatorial Guinea		*				0000	01	000	010	---
Eritrea	*					0010	00	000	010	00
Estonia	*					0101	00	010	001	00
Ethiopia		*				0000	01	000	000	---
Fiji		*				1100	10	001	000	---
Finland			*			0100	01	100	---	---
France				*		0011	10	---	---	---
Gabon		*				0000	00	111	110	---
Gambia		*				0000	10	011	010	---
Georgia	*					0101	00	010	100	00
Germany				*		0011	11	---	---	---
Ghana		*				0000	01	000	100	---
Greece			*			0100	01	101	---	---
Grenada	*					0000	11	001	100	00
Guatemala		*				0000	10	110	100	---
Guinea		*				0000	01	000	110	---
Guinea-Bissau	*					0000	01	001	000	00
Guyana		*				0000	10	110	110	---
Haiti		*				0000	10	111	000	---
Honduras		*				0000	10	111	010	---
Hungary			*			0100	01	110	---	---
Iceland		*				0100	11	001	100	---
India				*		1000	00	---	---	---
Indonesia			*			1000	10	100	---	---
Iran, Islamic Republic of			*			0111	00	110	---	---
Iraq			*			0111	00	101	---	---
Ireland		*				0100	11	001	010	---
Israel			*			0111	00	111	---	---
Italy				*		0011	00	---	---	---
Jamaica		*				0000	10	111	110	---
Japan				*		1000	01	---	---	---
Jordan			*			0111	01	000	---	---
Kazakhstan	*					0110	10	000	011	00
Kenya		*				0000	01	001	100	---
Kiribati	*					1100	10	001	110	00
Kuwait		*				0111	00	000	110	---
Kyrgyzstan	*					0110	00	000	001	00
Lao People's Democratic Republic		*				0111	00	001	000	---
Latvia	*					0101	00	000	010	11

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					
Lebanon			*			0111	01	001	---	--
Lesotho	*					0000	01	001	010	00
Liberia		*				0000	01	010	000	--
Libyan Arab Jamahiriya			*			0000	00	011	---	---
Lithuania	*					0101	00	000	011	11
Luxembourg	*					0100	11	010	000	00
Madagascar		*				0000	01	010	100	--
Malawi		*				0000	01	011	000	--
Malaysia			*			0111	01	010	---	--
Maldives	*					0000	01	011	010	00
Mali		*				0000	01	011	100	--
Malta	*					0100	11	010	010	00
Marshall Islands	*					1001	00	000	000	00
Mauritania	*					0000	01	011	110	00
Mauritius	*					0000	01	100	000	00
Mexico			*			0000	11	010	---	---
Micronesia, Federated States of	*					0110	10	000	001	00
Monaco	*					0100	11	010	100	00
Mongolia	*					0110	10	000	010	00
Montenegro	*					0101	00	010	110	00
Morocco			*			0000	00	100	---	---
Mozambique		*				0000	00	000	110	--
Myanmar		*				0111	00	000	100	--
Namibia	*					0010	00	000	001	00
Nauru	*					1100	10	001	010	00
Nepal		*				0111	00	001	010	--
Netherlands, Kingdom of the			*			0100	10	000	---	---
New Zealand			*			1100	10	000	---	---
Nicaragua		*				0000	11	000	000	--
Niger		*				0000	01	100	010	---
Nigeria		*				0000	01	100	100	--
Norway			*			0100	01	111	---	---
Oman	*					0111	00	001	100	00
Pakistan			*			0111	01	100	---	---
Palau	*					0110	10	000	100	00
Panama		*				0000	11	000	010	--
Papua New Guinea		*				1000	10	011	000	--
Paraguay		*				1110	10	001	000	--
Peru		*				1110	10	001	100	--
Philippines			*			0111	01	011	---	---
Poland			*			0100	10	001	---	---
Portugal			*			0100	10	010	---	---
Qatar	*					0000	01	101	010	00
Republic of Korea			*			0111	00	011	---	---
Republic of Moldova	*					0101	00	000	100	11
Romania			*			0100	10	100	---	---
Russian Federation					*	0001	---	---	---	---
Rwanda		*				0000	01	101	110	--

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						
Saint Lucia	*					1100	10	001	100	00	-----
Saint Vincent and the Grenadines	*					0000	10	111	100	00	-----
Samoa	*					1001	00	000	010	00	-----
San Marino	*					0101	00	000	000	00	-----
Sao Tome and Principe	*					0000	10	011	110	00	-----
Saudi Arabia			*			0111	00	010	---	--	-----
Senegal		*				0000	01	110	000	---	-----
Serbia			*			0100	11	000	---	--	-----
Seychelles	*					0000	01	110	100	00	-----
Sierra Leone	*					0000	01	110	110	00	-----
Singapore			*			0111	01	101	---	--	-----
Slovakia	*					0101	00	000	101	11	-----
Slovenia	*					0101	00	000	110	11	-----
Solomon Islands	*					1000	10	010	111	00	-----
Somalia		*				0000	01	111	000	---	-----
South Africa			*			0000	00	001	---	--	-----
Spain				*		0011	01	---	---	---	-----
Sri Lanka			*			0111	01	110	---	--	-----
Sudan		*				0000	01	111	100	---	-----
Suriname		*				0000	11	001	000	---	-----
Swaziland	*					0000	01	111	010	00	-----
Sweden			*			0100	10	101	---	--	-----
Switzerland			*			0100	10	110	---	--	-----
Syrian Arab Republic			*			0111	01	111	---	--	-----
Tajikistan	*					0101	00	010	101	00	-----
Thailand			*			1000	10	000	---	--	-----
The former Yugoslav Republic of Macedonia	*					0101	00	010	010	00	-----
Togo		*				0000	10	001	000	---	-----
Tonga	*					1100	10	001	101	00	-----
Trinidad and Tobago		*				0000	11	000	110	---	-----
Tunisia			*			0000	00	101	---	--	-----
Turkey			*			0100	10	111	---	--	-----
Turkmenistan	*					0110	00	000	001	10	-----
Uganda		*				0000	01	101	000	---	-----
Ukraine			*			0101	00	001	---	--	-----
United Arab Emirates		*				1000	10	010	110	---	-----
United Kingdom				*		0100	00	---	---	---	-----
United Republic of Tanzania		*				0000	10	000	000	---	-----
United States					*	1010	---	---	---	---	-----
Uruguay		*				1110	10	010	000	---	-----
Uzbekistan	*					0101	00	000	111	11	-----
Vanuatu	*					1100	10	010	000	00	-----
Venezuela			*			0000	11	011	---	--	-----
Viet Nam			*			1000	10	001	---	--	-----
Yemen		*				1000	10	010	000	---	-----
Zambia		*				0000	10	001	010	---	-----
Zimbabwe	*					0000	00	000	100	00	-----

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	1 043 576						
Other allocations											
ICAO ¹			*			1111	00	000	---	--	-----
ICAO ²	*					1000	10	011	001	00	-----
ICAO ²	*					1111	00	001	001	00	-----

1. ICAO administers this block for assigning temporary aircraft addresses as described in section 7.

2. Block allocated for special use in the interest of flight safety.

SCHEDULE 13

(Regulation 94)

1. HF DATA LINK PROTOCOL

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 (ICAO Doc 9741).

1.1 Physical layer RF characteristics

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

1.1.1 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.
** All tables and figures are located at the end of this schedule.*

1.1.2 CHANNELS

Channel utilization shall be in conformity with the table of carrier (reference) frequencies of Appendix 27 to the ITU Radio Regulations.

