ARINC

HF DATA LINK PROTOCOLS

ARINC SPECIFICATION 635-4

PUBLISHED: DECEMBER 22, 2003

AN ARINC DOCUMENT

Prepared by
AIRLINES ELECTRONIC ENGINEERING COMMITTEE
Published by
AERONAUTICAL RADIO, INC.
2551 RIVA ROAD, ANNAPOLIS, MARYLAND 21401

This document is based on material submitted by various participants during the drafting process. Neither AEEC nor ARINC has made any determination whether these materials could be subject to valid claims of patent, copyright or other proprietary rights by third parties, and no representation or warranty, express or implied, is made in this regard. Any use of or reliance on this document shall constitute an acceptance thereof "as is" and be subject to this disclaimer.

©2003 by
AERONAUTICAL RADIO, INC.
2551 Riva Road
Annapolis, Maryland 21401-7465 USA

ARINC SPECIFICATION 635-4

HF DATA LINK PROTOCOLS

Published: December 22, 2003

Prepared by the Airlines Electronic Engineering Committee

Specification 635	Adopted by the Airlines Electronic Engineering Committee:	October 31, 1995
Specification 635	Adopted by the Industry:	December 22, 1995

Summary of Document Supplements

Supplement	Adoption Date	Published
Specification 635-1	October 22, 1996	December 12, 1996
Specification 635-2	December 12, 1997	February 27, 1998
Specification 635-3	August 11, 2000	December 29, 2000
Specification 635-4	September 9, 2003	December 22, 2003

A description of the changes introduced by each Supplement is included on Goldenrod paper at the end of this document.

FOREWORD

Aeronautical Radio, Inc., the AEEC, and ARINC Standards

Aeronautical Radio, Inc. (ARINC) was incorporated in 1929 by four fledgling airlines in the United States as a privately-owned company dedicated to serving the communications needs of the air transport industry. Today, the major U.S. airlines remain the Company's principal shareholders. Other shareholders include a number of non-U.S. airlines and other aircraft operators.

ARINC sponsors aviation industry committees and participates in related industry activities that benefit aviation at large by providing technical leadership and guidance and frequency management. These activities directly support airline goals: promote safety, efficiency, regularity, and cost-effectiveness in aircraft operations.

The Airlines Electronic Engineering Committee (AEEC) is an international body of airline technical professionals that leads the development of technical standards for airborne electronic equipment-including avionics and in-flight entertainment equipment-used in commercial, military, and business aviation. The AEEC establishes consensus-based, voluntary form, fit, function, and interface standards that are published by ARINC and are known as ARINC Standards. The use of ARINC Standards results in substantial benefits to airlines by allowing avionics interchangeability and commonality and reducing avionics cost by promoting competition.

There are three classes of ARINC Standards:

a) ARINC Characteristics – Define the form, fit, function, and interfaces of avionics and other airline electronic equipment. ARINC Characteristics indicate to prospective manufacturers of airline electronic equipment the considered and coordinated opinion of the airline technical community concerning the requisites of new equipment including standardized physical and electrical characteristics to foster interchangeability and competition.

b) ARINC Specifications – Are principally used to define either the physical packaging or mounting of avionics equipment, data communication standards, or a high-level computer language.

c) ARINC Reports – Provide guidelines or general information found by the airlines to be good practices, often related to avionics maintenance and support.

The release of an ARINC Standard does not obligate any airline or ARINC to purchase equipment so described, nor does it establish or indicate recognition or the existence of an operational requirement for such equipment, nor does it constitute endorsement of any manufacturer's product designed or built to meet the ARINC Standard.

In order to facilitate the continuous product improvement of this ARINC Standard, two items are included in the back of this volume:

a) An Errata Report solicits any corrections to the text or diagrams in this ARINC Standard.

b) An ARINC IA Project Initiation/Modification (APIM) form solicits any recommendations for addition of substantive material to this volume which would be the subject of a new Supplement.

ARINC SPECIFICATION 635
TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

ARINC SPECIFICATION 635
TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose of this Document

The intent of this document is to provide general and specific design guidance for the development and installation of the protocols needed to exchange bit-oriented data using an air-ground HF data link operating in an Open System Interconnection (OSI) environment. The protocols defined herein are consistent with the concepts of the Aeronautical Telecommunications Network (ATN).

This document describes the functions to be performed by the airborne components of the HF Data Link System (HFDL) to successfully transfer messages between HF ground stations and avionics systems on aircraft where the data is encoded in a bit-oriented format. These functions are referred to as HFDL protocols. The compatibility with OSI is provided by defining a set of services and protocols in accordance with the OSI model.

COMMENTARY

> HFDL, as used in this document, refers to the digital communication protocols to be exercised by the HF transceiver and supporting avionics to exchange messages with any appropriately equipped ground system.

1.2 Background

Aeronautical data link communications were initiated using the Aircraft Communications Addressing and Reporting System (ACARS). The ACARS air-ground system description was initially included in ARINC Characteristic 597. It was later transferred to ARINC Specification 618, "Air-Ground Character-Oriented Protocol Specification".

