APPENDIX B

SARPS FOR HF DATA LINK
CHAPTER 11. HF DATA LINK

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11.2 DEFINITIONS AND SYSTEM CAPABILITIES

The following standards and recommendations are specific to the high frequency data link (HFDL) and are in addition to the requirements specified in the ITU Radio Regulations (Appendix S27). The HFDL is a constituent mobile subnetwork of the aeronautical telecommunication network (ATN), operating in the aeronautical mobile (R) high frequency bands. In addition, the HFDL may provide non-ATN functions, such as direct link service (DLS). The HFDL system shall enable aircraft to exchange data with ground based users.

11.2.2 Definitions

**Coded chip.** A “1” or “0” output of the rate 1/2 or 1/4 convolutional code encoder.

**Designated operational coverage (DOC) area.** The area in which a particular service is provided and in which the service is afforded frequency protection.

**Direct link service (DLS).** A data communications service that does not automatically correct errors, detected or undetected, at the link layer of the air-ground communications path.

**High frequency network protocol data unit (HFNPDU).** User data packet.

**Link protocol data unit (LPDU).** Data unit which encapsulates a segment of an HFNPDU.

**Media access protocol data unit (MPDU).** Data unit which encapsulates one or more LPDUs.

**M-phase phase shift keying (M-PSK) modulation.** A digital phase modulation that causes the phase of the carrier waveform to take on one of a set of M values.

**M-PSK symbol.** One of the M possible phase shifts of the M-PSK modulated carrier representing a group of \(\log_2 M\) coded chips.

**Peak envelope power (PEP).** The peak power of the modulated signal, supplied by the transmitter to the antenna transmission line.

**Physical layer protocol data unit (PPDU).** Data unit passed to the physical layer for transmission, or decoded by the physical layer after reception.

**Quality of service (QOS).** Information relating to the data transfer characteristics used by various communications protocols to achieve various levels of performance for network users.

**Reliable link service (RLS).** A data communications service that automatically provides for error control over its air-ground link through error detection and requested retransmission of signal units found to be in error, at the link layer.
**Squitter protocol data unit (SPDU).** Data packet which is broadcast every 32 seconds by an HFDL ground station on each of its operating frequencies, and which contains link management information.

### 11.4 HF DATA LINK SYSTEM

#### 11.4.2 System architecture

The HFDL system shall consist of one or more ground and aircraft station sub-systems, which implement the HFDL protocol (see section 11.3 below). The HFDL system shall also include a ground management sub-system (see section 11.4 below).

11.4.2.2 **AIRCRAFT AND GROUND STATION SUB-SYSTEMS**

The HFDL aircraft station sub-system and the HFDL ground station sub-system shall include the following functions:

- **b)** HF transmission and reception;
- **d)** data modulation and demodulation; and
- **f)** HFDL protocol implementation and frequency selection.

#### 11.4.4 Operational coverage

Frequency assignments for HFDL shall be protected throughout their designated operational coverage (DOC) area.

*Note.*—*Designated operational coverage (DOC) areas may be different from current MWARAs or RDARAs as defined in Appendix S27 to the ITU Radio Regulations.*

*Note.*—*Additional co-ordination with ITU is required in cases where DOC areas are not in conformity with the allotment areas specified in the ITU Radio Regulations.*

#### 11.4.6 Requirements for carriage of HFDL equipment

Requirements for carriage of HFDL equipment shall be made on the basis of regional air navigation agreements that specify the airspace of operation and the implementation time-scale.
11.4.8 Ground station networking

11.4.8.2 **Recommendation.**— *HFDL ground station sub-systems should interconnect through a common ground management sub-system.*

*Note.— This provides a distributed subnetwork, with a subnetwork point of attachment (SNPA), depending on the method of implementation, which allows for the maintenance of virtual circuit connections as aircraft stations transition between designated operational coverage areas. The distribution may be multi-regional or world-wide.*

11.4.10 Ground station synchronization

Synchronization of HFDL ground station sub-systems shall be to within +/- 25 ms of UTC. For any station not operating within +/- 25 ms of UTC, appropriate notification shall be made to all aircraft and ground station sub-systems to allow for continued system operation.