1.1.3 TUNING

The equipment shall be capable of operating on integral multiples of 1 kHz.

1.1.4 SIDEBAND

The sideband used for transmission shall be on the higher side of its carrier (reference) frequency.

1.1.5 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.

1.1.5.1 M-PSK CARRIER

The M-PSK carrier expressed mathematically shall be defined as:

$$s(t) = A \sum (p(t-kT) \cos[2\pi f_0 t + \varphi(k)]), k = 0, 1, \dots, N-1$$

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
- f₀ = 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 (ICAO Doc 9741).

1.1.5.2 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:

$$\begin{aligned} P(f) &= 1, & \text{if } 0 < |f| < (1 - b)/2T \\ P(f) &= \cos \{ \pi(2|f|T - 1 + b)/4b \}, & \text{if } (1 - b)/2T < |f| < (1 + b)/2T \\ P(f) &= 0, & \text{if } |f| > (1 + b)/2T \end{aligned}$$

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.

1.1.6 TRANSMITTER STABILITY

The basic frequency stability of the transmitting function shall be better than:

- (a) ±20 Hz for HF DL aircraft station subsystems; and
- (b) ±10 Hz for HF DL ground station subsystems.

1.1.7 . RECEIVER STABILITY

The basic frequency stability of the receiving function shall be such that, with the transmitting function stability specified in 1.1.6, the overall frequency difference between ground and airborne functions achieved in service does not exceed 70 Hz.

1.1.8 PROTECTION

A 15 dB desired to undesired (D/U) signal ratio shall apply for the protection of co-channel assignments for HF DL as follows:

- (a) data versus data;
- (b) data versus voice; and
- (c) voice versus data.

1.1.9 CLASS OF EMISSION

The class of emission shall be 2K80J2DEN

1.1.10 ASSIGNED FREQUENCY

The HF DL assigned frequency shall be 1 400 Hz higher than the SSB carrier (reference) frequency.

Note: By convention, the HF DL assigned frequency is offset from the SSB carrier (reference) frequency by 1 400 Hz.

The HF DL M-PSK carrier of the digital modulation is offset from the SSB carrier (reference) frequency by 1 440 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.

1.1.11 EMISSION LIMITS

For HF DL aircraft and ground station transmitters, the peak envelope power (Pp) of any emission on any discrete frequency shall be less than the peak envelope power (Pp) 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 HF DL assigned frequency, and on any frequency between 1.5 kHz and 4.5 kHz higher than the HF DL assigned frequency: at least 30 dB;
- (b) on any frequency between 4.5 kHz and 7.5 kHz lower than the HF DL assigned frequency, and on any frequency between 4.5 kHz and 7.5 kHz higher than the HF DL assigned frequency: at least 38 dB; and
- (c) on any frequency lower than 7.5 kHz below the HF DL assigned frequency and on any frequency higher than 7.5 kHz above the HF DL assigned frequency:
 - i. HF DL aircraft station transmitters: 43 dB;
 - ii. HF DL ground station transmitters up to and including 50 W: $[43 + 10 \log_{10} P_p(W)]$ dB; and
 - iii. HF DL ground station transmitters more than 50 W: 60 dB.

1.1.12 POWER

1.1.12.1 *Ground station installations.* The peak envelope power (Pp) supplied to the antenna transmission line shall not exceed a maximum value of 6 kW as provided for in Appendix 27 of the ITU Radio Regulations.

1.1.12.2 *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.

1.1.13 UNDESIRE SIGNAL REJECTION

For HF DL aircraft and ground station receivers, undesired input signals shall be attenuated in accordance with the following:

- (a) on any frequency between f_c and $(f_c - 300 \text{ Hz})$, or between $(f_c + 2\,900 \text{ Hz})$ and $(f_c + 3\,300 \text{ Hz})$: at least 35 dB below the peak of the desired signal level; and
- (b) on any frequency below $(f_c - 300 \text{ Hz})$, or above $(f_c + 3\,300 \text{ Hz})$: at least 60 dB below the peak of the desired signal level, where f_c is the carrier (reference) frequency.

1.1.14 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.

1.2 Physical layer functions

1.2.1 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.

1.2.2 TRANSMITTER AND RECEIVER CONTROL

The HF DL 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.

1.2.2.1 TRANSMITTER TO RECEIVER TURNAROUND TIME

The transmitted power level shall decay at least by 10 dB within 100 milliseconds after completing a transmission. An HF DL 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.

1.2.2.2 RECEIVER TO TRANSMITTER TURNAROUND TIME

An HF_{DL} 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.

1.2.3 TRANSMISSION OF DATA

Transmission of data shall be accomplished using a time division multiple access (TDMA) technique. The HF_{DL} data link ground station subsystems shall maintain TDMA frame and slot synchronization for the HF_{DL} 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.

1.2.3.1 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 HF_{DL} 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 HF_{DL} aircraft station subsystems, or as downlink random access slots for use by all HF_{DL} 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.

1.2.3.2 BROADCAST

The HF_{DL} 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 (ICAO Doc 9741).

1.2.4 RECEPTION OF DATA

1.2.4.1 FREQUENCY SEARCH

Each HF_{DL} aircraft station shall automatically search the assigned frequencies until it detects an operating frequency.

1.2.4.2 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 1.1.5, 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.

1.2.4.3 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 interleave settings to use during data demodulation;
- (d) achieve M-PSK symbol synchronization; and
- (e) train the equalizer.

1.2.4.4 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.

1.2.4.5 SPECIFIED PACKET ERROR RATE PERFORMANCE

1.2.4.5.1 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.

1.2.4.5.2 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.

1.3 Link layer

Note: Details on link layer functions are contained in the Manual on HF Data Link (ICAO Doc 9741).

The link layer shall provide control functions for the physical layer, link management and data service protocols.

1.3.1 CONTROL FUNCTIONS

The link layer shall pass commands for frequency tuning, transmitter keying and transmitter/receiver switching to the physical layer.

1.3.2 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.

1.3.3 DATA SERVICE PROTOCOLS

The link layer shall support a reliable link service (RLS) protocol and a direct link service (DLS) protocol.

1.3.3.1 RLS

1.3.3.1.1 The RLS protocol shall be used to exchange acknowledged user data packets between aircraft and ground peer link layers.

1.3.3.2 DLS

1.3.3.2.1 The DLS protocol shall be used to broadcast unsegmented uplink high frequency network protocol data units (HFNPDU) and other HFNPDU not requiring automatic retransmission by the link layer.

1.4 Sub network layer

Note: Details on sub network layer protocols and services are contained in the Manual on HF Data Link (ICAO Doc 9741).

1.4.1 PACKET DATA

The HFDL sub network layer in the HFDL aircraft station subsystem and HFDL ground station subsystem shall provide connection-oriented packet data service by establishing sub network connections between sub network service users.

1.4.2 CONNECTIVITY NOTIFICATION SERVICE

The HFDL sub network 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.

1.4.2.1 CONNECTIVITY NOTIFICATION EVENT MESSAGES

The connectivity notification service shall send connectivity notification event messages to the attached ATN router through the sub network access function.

1.4.3 HFDL SUB NETWORK LAYER FUNCTIONS

The HFDL sub network layer in both the HFDL aircraft station subsystem and HFDL ground station subsystem shall include the following three functions:

- (a) HFDL sub network dependent (HFSND) function;
- (b) sub network access function; and
- (c) interworking function.

1.4.3.1 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 HFNPDU. 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.

1.4.3.2 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.

1.4.3.3 INTERWORKING FUNCTION

The interworking function shall provide the necessary harmonization functions between the HFSND, the subnetwork access and the connectivity notification functions.