The development of HF Data Link service builds on the experiences of ACARS and operators in the HF environment to offer a reliable data link to remote regions. HF Data Link offers another communications path for the ATN environment to use.

The HF air-ground data communication functions described herein are compatible with the OSI Model. They were developed as the first step toward a fully OSI compliant protocol "stack".

1.3 Relationship of this Document to ARINC Characteristics

This Specification may be referenced by any appropriate equipment Characteristic: 753, 719 or 597. To obtain HFDL communications capability, the HFDL functions defined herein should be installed in an existing ARINC 597, 724 or 724B ACARS Management Unit (MU), 758 Communications Management Unit (CMU) Mark-2 or ARINC 753 HF Data Radio and HF Data Unit to produce a unit capable of exchanging information in a bit-oriented environment.

The description of the Internetworking Protocol, which accomplishes the routing function, is defined in ARINC Specification 637, "Internetworking Specification". Transport, Session, Presentation and Application Layer definitions are described in ARINC Specification 638, "OSI Upper Layer Specification".

1.3.1 ARINC Characteristic 758

ARINC Characteristic 758 defines a Communications Management Unit (CMU) Mark 2 for use in commercial aircraft. One function of the CMU is to serve as a router of VHF, HF, Satellite and other data link messages. ARINC Characteristic 758 defines a multi-lingual unit capable of handling character-oriented and bit-oriented communication. New aircraft should be designed with communications architectures intended to operate within the ATN. c-1

1.3.2 ARINC Characteristic 724B

ARINC Characteristic 724B describes ARINC 600-packaged equipment intended to perform communications routing functions for ACARS air-ground message transfers. The ARINC 724B ACARS Line Replaceable Units (LRUs) interface with the broadest range of ARINC "700-series" - avionics equipment.

The MU described in ARINC Characteristic 724B provides for input/output ARINC 429 data bus interfaces between the MU and two ARINC 702 Flight Management Computers (FMC) and multiple other on-board LRUs.

1.3.3 ARINC Characteristic 724

ARINC Characteristic 724 describes ARINC 600-packaged equipment intended to perform ACARS message routing. The MUs built to ARINC Characteristic 724 have a limited set of digital data bus interfaces and interacts with a dedicated Control/Display Unit (CDU).

1.3.4 ARINC Characteristic 597

ARINC Characteristic 597, "Aircraft Communications Addressing and Report System (ACARS)", describes ARINC 404A-packaged airborne ACARS equipment. Many MUs, built to ARINC Characteristic 597, were produced with relatively small memory capacity. These MUs are not considered appropriate candidates to perform the memory-intensive communication system functions defined in this document.

1.3.5 ARINC Characteristic 753

ARINC Characteristic 753 describes the digital data radio to be used for HF air-ground communications. This characteristic was developed to overcome the limitations of existing radios and provide high speed data transfer capability.

1.4 Relationship to OSI Protocols

HF Data Link uses ISO 8208 protocols to interface to the CMU. The HF Data Link avionics implements the DCE.

1.5 Conventions Used in This Document

In this document, the HF Data Link layer and the HF Subnetwork layer protocols are explicitly described by incoming events, outgoing events, and state transition tables. The state transition tables for the Data Link Layer are contained in Attachment 2-12 and 2-13.

The state transition tables define the mapping between protocol events and the service that the user can expect.

1.0 INTRODUCTION

1.5 Conventions Used in This Document (cont'd)

These state transition tables show the state of the protocol, the events that occur in the protocol, the actions taken and the resultant state.

Incoming events are represented in the first column of the state transition table. The protocol states are indicated above the entries in column 2 to N.

The intersection of an event and a state which is invalid may be left blank. The action to be taken in this case is one of the following:

a. For an event related to a received frame Incoming Event follow the frame reject procedure for the treatment of protocol errors. This action is only available to the packet layers.

b. For a service primitive or any other event (e.g., invalid timer firing) take no action, except to optionally report invalid condition to the higher layer entity.

At each intersection of state and event which is not blank, the state tables specify an action which includes an action constituted by a list of any number of Outgoing Events (none, one or more). This action is followed by the name or numeric identifier of the resultant state when a state transition occurs.

2.0 INTEROPERABILITY

2.1 Subnetwork Interoperability

The HFDL is one of a number of airplane-to-ground subnetworks which may be used to provide communications in the ATN between the airplane-based application processes and their ground-based peer processes. It is essential that each of these subnetworks be interoperable with the other subnetworks such that the network router (Internetworking Protocol) may choose to establish a path across any available subnetwork when communication is required.

One of the prime reasons for development of HFDL is to provide an HF data link that is interoperable with other airplane/ground subnetworks. These other subnetworks might include satellite communication, Gatelink, or VHF data link. Interoperability provides the capability for an application process to send or receive data messages over any of the available subnetworks. The application process is not required to select a particular subnetwork or even know which subnetwork is being used for a particular message.

3.0 FUNCTIONAL ASPECTS

3.1 General Description

This chapter provides the background information needed to enable the functional aspects of the airborne equipment to be appreciated, and may be regarded as a preface to the material of Sections 4 through 6.