11.4.12 Quality of service

11.4.12.2 **Residual packet error rate**

The undetected error rate for a network user packet which contains between 1 and 128 octets of user data shall be equal to or less than 1 in $10^6$.

11.4.12.4 **Speed of service**

Transit and transfer delays for network user packets (128 octets) with priorities defined in Part I, Chapter 4, Table 4-26 for message priorities 7 through 14, shall not exceed the following values:

<table>
<thead>
<tr>
<th>Direction</th>
<th>Priority</th>
<th>Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transit Delay</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To-aircraft</td>
<td>7 through 14</td>
<td>45 seconds</td>
</tr>
<tr>
<td>From-aircraft</td>
<td>7 through 14</td>
<td>60 seconds</td>
</tr>
<tr>
<td><strong>Transfer Delay (95 percentile)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>To-aircraft</td>
<td>11 through 14</td>
<td>90 seconds</td>
</tr>
<tr>
<td></td>
<td>7 through 14</td>
<td>120 seconds</td>
</tr>
<tr>
<td>From-aircraft</td>
<td>11 through 14</td>
<td>150 seconds</td>
</tr>
<tr>
<td></td>
<td>7 through 14</td>
<td>250 seconds</td>
</tr>
</tbody>
</table>

*Table 11-1. Transfer delays*
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 HFDL protocol shall consist of a physical layer, a link layer, and a subnetwork layer, as specified below. The details of the protocol are described in the appendix to these SARPs.

### 11.6.2 Physical layer RF characteristics

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

#### 11.6.2.2 Frequency bands

HFDL installations shall be capable of operating at any single side band (SSB) carrier (reference) frequency available to the aeronautical mobile (R) service in the band 2.8 - 22 MHz, and in compliance with the relevant provisions of the Radio Regulations.

#### 11.6.2.4 Channels

Channel utilization shall be in conformity with the table of carrier (reference) frequencies of Appendix S27.

#### 11.6.2.6 Tuning

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

#### 11.6.2.8 Sideband

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

#### 11.6.2.10 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 plus or minus 1 x 10^5. The value of M and the information data rate shall be as specified in Table 11-2.

<table>
<thead>
<tr>
<th>M</th>
<th>Information Data Rate (bits per second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>300 or 600</td>
</tr>
<tr>
<td>4</td>
<td>1 200</td>
</tr>
<tr>
<td>8</td>
<td>1 800</td>
</tr>
</tbody>
</table>

**Table 11-2. Value of M and Information Data Rate**
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 appendix to these SARPs.

11.6.2.10.2  \( M \)-PSK CARRIER

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

\[
s(t) = A \sum_{k=0}^{N-1} p(t-kT) \cos \left( 2\pi f_0 + \phi(k) \right), \quad k = 0, 1, ..., N-1
\]

where:

\[
\begin{align*}
N & = \text{number of } M \text{-PSK symbols in transmitted physical layer protocol data unit (PPDU)} \\
s(t) & = \text{analog waveform or signal at time } t \\
A & = \text{peak amplitude} \\
f_0 & = \text{SSB carrier (reference) + 1440 Hz} \\
T & = \text{M-PSK symbol period (1/1800 s)} \\
\phi(k) & = \text{phase of } k\text{th M-PSK symbol} \\
p(t-kT) & = \text{pulse shape of } k\text{th M-PSK symbol at time } t
\end{align*}
\]

Note.— The number of \( M \)-PSK symbols sent, \( N \), defines the length (duration = \( NT \) seconds) of the PPDU. These parameters are defined in the appendix to these SARPs.