TABLES FOR THIRTEENTH SCHEDULE

Table 11-1. Transfer delays

	<i>Direction</i>	<i>Priority</i>	<i>Delay</i>
<i>Transit delay</i>	To-aircraft	7 through 14	45 s
	From-aircraft	7 through 14	60 s
<i>Transfer delay (95 percentile)</i>	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

<i>M</i>	<i>Information data rate (bits per second)</i>
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

<i>Data rate (bits per second)</i>	<i>Number of channel paths</i>	<i>Multipath spread (milliseconds)</i>	<i>Fading bandwidth (Hz) per CCIR Report 5492</i>	<i>Frequency offset (Hz)</i>	<i>Signal to noise ratio (dB) in a 3 kHz bandwidth</i>	<i>MPDU size (octets)</i>
1 200	1 fixed	—	—	40	4	256
1 800	2 fading	2	1	40	16	400
1 200	2 fading	2	1	40	11.5	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

<i>Data rate (bits per second)</i>	<i>Number of channel paths</i>	<i>Multipath spread (milliseconds)</i>	<i>Fading bandwidth (Hz) per CCIR Report 5492</i>	<i>Frequency offset (Hz)</i>	<i>Signal to noise ratio (dB) in a 3 kHz bandwidth</i>	<i>MPDU size (octets)</i>
1 200	2 fading	4	1	40	13	256
1 200	2 fading	2	2	40	11.5	256

FIGURES FOR THE THIRTEENTH SCHEDULE

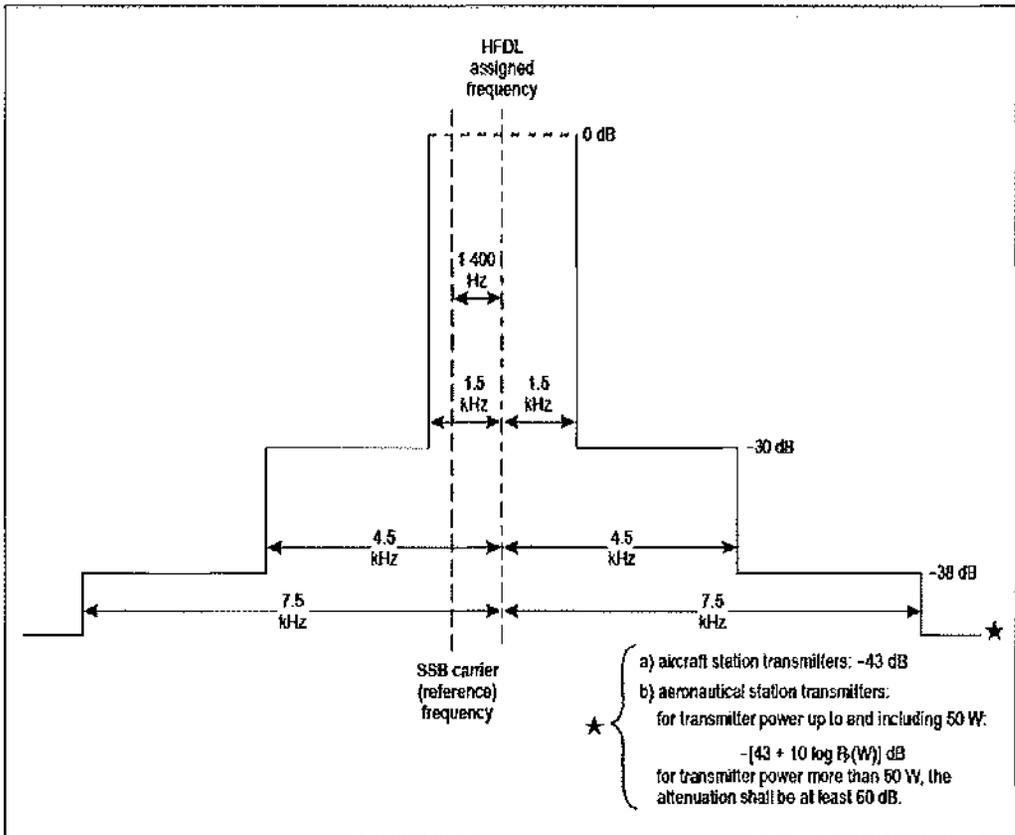


Figure 11-1. Required spectrum limits (in terms of peak power)
for HF DL aircraft and ground station transmitters

SCHEDULE 14

(Regulation 96 and 97)

UNIVERSAL ACCESS TRANSCEIVER (UAT)

1. 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) (ICAO Doc 9861), Part II of the Manual on the Universal Access Transceiver (UAT) (ICAO Doc 9861) (in preparation) will provide additional guidance material.

1.1 TRANSMISSION FREQUENCY

The transmission frequency shall be 978 MHz.

1.2 FREQUENCY STABILITY

The radio frequency of the UAT equipment shall not vary more than ± 0.002 per cent (20 ppm) from the assigned frequency.

1.3 TRANSMIT POWER

1.3.1 TRANSMIT POWER LEVELS

UAT equipment shall operate at one of the power levels shown in Table 12-1*.

1.3.2 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.

1.3.3 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.*

1.4 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.

1.5 POLARIZATION

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

The design polarization of emissions shall be vertical.

1.6 TIME/AMPLITUDE PROFILE OF UAT MESSAGE TRANSMISSION

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 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 should be at least 20 dB below the level on the selected port.
2. All power requirements for subparagraphs "a" and "f" assume a 300 kHz measurement bandwidth. All power requirements for subparagraphs "b", "c", "d" and "e" assume a 2 MHz measurement bandwidth.
3. The beginning of a bit is 1/2 bit period prior to the optimum sample point.
4. These requirements are depicted graphically in Figure 12-2.

(a) 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.

(b) 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) (ICAO Doc 9861) (in preparation).

(c) 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.

(d) 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.

- (e) 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.
- (f) 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.

2. SYSTEM CHARACTERISTICS OF UNIVERSAL ACCESS TRANSCEIVER GROUND INSTALLATION

2.1 Ground station transmitting function

2.1.1 GROUND STATION TRANSMITTER POWER

- 2.1.1.1 The effective radiated power shall be such as to provide a field strength of at least 280 microvolts per metre (minus 97 dBW/m²) 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 μ V/m standard 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.

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) (ICAO Doc 9861), with UAT air-to-ground performance estimates consistent with use of that receiver provided in Appendix B of that manual.

3. SYSTEM CHARACTERISTICS OF THE AIRCRAFT INSTALLATION

3.1 Aircraft transmitting function

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/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. 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 μ V/m and 160 μ V/m provides margin for excess path loss over free-space propagation when receiving a long UAT ADS-B message. A 4 dB 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.

3.2 Receiving function

3.2.1 RECEIVER SENSITIVITY

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; and
- (b) When the desired signal is of maximum modulation distortion allowed in 12.4.3, 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 1 of the Manual on the Universal Access Transceiver (UAT) (Doc 9861).

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 1 of the Manual on the Universal Access Transceiver (UAT) (ICAO Doc 9861).

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; and

- (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) (ICAO Doc 9861) (in preparation).*
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.*

3.2.2 RECEIVER SELECTIVITY

Notes.—

1. *The undesired signal used is an unmodulated carrier applied at the frequency offset.*
2. *This requirement establishes the receiver's rejection of the off-channel energy.*
3. *It is assumed that ratios in between the specified offsets will fall near the interpolated value.*
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.*
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.*
6. *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.*
 - a) *Standard UAT receivers shall meet the selectivity characteristics given in Table 12-3.*
 - b) *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.