3.2 System Architecture

The architecture, message protocols and message formats defined herein for HFDL are based on the concepts of the International Organization for Standardization Open System Interconnect (OSI) model for telecommunications and data processing services. The OSI model was developed specifically to facilitate data transfer between different end systems without one having precise knowledge of the other's transmission characteristics or the characteristics of all the links which connect them.

The OSI model represents an environment through which messages can be transported as a stream of digital bits. This environment is depicted in Attachment 1-1 as an accumulation of data processing networks, either public or private, which can be accessed by any user connected to the ATN and employing a compatible application process. All networks and intermediate nodes in the environment are expected to be compatible with the OSI environment.

Examples of the application process by which a user may enter the environment are: a person operating a manual keyboard terminal, an aircraft performance sensor with digital output, the sensing of a magnetic strip on an ID card, a digitally encoded time check or any other information transaction which is in digital form.

The term "Open", in Open Systems Interconnect, is used to convey the concept of one end-system, or user, communicating with another end-system, perhaps having a different design, provided both are compatible with the system architecture of the OSI model.

The OSI model has a structure comprised of a series of seven layers. For each layer functional responsibilities are assigned. The boundaries between these layers are called interfaces. Some layers have been sub-divided, producing additional interfaces.

The value of the model is that it provides a uniform nomenclature and an orderly manner in which the responsibility for various network activities can be distributed. The manner in which these activities are executed is known as the protocol. Protocols are used to regulate the interaction across these interfaces. A protocol is defined for each layer (sublayer). HFDL protocols are defined by: (1) standards, such as those developed by ISO, and included in this Specification by reference or (2) defined in this Specification.

The service interface definition describes the way in which each layer, as a functional unit, interacts with the adjacent (upper and lower) layers within a system. The protocol determines how each layer is to communicate with its peer layers. For each layer of the source, a complementary peer layer is normally present at the other end of the communication path. Complementary peer layers may also appear at points along the communication path.

Actually, data are not exchanged directly between peer layers (see Attachment 1-2), but rather sent down through the lower layers to the physical medium, across the physical medium and then up through the layers at the receiving end. Each layer contributes a portion of the header, which is treated as data by the next lower layer. At the receiving terminal, the appropriate portion of the header, containing the protocol control information, is read and understood by the peer layer, then discarded.

Layer interface protocols are identified in a series of fields in the header inserted at each layer. These headers contain the information necessary for the appropriate receiving layer to process the message. The format and contents of the header fields are described in the associated sections of this Specification pertaining to a particular layer.

3.2.1 Architectural Guidelines

HFDL represents a significant architectural extension of the original ACARS air-ground data link. The following set of Architectural Design Guidelines were developed to assure complete compatibility while providing maximum user utility. These guidelines should be used as a basis for HFDL capable LRU design to achieve avionics compatibility with both the aircraft environment and the ground network.

a. Various levels of aircraft equipment are expected to be able to co-exist for extended periods. At any one time in the future, aircraft containing ATN/ACARS equipment of various developmental levels may occupy the same airspace. Aircraft equipment replacement should be dictated by business factors, not to avoid incompatibilities with newer system definitions.

b. All levels of avionics equipment designed to operate within the HFDL environment should be able to utilize a set of designated radio frequencies within a particular airspace.

c. Frequency management should be a cooperative effort between ground network and the aircraft. The ground service provider has primary responsibility for aircraft tracking. Ground service providers may dynamically assign operational frequencies within a particular airspace to resolve factors beyond the control of the aircraft. If needed, negotiations with the aircraft for frequency use should be initiated by the ground service provider and resolved to a mutual satisfaction. The resulting "system" should be able to freely adjust frequencies to account for volumes, area of responsibility and political jurisdiction.

d. Maximizing message throughput is an important consideration in HFDL design.

e. HFDL should be able to participate in, and contribute to the establishment and maintenance of a reliable communications path between the aircraft and the ground network. An HFDL system should exercise methods of radio station tracking so as to minimize misdirected transmissions as the aircraft transitions, from the reception area of one ground station to another. Similarly, the HFDL system should be capable of transitioning from one ground network to another. It should be able to maintain continuity for a

3.0 FUNCTIONAL ASPECTS

message, originating either on the ground or in the air, without manual intervention or prompting.

f. HFDL should be "data transparent"; i.e., totally insensitive to the textual content of messages it carries. Changes in message content and format should have no effect on the implementation or effectiveness of HFDL communications.

g. Many computer networks and systems in place today are constrained by prior generations of software and hardware. HFDL should not be affected by those constraints. HFDL implementations should be independent of data rate.

h. HFDL should be able to tolerate less than optimum operating conditions. Degradation should be gradual when operating within adverse operational scenarios, including failure modes. Neither a ground station nor an aircraft should be able to abuse a channel.

i. Installation of a data radio, using state-of-the-art features, would improve communications reliability and reduce costs.