11.6.2.10.4  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

\[
\begin{align*}
P(f) & = 1, \quad \text{if } 0 < |f-f_0| < \frac{(1-b)}{2T} \\
P(f) & = \cos \left\{ \pi \left(2|f|T - 1 + b\right)/4b \right\}, \quad \text{if } \frac{(1-b)}{2T} < |f-f_0| < \frac{(1+b)}{2T} \\
P(f) & = 0, \quad \text{if } |f-f_0| > \frac{(1+b)}{2T}
\end{align*}
\]

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) + 2590 Hz and the peak-to-average power ratio of the waveform is less than 5 dB.

11.6.2.12  TRANSMITTER STABILITY

The basic frequency stability of the transmitting function shall be such that the difference between the actual carrier of the PSK transmission and the SSB assigned frequency shall not exceed:

\[
\begin{align*}
b) & \quad 20 \text{ Hz for HFDL aircraft station sub-systems; and} \\
d) & \quad 10 \text{ Hz for HFDL ground station sub-systems.}
\end{align*}
\]
11.6.2.14 RECEIVER STABILITY

The basic frequency stability of the receiving function shall be such that, with the transmitting function stability specified in 11.3.1.6 above, the over-all frequency difference between ground and airborne functions achieved in service does not exceed 70 Hz.

11.6.2.16 PROTECTION

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

b) data versus data;

d) data versus voice; and

f) voice versus data.

11.6.2.18 CLASS OF EMISSION

The class of emission shall be 2K80J2DEN.

11.6.2.20 ASSIGNED FREQUENCY

The SSB assigned frequency shall be 1400 Hz higher than the SSB carrier (reference) frequency.

Note.—The HFDL assigned frequency is offset from the channel carrier frequency by 1400. The digital modulation is fully contained within the same over-all channel bandwidth as the voice signal and complies with the provisions of Appendix S27 to the ITU Radio Regulations.

11.6.2.22 EMISSION LIMITS

For HFDL aircraft and ground station transmitters, the peak envelope power ($P_p$) of any emission on any discrete frequency shall be less than the peak envelope power ($P_{po}$) of the transmitter in accordance with the
Figure 11-1. Required spectrum limits (in terms of peak power) for HFDL aircraft and ground station transmitters

following (see Figure 11-1):

b) on any frequency between 1.5 kHz and 4.5 kHz lower than the SSB assigned frequency, and on any frequency between 1.5 kHz and 4.5 kHz higher than the SSB assigned frequency: at least 30 dB;

d) on any frequency between 4.5 kHz and 7.5 kHz lower than the SSB assigned frequency, and on any frequency between 4.5 kHz and 7.5 kHz higher than the SSB assigned frequency: at least 38 dB; and

f) on any frequency lower than 7.5 kHz below the SSB assigned frequency and on any frequency higher than 7.5 kHz above the SSB assigned frequency:

2) HFDL aircraft station transmitters: 43 dB;

4) HFDL ground station transmitters up to and including 50 W:

\[43 + 10 \log_{10} P_p(W)\] dB; and

6) HFDL ground station transmitters more than 50 W: 60 dB.
11.6.2.24 POWER

The transmitter peak envelope power supplied to the antenna transmission line shall not exceed 6 kilowatts for each transmitter at the ground station and 400 watts for aircraft stations.

11.6.2.26 DESIRED SIGNALS

For HFDL aircraft and ground station sub-system receivers, input signals shall be attenuated in accordance with the following:

On any frequency between \( (f_c + 350 \text{ Hz}) \) and \( (f_c + 2\,500 \text{ Hz}) \): not more than 4 dB below the peak of the desired signal,

where \( f_c \) is the carrier (reference) frequency.

11.6.2.28 UNDESIRABLE SIGNAL REJECTION

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

b) 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

d) 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.