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.

3.2.4 RECEIVER TOLERANCE TO PULSED INTERFERENCE

Note. — All power level requirements in this section are referenced to the PMP.

- (a) for Standard and High-Performance receivers the following requirements shall apply:
 - (i) 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.
 - (ii) 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 3.2.1) within 12 microseconds.
- (b) for the standard UAT receiver the following additional requirements shall apply:
 - (i) 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.
 - (ii) 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.
- (c) for the high-performance receiver the following additional requirements shall apply:
 - (1) 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.
 - (2) 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.

4. PHYSICAL LAYER CHARACTERISTICS

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.

4.2 Modulation type

- (a) 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;
- (b) 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 1.3.3. This filtering may cause the deviation to exceed these values at points other than the optimum sampling points.*

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.

4.3 Modulation distortion

- (a) 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.
- (b) 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.
- (c) 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.
- (d) 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 4.4 defines the UAT ADS-B message types.*
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).*

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.

4.4.1 UAT ADS-B MESSAGE

The Active portion (see 1.6) of a UAT ADS-B message shall contain the following elements, in the following order:

- Bit synchronization
- Message data block
- FEC parity

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:

111010101100110111011010010011100010

with the left-most bit transmitted first.

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).

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.

4.4.1.3.1 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.

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)).

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.

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:

- Bit synchronization
- Interleaved message data block and FEC parity.

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:

000101010011001000100101101100011101

with the left-most bit transmitted first.

4.4.2.2 INTERLEAVED MESSAGE DATA BLOCK AND FEC PARITY

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 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) (ICAO Doc 9861).

4.4.2.2.2 FEC parity (before interleaving and after de-interleaving)

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 4.4.2.2.3 provides details on the interleaving procedure.

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:

$$\prod_{i=1}^P (x - \alpha^i)$$

where:

$P = 139$, and

α is a primitive element of a Galois field of size 256 (i.e. GF(256)).

4.4.2.2.2 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.

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.

v. GUIDANCE MATERIAL

Notes:

1. *The Manual on the Universal Access Transceiver (UAT) (ICAO Doc 9861), Part I, provides detailed technical specifications on UAT, including ADS-B message data blocks and formats, procedures for operation of UAT transmitting subsystems, and avionics interface requirements with other aircraft systems.*

2. *The Manual on the Universal Access Transceiver (UAT) (ICAO Doc 9861), Part II, provides information on UAT system operation, description of a range of example avionics equipment classes and their applications, guidance on UAT aircraft and ground station installation aspects, and detailed information on UAT system performance simulation.*

TABLES FOR THE FOURTEENTH SCHEDULE

Table 12-1. Transmitter power levels

<i>Transmitter type</i>	<i>Minimum power at PMP</i>	<i>Maximum power at PMP</i>	<i>Intended minimum air-to-air ranges</i>
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

<i>Frequency offset from centre</i>	<i>Required attenuation from maximum power level (dB as measured at the PMP)</i>
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

<i>Frequency offset from centre</i>	<i>Minimum rejection ratio (Undesired/desired level in dB)</i>
-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

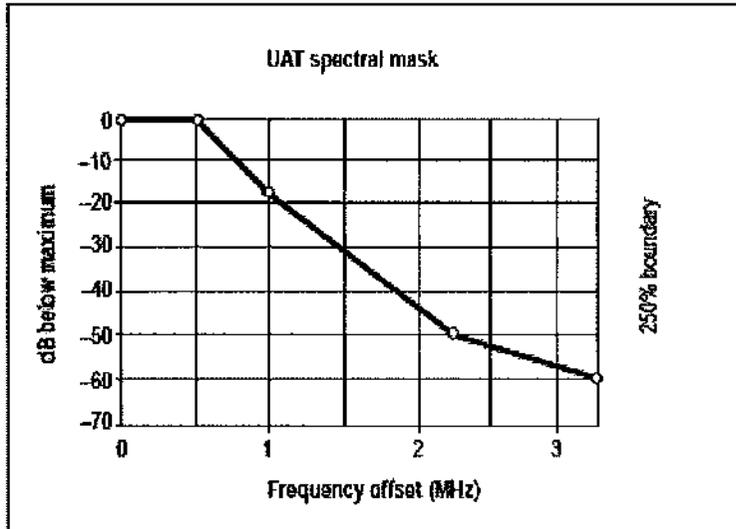
<i>Frequency offset from centre</i>	<i>Minimum rejection ratio (Undesired/desired level in dB)</i>
-1.0 MHz	30
+1.0 MHz	40
(±) 2.0 MHz	50
(±) 10.0 MHz	60

Table 12-5. Ground uplink interleaver matrix

<i>RS Block</i>	<i>MDB Byte #</i>						<i>FEC Parity (Block/Byte #)</i>			
	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 the block (A).