3.2.2 Layers of the OSI Model

Each communication in the ATN environment represents a series of functions which are expected to be arranged in a logical order to be clearly understood. The OSI model uses the technique of layering to achieve a logical balance between a complicated system structure and complicated protocol. Seven layers are used in the OSI model to provide the functions needed to make the transition from the user's application process to the transmission medium; e.g., the HF radio. These seven layers, depicted in Figure 3-1, are briefly described as follows:

User's Application Process

Layer		
7. Application Layer		
6. Presentation Layer	Application	Service
5. Session Layer		
4. Transport Layer	Transport	Services
3. Network Layer		
2. Link Layer	Network	Services
1. Physical Layer		

Transmission Medium

Figure 3-1 – Layers of the OSI Model

3.2.2.1 Layer 1, The Physical Layer

The Physical Layer provides services to activate, maintain and deactivate connections for bit transmission in the Data Link Layers. The following service elements are the responsibility of the Physical Layer.

a. Activation of the transmission channel

b. Establishment of bit synchronization

c. Physical data transmission by an appropriate radio system

d. Channel status signaling

e. Fault condition notification

f. Local network definitions

g. Service quality parameters

3.2.2.2 Layer 2, The Link Layer

The Link Layer is responsible for transferring information from one network entity to another and for annunciating any errors encountered during transmission.

The Link Layer draws on the service provided by the Physical Layer. The service responsibility of the Link Layer includes the following:

a. Frame assembly and disassembly

b. Establish frame synchronization

c. Rejection of non-standard frame types

d. Detection and control of frame errors

e. RF channel selection

f. Address recognition

g. Initiate receiver muting

h. Generate the frame check sequence

The Link Layer provides the basic bit transmission service over the RF channel. Data at the Link Layer are transmitted as a bit stream in a series of frames exchanged between the aircraft transceiver and the ground-based radio elements.

3.2.2.2.1 Layer 2, Higher Layer Entities

Layer 2 has the responsibility of reliably transferring data provided by a Higher Layer Entity (HLE). For HF Data Link, the HLEs include ACARS, Network Layer, and Delayed Echo Application (DEA). ACARS and the Network Layer are elements of each HFDR. c-2

The DEA is an optional application user of the HF Data Link Layer. If the DEA is not implemented, then the HF Data Link Layer should be capable of discarding HFNPDUs received with a header of 'FF DE_h'. The DEA is described in detail in Appendix C.

3.2.2.3 Layer 3, The Network Layer

It is the responsibility of the Network Layer to ensure that data packets are properly routed between the source airborne end system and the designated recipient ground end system (or vice versa). The Network Layer expects the Link Layer to supply data from correctly received frames;

3.0 FUNCTIONAL ASPECTS

3.2.2.3 Layer 3, The Network Layer (cont'd)

however, it does not assume reliable transmission. Specific responsibilities of the Network Layer include the following:

a. Data packet assembly and disassembly

b. Routing

c. Error resolution

d. Equipment error resolution

e. Priority handling

At the Network Layer, messages (data) are broken into packets of a size appropriate for the transmission media. The message is then transmitted as a series of packets. A complete message may consist of one or more packets.

The Network Layer has been divided into three Sublayers. These are the Subnetwork Sublayer, the Subnetwork Convergence Function Sublayer and the Internetwork Sublayer. See Attachment 1-2, HFDL Reference Model.

3.2.2.4 Layer 4, Transport Layer

The Transport Layer controls the transportation of data from a source end-system to a destination end-system. It provides "network independent" data delivery between these processing end-systems. It is the highest order of function involved in moving data between systems. It relieves higher layers from any concern with the pure transportation of information between them. Service responsibilities of the Transport Layer include:

a. Multiplexing

b. Sequence control

c. Error detection and recovery

d. Segmentation

e. Flow control

3.2.2.5 Layer 5, Session Layer

This layer provides the means for a pair of end-system functions to be properly initialized, sequenced, terminated and if necessary, restarted, taking care of the relationship or "session" between the distributed processes. This layer allows end-system functions competing for transport access to regulate their dialogue and conduct an orderly exchange of messages. Service responsibilities of the Session Layer include:

a. Establish the type of interaction, alternate or simultaneous

b. Sequencing and acknowledgement of information

c. Establishment of reset and restart points

3.2.2.6 Layer 6, Presentation Layer

This layer formats and structures data for the benefit of an application. It provides for syntax transformation and selection (i.e., code and character set conversion, modification of layout of data) between dissimilar applications. Responsibilities of the Presentation Layer include:

a. Syntax selection

b. Data translation and formatting

3.2.2.7 Layer 7, Application Layer

This layer provides a means for an application process to access the OSI environment. In addition to information transfer, and together with OSI management, this layer provides:

a. Identification and authentication of communication partner

b. Determination of quality of service, cost and resources

c. Agreement on error recovery and data integrity procedures

3.2.3 HFDL Functional Organization

The three upper layers (application services) provide direct support of the application process while the lower three layers (network services) support the transmission of information between the end systems. The Transport Layer is the essential link between these services providing end-to-end integrity of the communication.

HFDL is constituted of the protocols of layers 1, 2, and the first sublayer of layer 3. See Attachment 1-2 for a diagram showing the interaction of these layers.

The OSI model is organized to permit a user's application process to communicate with its counterpart in another end-system. The actual communication path, however, descends through the layers from the sender's process and ascends through the layers to the recipient's process. As the data block descends through the layers a header containing protocol control information is attached to the data. The header is a set of instructions intended to be "read" by the peer layer in the recipient's process. No layer is aware of the header used by the other layers. As a received frame ascends through the layers, the headers are read by the peer layer and then removed as the message segment is passed on.