*Note.— See Figure 11-2.*
11.6.2.30 RECEIVER RESPONSE TO TRANSIENTS

**Recommendation.**— The receiving function should recover from an instantaneous increase in RF power at the antenna terminal of 60 dB within 10 milliseconds. The receiving function should recover from an instantaneous decrease in RF power at the antenna terminal of 60 dB within 25 milliseconds.

11.6.4 Physical layer functions

11.6.4.2 FUNCTIONS

The functions provided by the physical layer shall include the following:

b) transmitter and receiver control;

d) transmission of data; and

f) reception of data.
11.6.4.4 TRANSMITTER AND RECEIVER CONTROL

The HFDL physical layer shall implement the transmitter/receiver switching and frequency tuning as commanded by the link layer. The physical layer shall perform transmitter keying on demand from the link layer to transmit a packet.

11.6.4.4.2 TRANSMITTER TO RECEIVER TURNAROUND TIME

The transmitted power level shall decay at least by 10 dB within 100 milliseconds after completing a transmission. An HFDL station sub-system shall be capable of receiving and demodulating, with nominal performance, an incoming signal within 200 milliseconds of the start of the subsequent receive slot.

11.6.4.4.4 RECEIVER TO TRANSMITTER TURNAROUND TIME

An HFDL station sub-system 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.

11.6.4.6 TRANSMISSION OF DATA

Transmission of data shall be accomplished using a time division multiple access (TDMA) technique. The HFDL data link ground station sub-systems shall maintain TDMA frame and slot synchronization for the HFDL system. To ensure that slot synchronization is maintained, each HF data link modulator shall begin outputting a prekey segment at the beginning of a time slot plus or minus 10 milliseconds.

11.6.4.6.2 TDMA STRUCTURE

Each TDMA frame shall be 32 seconds. Each TDMA frame shall be divided into thirteen equal duration slots as follows:

b) the first slot of each TDMA frame shall be reserved for use by the HFDL ground station sub-system to broadcast link management data in SPDU packets; and
d) the remaining slots shall be designated either as uplink slots, downlink slots reserved for specific HFDL aircraft station sub-system, or as downlink random access slots for use by all HFDL aircraft station sub-system on a contention basis. These TDMA slots shall be assigned on a dynamic basis using a combination of reservation, polling and random access assignments.

11.6.4.6.4 BROADCAST

The HFDL ground station sub-system 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, prekey segment, data structures, including the SPDU, are contained in the appendix to these SARPs.
11.6.4.8 RECEPTION OF DATA

11.6.4.8.2 FREQUENCY SEARCH

Each HFDL aircraft station shall search the assigned frequencies until it detects an operating frequency.

11.6.4.8.4 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 11.3.1.5, subject to the following distortion:

b) the 1440 Hz audio carrier offset by plus or minus 70 Hz;

d) discrete and/or diffuse multipath distortion with up to 5 ms multipath spread;

f) multipath amplitude fading with up to 2 Hz two-sided RMS Doppler spread and Rayleigh statistics; and

h) additive Gaussian and broadband impulsive noise with varying amplitude and random arrival times.

Note.—Reference CCIR Report 549-2

11.6.4.8.6 DECODING OF PPDUs

Upon receipt of the preamble segment the receiver shall:

b) detect the beginning of a burst of data;

d) measure and correct the frequency offset between the transmitter and receiver due to Doppler shift and transmitter/receiver frequency offsets;

f) determine the data rate and interleaver settings to use during data demodulation;

h) achieve M-PSK symbol synchronization; and

j) train the equalizer.

11.6.4.8.8 SYNCHRONIZATION

Each HFDL aircraft station sub-system shall synchronize its slot timing to that of its corresponding ground station with respect to the reception time of the last received SPDU.

11.6.4.8.10 SPECIFIED PACKET ERROR RATE PERFORMANCE

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.
### Table 11-3. HF signal-in-space conditions

**Recommendation.**—The number of HFDL MPDUs received with one or more bit errors should 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.