Figures for the Fourteenth Schedule



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

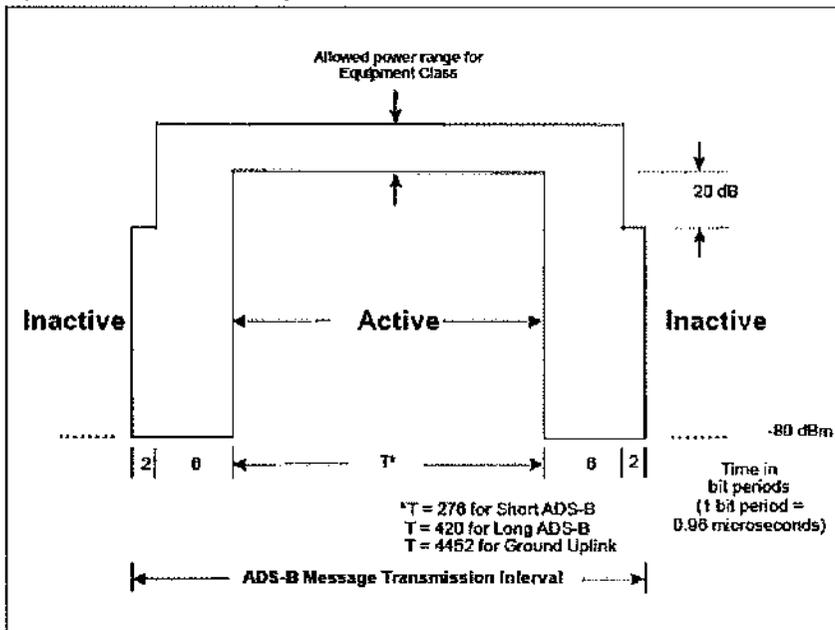


Figure 12-2. Time/amplitude profile of UAT message transmission

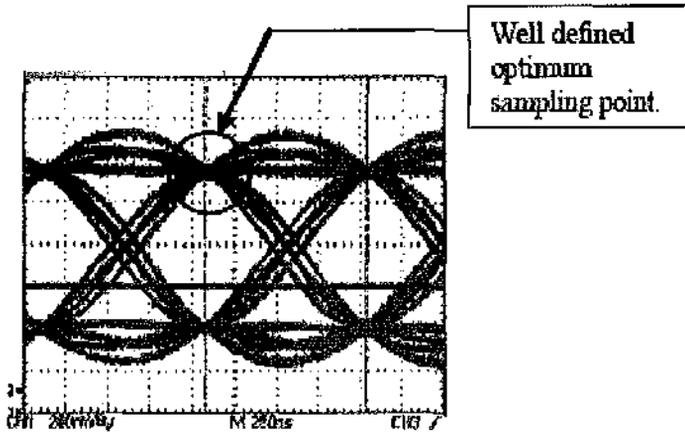


Figure 12-3. Ideal eye diagram

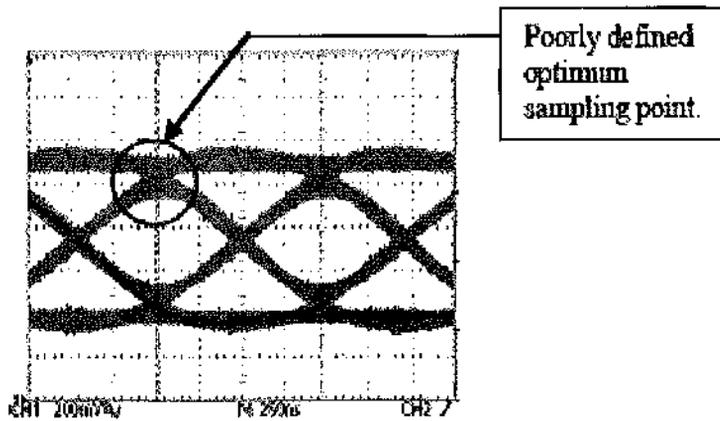


Figure 12-4. Distorted eye diagram

SCHEDULE 15

(Regulations 98(1) and 99)

AERONAUTICAL MOBILE SERVICE

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.

1.1 The characteristics of the air-ground VHF communication system used in the International Aeronautical Mobile Service shall be in conformity with the following specifications:

1.1.1 Radiotelephone emissions shall be double sideband (DSB) amplitude modulated (AM) carriers. The designation of emission is A3E, as specified in the ITU Radio Regulations.

1.1.2 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.

1.1.3 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 Civil Aviation (Radio Frequency Spectrum Utilization) Regulations 2020.

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).

1.1.4 The design polarization of emissions shall be vertical.

2. SYSTEM CHARACTERISTICS OF THE GROUND INSTALLATION

2.1 Transmitting function

2.1.1 *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 Civil Aviation (Radio Frequency Spectrum Utilization) Regulations 2020, 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 Civil Aviation (Radio Frequency Spectrum Utilization) Regulations 2020, 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.

2.1.1.1 *Offset carrier systems in 8.33 kHz, 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 for 8.33 kHz channel spacing shall be limited to two-carrier systems using a carrier offset of plus and minus 2.5 kHz.

2.1.2 POWER

On a high percentage of occasions, the effective radiated power shall be such as to provide a field strength of at least 75 microvolts per metre (minus 109 dBW/m²) within the defined operational coverage of the facility, on the basis of free-space propagation.

2.1.3 *Modulation.* A peak modulation factor of at least 0.85 shall be achievable.

2.1.4 Means shall be provided to maintain the average modulation factor at the highest practicable value without over-modulation.

2.2 Receiving function

2.2.1 *Frequency stability.* Where 8.33 kHz channel spacing is introduced in accordance with Civil Aviation (Radio Frequency Spectrum Utilization) Regulations 2020, the radio frequency of operation shall not vary more than plus or minus 0.0001 per cent from the assigned frequency.

2.2.2 *Sensitivity.* After due allowance has been made for feeder 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 20 microvolts per metre (minus 120 dBW/m²) or more.

- 2.2.3 *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 2.2.2 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 2.2.2 has a carrier frequency within plus or minus 0.0005 per cent of the assigned frequency.

Note: The effective acceptance bandwidth includes Doppler shift.

- 2.2.4 *Adjacent channel rejection.* The receiving system shall ensure an effective rejection of 60 dB or more at the next assignable channel.

Note: The next assignable frequency will normally be plus or minus 50 kHz. Where this channel spacing will not suffice, the next assignable frequency will be plus or minus 25 kHz, or plus or minus 8.33 kHz, implemented in accordance with the provisions of Volume V. It is recognized that in certain areas of the world receivers designed for 25 kHz, 50 kHz or 100 kHz channel spacing may continue to be used.

3. SYSTEM CHARACTERISTICS OF THE AIRBORNE INSTALLATION

3.1 Transmitting function

- 3.1.1 *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.
- 3.1.2 *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.
- 3.1.3 *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.

Note: The voice spectrum is assumed to be a constant level between 300 and 800 Hz and attenuated by 10 dB per octave above 800 Hz.

- 3.1.4 *Modulation.* A peak modulation factor of at least 0.85 shall be achievable.

- 3.1.5 Means shall be provided to maintain the average modulation factor at the highest practicable value without over-modulation.

3.2 Receiving function

- 3.2.1 *Frequency stability.* Where 8.33 kHz channel spacing is introduced in accordance with Civil Aviation (Radio Frequency Spectrum Utilization) Regulations 2020, the radio frequency of operation shall not vary more than plus or minus 0.0005 per cent from the assigned frequency.

3.2.2 SENSITIVITY

- 3.2.2.1 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).

Note.— For planning extended range VHF facilities, an airborne receiving function sensitivity of 30 microvolts per metre may be assumed.

- 3.2.3 *Effective acceptance bandwidth for 100 kHz, 50 kHz and 25 kHz channel spacing receiving installations.* When tuned to a channel designated in Volume V 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 3.2.2 has a carrier frequency within 8 kHz of the assigned frequency; and
- (b) in areas where offset carrier systems are not employed, the receiving function shall provide an adequate audio output when the signal specified at 3.2.2 has a carrier frequency of plus or minus 0.005 per cent of the assigned frequency.

- 3.2.4 *Effective acceptance bandwidth for 8.33 kHz channel spacing receiving installations.* When tuned to a channel designated in Civil Aviation (Radio Frequency Spectrum Utilization) Regulations 2020, as having a width of 8.33 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 in 3.2.2 has a carrier frequency of plus or minus 2.5 kHz of the assigned frequency; or

- (b) in areas where offset carrier systems are not employed, the receiving function shall provide an adequate audio output when the signal specified in 3.2.2 has a carrier frequency within plus or minus 0.0005 per cent of the assigned frequency.

Note 1: The effective acceptance bandwidth includes Doppler shift.

Note 2: When using offset carrier systems (ref. 3.2.3 and 3.2.4), receiver performance may become degraded when receiving two or more similar strength offset carrier signals. Caution is therefore advised with the implementation of offset carrier systems.

3.2.5 *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;

Note: The receiver local oscillator phase noise should be sufficiently low to avoid any degradation of the receiver capability to reject off carrier signals. A phase noise level better than minus 99 dBc/Hz 8.33 kHz away from the carrier is necessary to comply with 45 dB adjacent channel rejection under all operating conditions.

- (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; and
- (d) 100 kHz channel spacing environment: 50 dB or more at plus or minus 100 kHz with respect to the assigned frequency.

3.2.6 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.

Note: Frequency planning is normally based on an assumption of 60 dB effective adjacent channel rejection at plus or minus 25 kHz, 50 kHz or 100 kHz from the assigned frequency as appropriate to the channel spacing environment.

3.2.7 In the case of receivers complying with 3.2.3 or 3.2.4 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; and

- (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.

3.2.8 VDL INTERFERENCE IMMUNITY PERFORMANCE

3.2.8.1 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/m²) 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 fifth schedule 1.4 with an effective transmitter/receiver isolation of 68 dB. Better transmitter and receiver performance could result in less isolation required.

3.2.8.2 After 1 January 2002, 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 3.2.8.1.

3.2.8.3 After 1 January 2005, 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 3.2.8.1, subject to the conditions of 3.2.8.4.