3.3 Radio Frequency Management

HFDL operates on one of multiple authorized frequencies at a time as described in Section 5.2.5.1. It should be able to tune to any discrete frequency within the assigned frequency range and the limits of ARINC Characteristic 753. Tuning is automatically performed by HFDL for Data mode operation.

3.4 Message Composition

The bit-oriented protocol used in HFDL permits user definition of all bits in the data field. The only segments of the message for which the bit pattern is preassigned are those used for identification, control (link maintenance) and message quality.

3.0 FUNCTIONAL ASPECTS

3.5 Priorities

The Aeronautical HF Data Link Service (HFDLS) is recognized as comprising four categories of communications:

a. Air Traffic Services (ATS)

b. Aeronautical Operational Control (AOC)

c. Aeronautical Administrative Communications (AAC)

d. Aeronautical Passenger (or Public) Communications (APC)

The first two categories above, taken together, are classified as services associated with the safety and regularity of flight. The last two categories above are considered to be non-safety services. This document addresses Safety and Regularity of Flight services, and it takes into consideration issues that derive from the sharing of system resources among safety and non-safety services. These issues include system capacity, interference, priority and preemption.

In the HFDL Subnetwork, a detailed priority structure is defined for these categories, and for the specific kinds of communications that can exist within each category. It is assumed that the other elements of the end-to-end system support this priority structure and convey the priority of a communication to the HFDL Subnetwork, as necessary to provide for the appropriate priority, precedence and preemption actions.

COMMENTARY

> The HF Data Link Subcommittee recognized that the primary use of HF Data Link should be for ATC and AOC purposes, utilizing spectrum allocated exclusively for these purposes.

3.5.1 Safety

Aeronautical safety communications, by the International Civil Aviation Organization (ICAO) and International Telecommunication Union (ITU) regulations, are to be assured of having the highest priorities, and are accorded special measures for protection from interference. A system supporting safety communications has appropriate priority and preemption control mechanisms embodied in all elements comprising the system.

3.5.2 Priority, Precedence and Preemption

The HFDL system, and other subsystems, are expected to have means for effecting the priority structure necessary for safety services. This includes the mechanisms for controlling the precedence of both safety and non-safety messages, for the preemption of system resources as needed to support safety services and to provide for the added measure of protection to be accorded the safety services.

A Subnetwork connection (SNC) of the lowest priority should be cleared as necessary to accept a request for higher priority service.

COMMENTARY

> The priority of a packet or enveloped message is determined by the sender.

Each of the packet-mode data subnetworks should identify the priority of each message when it is initially received, and should ensure that it is transmitted prior to messages of lower priority.

For example, if a lower priority message is occupying limited HFDL resources when a higher priority message is received, then transmission of the lower priority message should be interrupted as necessary to permit transmission of the higher priority message, i.e., "ruthless preemption".

3.5.3 Intrasystem Coordination

The following intrasystem coordination functions should be provided within an HFDL subsystem:

a. Access control with means to deny access to stations that cause failure of the HFDL subsystem to meet interoperability standards in any way

b. Monitoring and verification of correct operation of system components (e.g., equipment, terminals, aircraft stations) and provision of mechanisms for disabling aberrant system components including aircraft stations, which could derogate the system

c. Management of information supplied to aircraft stations to assist in their acquisition of the HFDL subsystem resources (e.g., ground station locations and system channel frequencies)

d. Management of frequency assignments

e. Management of service requests of aircraft stations

f. Control of mechanisms governing assignment and use of system resources supporting priority and preemption

g. Log-on/log-off of aircraft stations

h. Handoff of mobile terminals when crossing boundaries of intrasystem coverage

i. Provisioning of backup, alternative resources

j. An infrastructure and procedures for control of design and configuration of system components including aircraft stations

k. An infrastructure and procedures for control of qualification, acceptance, registration, andsubsequent maintenance and verification of system components including aircraft stations

3.5.4 ADS Support

The users of the HF Data Link system for communicating Automatic Dependent Surveillance (ADS) reports should be aware that the system operates most effectively if the ADS reporting rate is 32 seconds or longer. The HFDL

3.0 FUNCTIONAL ASPECTS

3.5.4 ADS Support (cont'd)

system has been designed to fully support the ADS Emergency Reporting Rate of 64 seconds and it is recommended that this be the highest reporting rate used on the HFDL system.

4.0 AIR/GROUND INTERFACES AND PROTOCOLS FOR LAYER 1 - THE PHYSICAL LAYER

4.1 Introduction

The airborne terminal of the HFDL system accesses the HF air-ground network with a HF radio transceiver operating in a simplex mode. ATN systems often refer to HFDL as a subnetwork. HFDL is not dependent on any particular modulation technique for data transfer.

4.2 Physical Layer Service Definition

The lowest level layer in the OSI 7-layer protocol model is Layer 1, known as the Physical Layer. The Physical Layer is concerned only with the unstructured bit stream over the physical medium (HF radio). It is the most basic protocol level in the OSI model dealing only with the physical interface between devices and the rules by which bits are passed from one to another.