<table>
<thead>
<tr>
<th>Data Rate (bits per second)</th>
<th>Number of Channel Paths</th>
<th>Multipath Spread (milliseconds)</th>
<th>Fading Bandwidth (Hz) per CCIR Report 549-2</th>
<th>Frequency Offset (Hz)</th>
<th>Signal to Noise Ratio (dB) in a 3 kHz bandwidth</th>
<th>MPDU Size (octets)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 200</td>
<td>1 Fixed</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>4</td>
<td>256</td>
</tr>
<tr>
<td>1 800</td>
<td>2 Fading</td>
<td>2</td>
<td>1</td>
<td>40</td>
<td>16</td>
<td>400</td>
</tr>
<tr>
<td>1 200</td>
<td>2 Fading</td>
<td>2</td>
<td>1</td>
<td>40</td>
<td>11.5</td>
<td>256</td>
</tr>
<tr>
<td>600</td>
<td>2 Fading</td>
<td>2</td>
<td>1</td>
<td>40</td>
<td>8</td>
<td>128</td>
</tr>
<tr>
<td>300</td>
<td>2 Fading</td>
<td>2</td>
<td>1</td>
<td>40</td>
<td>5</td>
<td>64</td>
</tr>
</tbody>
</table>

### Table 11-3a. HF signal-in-space conditions

#### 11.6.6 Link layer

**Note.**—Details on link layer functions are contained in the appendix to these SARPs.

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

#### 11.6.6.2 Control functions

The link layer shall pass commands for frequency tuning, transmitter keying and transmitter/receiver switching to the physical layer.
11.6.6.4 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.

11.6.6.6 DATA SERVICE PROTOCOLS

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

11.6.6.6.2 RLS

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

11.6.6.6.4 DLS

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

11.6.8 Subnetwork layer

Note.— Details on subnetwork layer protocols and services are contained in the appendix to these SARPs.

11.6.8.2 PACKET DATA

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

11.6.8.4 CONNECTIVITY NOTIFICATION SERVICE

The HFDL subnetwork layer in the HFDL aircraft station sub-system shall provide the additional connectivity notification service by sending connectivity notification event messages to the attached ATN router.

11.6.8.4.2 CONNECTIVITY NOTIFICATION EVENT MESSAGES

The connectivity notification service shall send connectivity notification event messages to the attached ATN router through the subnetwork access function.
11.6.8.6 HFDL SUBNETWORK LAYER FUNCTIONS

The HFDL subnetwork layer in both the HFDL aircraft station sub-system and HFDL ground station sub-system shall include the following three functions:

b) HFDL subnetwork dependent (HFSND) function;

d) subnetwork access function; and

f) interworking function.

11.6.8.6.2 HFSND FUNCTION

The HFSND function shall perform the HFSND protocol between each pair of HFDL aircraft station sub-system and HFDL ground station sub-system by exchanging HFNPDU. It shall perform the HFSND protocol aircraft function in the HFDL aircraft station sub-system and the HFSND protocol ground function in the HFDL ground station sub-system.

11.6.8.6.4 SUBNETWORK ACCESS FUNCTION

The subnetwork access function shall perform the ISO 8208 protocol between the HFDL aircraft station sub-system or HFDL ground station sub-system and the attached routers by exchanging ISO 8208 packets. It shall perform the ISO 8208 DCE function in the HFDL aircraft station sub-system and the HFDL ground station sub-system.

11.6.8.6.6 INTERWORKING FUNCTION

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

11.8 GROUND MANAGEMENT SUB-SYSTEM

Note.— Details on the ground management sub-system functions and interfaces are contained in the appendix to these SARPs.

11.8.2 Management functions

The ground management sub-system shall perform the functions necessary to establish and maintain communications channels between the HFDL ground and aircraft station sub-systems.
11.8.4 Management/control information exchange

The ground management sub-system shall interface with the ground station sub-system in order to exchange control information required for frequency management, system table management, log status management, channel management, and quality of service (QOS) data collection.