3.2.8.4 Requirements for mandatory compliance of the provisions of 3.2.8.3 shall be made on the basis of regional air navigation agreements which specify the airspace of operation and the implementation timescales.

3.2.8.4.1 The agreement indicated in 3.2.8.4 shall provide at least two years' notice of mandatory compliance of airborne systems.

3.3 Interference immunity performance

3.3.1 After 1 January 1998, the VHF communications receiving system shall provide satisfactory performance in the presence of two signal, third-order intermodulation products caused by VHF FM broadcast signals having levels at the receiver input of minus 5 dBm.

3.3.2 After 1 January 1998, 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.

3.3.3 After 1 January 1995, all new installations of airborne VHF communications receiving systems shall meet the provisions of 3.3.1 and 3.3.2.

3.3.4 Airborne VHF communications receiving systems meeting the immunity performance Standards of 2.3.3.1 and 2.3.3.2 shall be placed into operation at the earliest possible date.

4 SINGLE SIDEBAND (SSB) HF COMMUNICATION SYSTEM CHARACTERISTICS FOR USE IN THE AERONAUTICAL MOBILE SERVICE

4.1 The characteristics of the air-ground HF SSB system, where used in the Aeronautical Mobile Service, shall be in conformity with the following specifications.

4.1.1 FREQUENCY RANGE

4.1.1.1 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.

Note 2.— The ITU World Administrative Radio Conference, Aeronautical Mobile (R) Service, Geneva, 1978, established a new Allotment Plan (Appendix 27, Aer to the Radio Regulations) based on single sideband replacing the earlier double sideband Allotment Plan. The World Radio communication Conference 1995 redesignated it as Appendix S.27. Minor editorial changes were made at the World Radio communication Conference 1997.

4.1.1.2 The equipment shall be capable of operating on integral multiples of 1 kHz.

4.1.2 SIDEBAND SELECTION

4.1.2.1 The sideband transmitted shall be that on the higher frequency side of its carrier (reference) frequency.

4.1.3 CARRIER (REFERENCE) FREQUENCY

4.1.3.1 Channel utilization shall be in conformity with the table of carrier (reference) frequencies at 27/16 and the 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.

Note: It is intended that only the carrier (reference) frequency be promulgated in Regional Plans and Aeronautical Publications.

4.1.4 CLASSES OF EMISSION AND CARRIER SUPPRESSION

- 4.1.4.1 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.
- 4.1.4.2 By 1 February 1982 aeronautical stations and aircraft stations shall have introduced the appropriate class(es) of emission prescribed in 4.1.4.1. Effective this date the use of class A3E emission shall be discontinued except as provided in 4.1.4.4.
- 4.1.4.3 Until 1 February 1982 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. Effective this date the use of class H3E emission shall be discontinued except as provided in 4.1.4.4.
- 4.1.4.4 For stations directly involved in coordinated 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 services shall be involved, A3E and H3E classes of emission shall be used.
- 4.1.4.5 After 1 April 1981 no new DSB equipment shall be installed.
- 4.1.4.6 Aircraft station transmitters shall be capable of at least 26 dB carrier suppression with respect to peak envelope power (Pp) for classes of emission J3E, J7B or J9B.

All figures are located at the end of this chapter.

- 4.1.4.7 Aeronautical station transmitters shall be capable of 40 dB carrier suppression with respect to peak envelope power (Pp) for classes of emission J3E, J7B or J9B.

4.1.5 AUDIO FREQUENCY BANDWIDTH

- 4.1.5.1 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 4.1.7).

Note: For aircraft and aeronautical station transmitter types first installed before 1 February 1983 the audio frequencies will be limited to 3 000 Hz.

- 4.1.5.2 For other authorized classes of emission, the modulation frequencies shall be such that the required spectrum limits of 4.1.7 will be met.

4.1.6 FREQUENCY TOLERANCE

4.1.6.1 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.

4.1.6.2 The basic frequency stability of the receiving function shall be such that, with the transmitting function stabilities specified in 4.1.6.1, the overall 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.

4.1.7 SPECTRUM LIMITS

4.1.7.1 For aircraft station transmitter types and for aeronautical station transmitters first installed before 1 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:

- on any frequency removed by 2 kHz or more up to 6 kHz from the assigned frequency: at least 25 dB;
- on any frequency removed by 6 kHz or more up to 10 kHz from the assigned frequency: at least 35 dB;
- on any frequency removed from the assigned frequency by 10 kHz or more:
 - (a) aircraft station transmitters: 40 dB; and
 - (b) aeronautical station transmitters:

$$[43 + 10 \log_{10} P_m (W)] \text{ dB}$$

4.1.7.2 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:

- on any frequency removed by 1.5 kHz or more up to 4.5 kHz from the assigned frequency: at least 30 dB;

- on any frequency removed by 4.5 kHz or more up to 7.5 kHz from the assigned frequency: at least 38 dB;
- on any frequency removed from the assigned frequency by 7.5 kHz or more:
 - (a) aircraft station transmitters: 43 dB; and
 - (b) aeronautical station transmitters: for transmitter power up to and including 50 W:

$$[43 + 10 \log_{10} P_p (W)] \text{ dB}$$

For transmitter power more than 50 W: 60 dB

4.1.8 POWER

4.1.8.1 *Aeronautical station installations.* Except as permitted by the relevant provisions of Appendix S27 to the ITU Radio Regulations, the peak envelope power (Pp) 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.

4.1.8.2 *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:

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 should 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.

S27/60 Unless otherwise specified, 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:

<i>Class of emission</i>	<i>Stations</i>	<i>Max. peak envelope power (P_e)</i>
H2B, J3E, J7B, J9B, A3E*, H3E* (100% modulation)	Aeronautical stations Aircraft stations	6 kW 400 W
Other emission such as A1A, F1B	Aeronautical stations Aircraft stations	1.5 kW 100 W

* A3E and H3E to be used only on 3 023 kHz and 5 680 kHz.

4.1.8.3 *Method of operation.* Single channel simplex shall be employed

4.2 SATELLITE VOICE COMMUNICATION (SATVOICE) SYSTEM CHARACTERISTICS

Manual on the Aeronautical Mobile Satellite (Route) Service (*Doc 9925*). *Additional guidance for SATVOICE systems is contained in the Satellite Voice Operations Manual (Doc 10038), and the Performance-based Communication and Surveillance (PBCS) Manual (Doc 9869).*

- 4.2.1 For ground-to-air calls, the SATVOICE system shall be capable of contacting the aircraft and enabling the ground party/system to provide, as a minimum, the following:
- (a) secure calling;
 - (b) priority level as defined in Table 2-1; and
 - (c) aircraft SATVOICE number, which is the aircraft address expressed as an 8-digit octal number
- 4.2.2 For ground-to-air calls, the SATVOICE system shall be capable of locating the aircraft in the appropriate airspace regardless of the satellite and ground earth station (GES) to which the aircraft is logged on.
- 4.2.3 For air-to-ground calls, the SATVOICE system shall be capable of:
- (a) contacting the aeronautical station via an assigned SATVOICE number, which is a unique 6-digit number or public switched telephone network (PSTN) number; and
 - (b) allowing the flight crew and/or aircraft system to specify the priority level for the call as defined in Table 2-1.