COMMENTARY

> Certain application processes that are expected to use HFDL may require continuous data link capacity. Therefore, it is recommended that the radio be dedicated for data only operation, although voice capability is supported for non-routine operation.

This section specifies the services offered by the HFDL Physical Layer.

Within the context of this document a service user is an entity at a layer which makes use of the services provided by the layer below. The Physical Layer (Layer 1) service user is the Data Link Layer (Layer 2); the Physical Layer service user makes use of the Physical Layer services. Similarly the Physical Layer service provider provides service to a service user at the Data Link Layer. These services are provided at Service Access Points (SAP) through the use of service primitives. See Section 4.2.4 for a definition of physical layer service primitives utilized within HFDL.

Data Link Layer user data is passed to the Physical Layer from the Data Link Layer on primitives. Data link user data received by the Physical Layer entity from a remote Physical Layer entity via the HF media is passed up to the Data Link Layer on a primitive. Any indications used for diagnostic or error conditions are passed between these layers on service primitives.

The functions provided by the Physical Layer include the following:

a. Transceiver control

b. Reception of data on the HF radio

c. Transmission of data on the HF radio

d. Operational performance notification

4.2.1 Transceiver Control

The Physical Layer controls the radio equipment which in turn provides for the transmission and reception of the data. Control of this equipment involves transmit/receive mode switching and frequency tuning. Frequency selection is performed upon requests passed on from the Data Link Layer. Transmitter keying is performed on demand from the Data Link Layer to transmit a frame. HFDL does not support Voice/Data mode switching as defined in ACARS.

4.2.2 Data Reception

Signals received by the HF transceiver are conveyed to the demodulator to initiate the data processing cycle. The Physical Layer decodes these signals so they may be accurately read by the next higher layer.

4.2.2.1 Data Packet Detection

The HF Data Link receiving system provides the means to detect, synchronize, demodulate and decode packets modulated according to the waveform defined in Section 4.2.3 subject to the following distortion:

a. Audio carrier shifted by ± 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

d. Additive Gaussian and broadband impulsive noise with varying amplitude and random arrival times

4.2.2.2 Equalization

The HF Data Link receiving system provides the means to equalize the distortion introduced by HF channel multipath spreads and Doppler spreads defined in Section 4.2.2.1 such that the performance goals defined in Section 4.2.2.4 are met.

4.2.2.3 Forward Error Correction

The HF Data Link demodulator system should implement an error correcting decoding algorithm capable of decoding the rate 1/2 and 1/4 convolutional codes defined in Section | c-1
4.2.3.2.2.1 such that the performance goals defined in Section 4.2.2.4 are met.

4.2.2.4 Average Error Rate Performance Goals

The HF Data Link physical layer transmitting/receiving system should meet the packet error rate performance goals defined in Attachment 2-5 for the stated channel multipath and Doppler spread conditions.

4.2.2.5 Signal Quality Analysis

The HF Data Link receiving system provides a quantitative measure of the quality of each received packet. This measure is reported in the Ph-SIGNAL_QUALITY.indication service primitive.

4.2.2.6 TDMA Receive Slot Synchronization

The HF Data Link air/ground protocols employ a slotted Time Division Multiple Access (TDMA) protocol (See Section 5.2.1).

The HF Data Link ground stations maintain slot synchronization. Each aircraft should synchronize its slot timing clock to that of the ground station from an indication | c-2
of the reception time of each uplink squitter transmitted by

4.0 AIR/GROUND INTERFACES AND PROTOCOLS FOR LAYER 1 - THE PHYSICAL LAYER

4.2.2.6 TDMA Receive Slot Synchronization (cont'd)

the ground station. Therefore, whenever the HF Data Link demodulator system detects reception of an HF Data Link Transmission with a valid preamble encoded as defined in Section 4.2.3.2 it should provide an indication at the time at which the first symbol in the data segment (see Section 4.2.3.2 and Attachment 2-2 for definition of start of the data segment) is received. This indication is referred to as the Ph-Rx_TIME.indication service primitive. The beginning of the slot may be determined from the Ph-Rx_TIME.indication and knowledge of the duration of the prekey and preamble segments.

4.2.3 HF Data Link Signal-In-Space Definition

When data is to be transmitted, the modulator transforms the information to a form satisfactory for transmission on the HF channel. The Physical Layer encodes the data so that the information can be successfully transferred to a receiving demodulator.

4.2.3.1 Analog Waveform Definition

HF Data Link employs M-ary Phase Shift Keying (M-PSK) to modulate a carrier centered at RF + 1440 Hz, where RF is the HF frequency to be used. The carrier is to be modulated at an 1800 symbols per second ± 10 ppm (i.e., 0.018 symbols per second). However, the rate at which user data bits are transmitted (i.e. the information data rate) is to be selectable from 300, 600, 1200, and 1800 bps. c-3

COMMENTARY

> The term M-ary refers to the number of possible phase values that a PSK symbol may take on. This number may change from one data transmission to another depending on the data rate selected via a Ph-DATA_RATE.request service primitive.

The M-PSK carrier may be expressed mathematically as:

c-2 $s(t) = A\ \Sigma(p(t-kT) \cos [2\pi\ ft + \Phi(k)]),\ k = 0,1,...,N-1$

where:

N	=	number of PSK symbols in transmitted Physical Layer Protocol Data Unit (PPDU)
s(t)	=	analog waveform or signal at time t
A	=	peak amplitude (nominal 250 millivolts into 600 ohms)
f	=	carrier or center frequency (RF + 1440 Hz)
1/T	=	PSK symbol or signaling rate (1800 Hz)
Φ(k)	=	phase of kth PSK symbol
p(t-kT)	=	pulse shape of kth PSK symbol at time t

The phase of each PSK symbol contains the information to be sent. The number of PSK symbols sent, N, defines the length (duration = NT seconds) of the PPDU. These are defined in Section 4.2.3.2.

The pulse shape, p(t), determines the spectral confinement of the transmitted signal. The Fourier transform of the pulse shape, P(f), is given by:

if $0 < |f| < (1 - b)/2T$
then $P(f) = 1$

if $0 < |f| < (1 - b)/2T$
then $P(f) = \cos \{\pi (2|f|T-1 + b)/4b\}$ c-1

if $|f| > (1 + b)/2T$
then $P(f) = 0$

where the spectral roll-off parameter, b = 0.31 has been chosen so that the -20 dB points of the RF signal are at RF + 290 Hz and RF + 2590 Hz and the peak-to-average power ratio of the waveform is less than 5 dB. c-2

The pulse shape, p(t), corresponding to the square root raised cosine spectrum specified above is given by: c-2

$$p(t)= \frac{(1-b)/T}{1-(4bt/T)^2} \left\{ \frac{\sin [\pi(1-b)t/T]}{\pi(1-b)t/T} + \frac{4b}{\pi(1-b)} \cos[\pi(1+b)t/T] \right\}$$

4.2.3.2 Data Packet Encoding

The encoding of the data packet that modulates the 1440 Hz carrier consists of three distinct segments defined as follows:

Prekey	249 ms	448 2-PSK symbols
Preamble	295 ms	531 2-PSK symbols
Data	1.8 or 4.2 sec	3240 or 7560 M-PSK Symbols

The data segment consists of frames of 45 M-PSK symbols, 30 of which are information carrying (unknown data) symbols and 15 are known 2-PSK probe symbols multiplexed with the data to assist with the adaptive equalization processing at the receiving side. The known 2-PSK probe symbols and the data/probe framing structure are defined in Attachment 2-2.

The M-PSK modulation employed to encode the unknown data symbols is data rate dependent. Reference Table 4-1 below.

Table 4-1 Modulation Employed to Encode Unknown Data Symbols

Data Rate	Data PSK Modulation	# Coded chips per PSK symbol	PSK symbol Phase Mapping
1800	8-PSK	3	Gray code
1200	4-PSK	2	Gray code
600	2-PSK	1	
300	2-PSK	1	

c-2

The Gray coding for 4-PSK and 8-PSK is defined in 4.2.3.2.2.3.

4.0 AIR/GROUND INTERFACES AND PROTOCOLS FOR LAYER 1 - THE PHYSICAL LAYER

4.2.3.2.1 Prekey and Preamble Definition

The main purpose of the prekey is to allow the HF transmitter to reach full power and the HF receiver Automatic Gain Control (AGC) to settle and to allow for interference from preceding slot users to fade out. Some of the data sent during this time may be lost. During the prekey the modulator should transmit a 1440 Hz tone above the SSB carrier frequency with a constant phase modulation of 180 degrees. The duration of the prekey should be 249 ms.

The prekey should be immediately followed by a synchronization preamble consisting of a known data pattern transmitted to allow the demodulator to: i) detect the beginning of a burst of data; ii) measure and correct the frequency offset between transmitter and receiver due to airplane Doppler and transmitter/receiver frequency offset; iii) determine the data rate and interleaver settings to use during data demodulation; iv) achieve PSK symbol synchronization; and v) train the equalizer. The preamble sequence is defined in Attachment 2-2.

4.2.3.2.2 Data Symbol Formation

The steps involved in the encoding of the information carrying data symbols (as well as subsequent multiplexing with the known training symbols and preamble) are shown in Attachment 2-3. Prior to encoding, the data segment of the transmitted burst consists of user data bits followed by trailer (encoder and interleaver flush) bits. Reference Table 4-2 below.

Table 4-2
Data Segment of Transmitted Burst Prior to Encoding

Data Rate	User + Flush Bits	
	1.8 sec Interleaver	4.2 sec Interleaver
@ 1800 bps	3240 bits	7560 bits
@ 1200 bps	2160 bits	5040 bits
@ 600 bps	1080 bits	2520 bits
@ 300 bps	540 bits	1260 bits

COMMENTARY

The physical layer user bits are the Media Access Control Protocol Data Unit (MPDU) and Squitter Protocol Data Unit (SPDU) packets which include encoder flush bits as defined in Sections 5.2.1.7 and 5.2.2. The number of interleaver flush bits depends on the number of user data bits to be sent. It is chosen to make the actual number of user data plus flush bits equal to the product of the data rate times 1.8 or 4.2 seconds, whichever is specified by the Ph-INTERLEAVER.request service primitive.