Table 2-1. Priority levels for SATVOICE calls (air-to-ground/ground-to-air)

Priority level	Application category
1 / EMG / Q15 Emergency (highest) Safety of flight	Distress and urgency. For use by flight crew, when appropriate.
2 / HGH / Q12 Operational high (second highest) Safety of flight	Flight safety. Typically assigned to calls between aircraft and ANSPs.
3 / LOW / Q10 Operational low (third highest) Safety of flight	Regularity of flight, meteorological, administrative. Typically assigned to calls between aircraft operators and their aircraft.
4 / PUB / Q9 Non-operational (lowest) Non safety	Public correspondence.

FIGURES FOR FIFTEENTH SCHEDULE

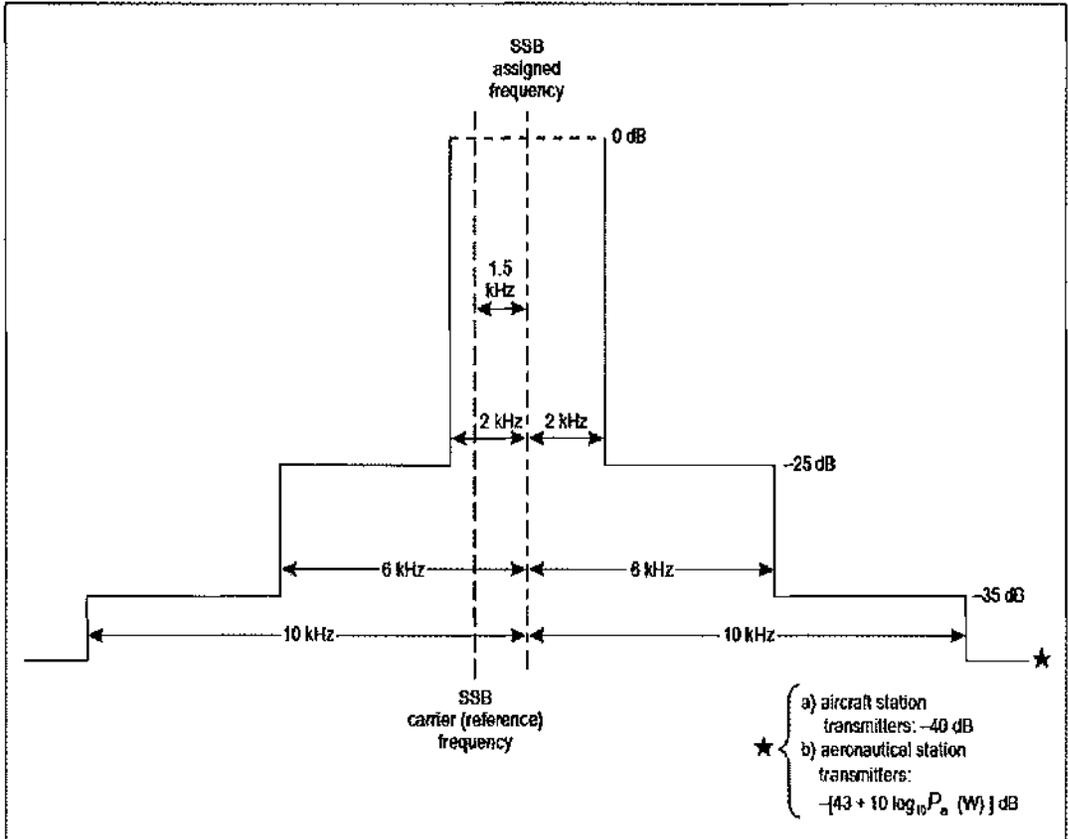


Figure 2-1. Required spectrum limits (in terms of mean power) for aircraft station Transmitter types and for aeronautical station transmitters first installed before 1 February 1983

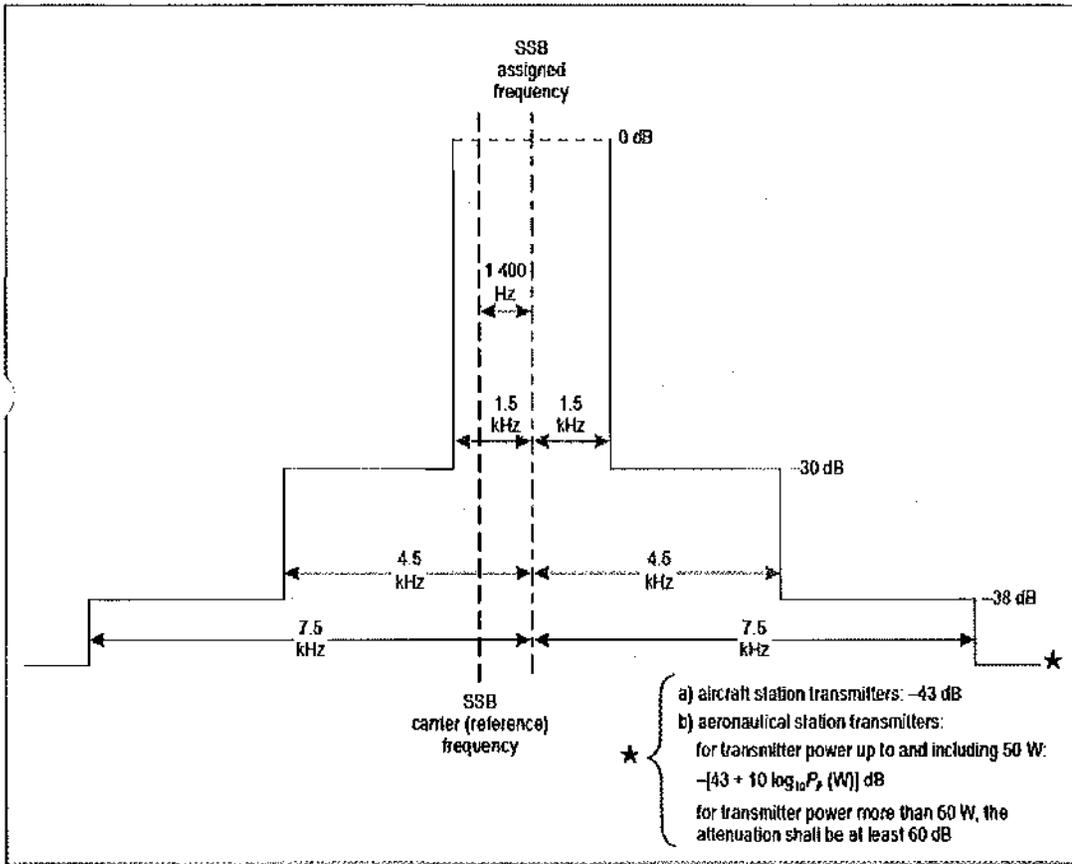


Figure 2-2. Required spectrum limits (in terms of peak power) for aircraft station transmitters first installed after 1 February 1983 and aeronautical station transmitters in use after 1 February 1983

SCHEDULE 16

(Regulation 100 (1), (2))

1. SELCAL SYSTEM

1.1 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.

1.2 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:

Designation	Frequency (Hz)
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	1 029.2
Red 6	1 141.6
Red 7	1 266.2
Red 8	1 404.4
Red 9	1 557.8

Table 3-1. SELCAL tones designated by colour and letter or number

Note 1.— that 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.

- 1.3 The aeronautical stations which are required to communicate with SELCAL-equipped aircraft shall have SELCAL encoders that supports all tones in accordance with Table 3-1.
- 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.

SCHEDULE 17

(Regulation 106 (1),(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

- 1.1 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.
- 1.2 The ELT shall be uniquely coded in accordance with 1.3 and be registered with the appropriate authority.
- 1.3 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; and

(c) aircraft nationality and registration marks.

- 1.4 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

2. ELT CODING

- 2.1 The ELT digital message shall contain information relating to the message format, coding protocol, country code, identification data and location data, as appropriate.
- 2.2 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.

2.3 Protected data field

- 2.3.1 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.
- 2.3.2 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.
- 2.3.3 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.
- 2.3.4 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.

- 2.3.5 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.
- 2.3.6 The ELT digital message shall contain either the transmitter serial number or an identification of the aircraft or operator as shown below.
- 2.3.7 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: The Authority 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

- 2.3.8 Certificate Number, which is a unique number, assigned by COSPAS-SARSAT for each approved ELT model, as part of the ELT message.
- 2.3.9 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.
- 2.3.10 Bits 84 and 85 (user or user location protocol) or bit 112 (location protocols) shall indicate any homing that may be integrated in the ELT.
- 2.3.11 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

<i>Letter</i>	<i>Code</i>		<i>Figure</i>	<i>Code</i>	
	<i>MSB</i>	<i>LSB</i>		<i>MSB</i>	<i>LSB</i>
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

LSB = least significant bit

* - hyphen

** = space

EXAMPLES OF CODING

ELT serial number

25	27	36	37	40	44	63	64	73	74	83	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	36	37	40	44	67	68	73	74	83	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	36	37	40	44	61	62	73	74	83	85			
F	1	COUNTRY	0	1	1	T	T	T	C	OPERATOR 3-LETTER DESIGNATOR	SERIAL NUMBER 1-4098	SEE NOTE 2	A	A

Aircraft registration marking

25	27	36	37	40	81	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 39→	←-40 83→	←-48 85→	←-65 105→	←-107 112→	←-113 132→	←-133 144→					
1	1	10	3	48	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	DEG	MIN	E	DEG	MIN	
								?	0-90	0-56	/	0-180	0-56	
								S	(1 d)	(4 m)	W	(1 d)	(4 m)	

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	←-48 85→	←-65 105→	←-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			21-BIT BCH CODE	12-BIT BCH CODE					
				24	1	9	1	10	SD			Δ LATITUDE	Δ LONGITUDE			
			0011	AIRCRAFT 24 BIT ADDRESS	N = 0	LAT	E = 0	LONG	1			5	4	1	5	4
			0101	AIRCRAFT OPER. DESIGNATOR	S = 1	0-90	W = 1	0-180				M	S		M	S
			0100	SERIAL No						I	E		I	E		
				1-511						U	C		U	C		
				1-1023						U	0		U	0		
				1-16383						T	H		Y	N		
										E	0		E	0		
										S	5		S	5		
										0-30	0-56		0-30	0-56		
										(1 m)	(4 s)		(1 m)	(4 s)		

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	←37		←86	107	←113		←133										
		36→	40→ ←41		85→	106→	112		132→	144→									
←----- 61 BITS PDF-1 ----->					BCH-1	←----- 25 BITS PDF-2 ----->					BCH-2								
1	1	10	4	45					21	6	7	7	6	12					
1	0	CC	1000	10 bits ID	27 bits LATITUDE					21-BIT BCH CODE	SD	Δ LATITUDE			Δ LONGITUDE			6 NU	12-BIT BCH CODE
				18	1	7	5	1	8		5	1	2	4					
				NATIONAL ID NUMBER	N=0 S=1	D E R E S	M N U E S	E=0 W=1	D E R E S		M N U E S	- = 0 + = 1	M N U E S	S C O N S	- = 0 + = 1	M N U E S	T N E S		

CC = Country Code;

ID = Identification Data = 8-bit identification data consisting of a serial number assigned by the appropriate national authority

SD = Supplementary Data = 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).

SCHEDULE 18

(Regulations 72, 78)

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

Note 2- The values in Table 7-1 assume a receiver noise figure of 8 dB.

Note 3 - The sensitivity values in Table 7-1 assume absence of any source of interference except for thermal and receiver noise.

SCHEDULE 19

(Regulation 67)

1. Physical layer protocols and services

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

1.1 FUNCTIONS

1.1.1 TRANSMITTED POWER

1.1.1.1.1 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/m²) 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.

1.1.1.1.2 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/m²) within the defined operational coverage of the facility, on the basis of free-space propagation.

1.1.1.1.2 TRANSMITTER AND RECEIVER FREQUENCY CONTROL

1.1.1.1.2.1 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.

1.1.1.1.3 DATA RECEPTION BY RECEIVER

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

1.1.1.1.4 DATA TRANSMISSION BY TRANSMITTER

1.1.1.1.4.1 *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.

1.1.1.1.4.2 *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 Sections 1.1.1.2.3.1 to 1.1.1.2.3.4.

1.1.1.1.4.3 *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".

1.1.1.1.5 NOTIFICATION SERVICES

1.1.1.1.5.1 *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.

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

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

1.1.1.2 PROTOCOL DEFINITION FOR GFSK

1.1.1.2.1 *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).

1.1.1.2.2 *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 \pm 50 ppm.

1.1.1.2.3 STAGES OF TRANSMISSION

1.1.1.2.3.1 *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.

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

1.1.1.2.3.3 *Ambiguity resolution and data transmission.* The transmission of the first bit of data shall start 40 bit intervals (approximately 2 083.3 microseconds) \pm 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.

1.1.1.2.3.4 *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.

1.1.1.3 CHANNEL SENSING

1.1.1.3.1 *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.

1.1.1.3.2 *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 VDL Mode 4 Technical Specifications.

1.1.1.3.3 *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.

1.1.1.3.3.1 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.

1.1.1.3.3.2 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.

1.1.1.3.4 CHANNEL BUSY TO IDLE DETECTION

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

1.1.1.3.4.2 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.

1.1.1.3.4.3 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.

1.1.1.4 RECEIVER/TRANSMITTER INTERACTION

1.1.1.4.1 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.

1.1.1.4.2 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.

1.1.1.4.3 *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.

1.1.1.5 PHYSICAL LAYER SYSTEM PARAMETERS

1.1.1.5.1 PARAMETER P1 (MINIMUM TRANSMISSION LENGTH)

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

1.1.1.5.1.2 The value of P1 shall be 19 200 bits.

1.1.1.5.2 PARAMETER P2 (NOMINAL CO-CHANNEL INTERFERENCE PERFORMANCE)

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

1.1.1.5.2.2 The value of P2 shall be 12 dB.

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

1.1.1.6.1 A VDL Mode 4 station shall conform to the requirements defined in section 6.3.5.4 when operating in the band 117.975–137 MHz.

1.1.1.6.2 A VDL Mode 4 station shall conform to the requirements defined below when operating in the band 108–117.975 MHz.

1.1.1.6.2.1 The VDL Mode 4 receiving system shall meet the requirements specified in 6.3.5.1 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.

$N1$ and $N2$ 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 1.1.1.6.2.2.

$\Delta f = 108.1 - f1$, where $f1$ is the frequency of $N1$, 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.

1.1.1.6.2.2 The VDL Mode 4 receiving system shall not be desensitized in the presence of VHF FM broadcast signals having levels in accordance with Table I-1

Table I-1. 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.

1.2 Link layer

Note: Details on link layer functions are contained in the Manual on VDL Mode 4 Technical Specifications.

1.3 Subnetwork layer and SNDCF

Note: Details on subnetwork layer functions and SNDCF are contained in the Manual on VDL Mode 4 Technical Specifications.

1.4 ADS-B applications

Note: Details on ADS-B application functions are contained in the ICAO Manual on VDL Mode 4 Technical Specifications.

MADE this 13th day of June, 2022.

ERIC MOTHIBI MOJALE,
*Minister for Transport and Public
Works.*