The user data and flush bits should then be encoded, interleaved, mapped into PSK symbols, scrambled and multiplexed with equalizer training symbols, in that order, as defined below.

4.2.3.2.2.1 Forward Error Correction Encoding

Tables 4-3 and 4-4 below define the Forward Error Correction (FEC) encoding of user bits for each data rate.

Table 4-3 FEC of User Bits For 1.8 Second Interleaver

Data Rate	Maximum # User Bits	Maximum # Coded Chips	Code Rate	Implementation of code rate
1800	3240	6480	1/2	1/2
1200	2160	4320	1/2	1/2
600	1080	2160	1/2	1/2
300	540	2160	1/4	1/2, 2 repeats

Table 4-4 FEC of User Bits For 4.2 Second Interleaver

Data Rate	Maximum # User Bits	Maximum # Coded Chips	Code Rate	Implementation of code rate
1800	7560	15120	1/2	1/2
1200	5040	10080	1/2	1/2
600	2520	5040	1/2	1/2
300	1260	5040	1/4	1/2, 2 repeats

The rate 1/2 encoder should be a 64-state (constraint length 7) convolutional encoder with octal generator coefficients G1 = 133 and G2 = 171. The rate 1/2 encoder is shown in Attachment 2-4.

The rate 1/4 encoding should be accomplished using the rate 1/2 encoder and repeating each output chip 2 times, so that for every input bit to the encoder, 4 output chips are transmitted. Table 4-5 below defines the implementation of the rate 1/4 encoder where c(n) are the encoder chip outputs per Attachment 2-4. c-1

Table 4-5a and 4-5b
Rate 1/2 and 1/4 Encoder Chip Outputs c-1

Code Rate	Chip Index					
	1	2	3	4	5	6
1/2	c(1)	c(2)	c(3)	c(4)	c(5)	c(6)
1/4	c(1)	c(1)	c(2)	c(2)	c(3)	c(3)

c-1

Code Rate	Chip Index				
	7	8	9	10	etc.
1/2	c(7)	c(8)	c(9)	c(10)	etc.
1/4	c(4)	c(4)	c(5)	c(5)	etc.

c-1

4.2.3.2.2.2 Interleaving

Data interleaving should be accomplished by writing the coded chips into the columns of a 40 row x N column block

4.0 AIR/GROUND INTERFACES AND PROTOCOLS FOR LAYER 1 - THE PHYSICAL LAYER

4.2.3.2.2.2 Interleaving (cont'd)

buffer one column at a time, starting at column zero as follows: the first chip is loaded into row 0, the next chip is loaded into row 9, the third chip is loaded into row 18, etc. Thus, the row location for the chips increases by 9 modulo 40. Thus, this process continues until all 40 rows are loaded. The loading process then advances to column 1 and the process is repeated until the matrix block is filled. The number of columns in the block interleaver for each data rate and interleaver size should be as shown in Table 4-6 below:

Table 4-6 Number of Interleaver Columns N

Data Rate	# INTERLEAVER Columns N	
	1.8 sec INTLV	4.2 sec INTLV
1800	162	378
1200	108	252
600	54	126
300	54	126

Once the interleaver buffer is full, the chips are read out starting with the first chip being taken from row 0, column 0. The location of each successive fetched chip is determined by incrementing the row by one and decrementing the column number by 17 modulo N (the number of columns in the interleaver matrix), if the 1.8 second interleaver is being used, or decrementing the column number by 23 modulo N, if the 4.2 second interleaver is being used. Thus, if the 1.8 second interleaver with N = 108 is being used, the second chip comes from row 1, column 91, and the third chip from row 2, column 74. This process should continue until the row number reaches 39. At this point the row number should be reset to 0, the column number increased by 1 and then decreased by 17 modulo N or 23 modulo N. The process is then continued until the entire matrix data block is unloaded.

4.2.3.2.2.3 Coded Chip to M-PSK Symbol Mapping

Each PSK symbol has a phase associated with it which varies depending on whether 2-PSK, or 4-PSK, or 8-PSK modulation is used. The phase is selected as shown in Table 4-7 below:

Table 4-7 Coded Chip to M-PSK Symbol Mapping

2-PSK		4-PSK		8-PSK	
phase	coded chips	phase	coded chips	phase	coded chips
0^o	0	0^o	00	0^o	000
180^o	1	90^o	01	45^o	001
		180^o	11	90^o	011
		270^o	10	135^o	010
				180^o	110
				225^o	111
				270^o	101
				315^o	100

4.2.3.2.2.4 M-PSK Symbol Scrambling

The purpose of PSK symbol scrambling is to reduce the likelihood of short term direct current buildup in the transmitted waveform. Note that only the information carrying symbols are scrambled.

The phase of each PSK symbol should be scrambled by adding 0 or 180 degrees to it depending on the state of a periodically repeating binary scrambling pattern 120 symbols long. A binary "1" in the scrambling pattern should cause a 180 degree phase reversal of the PSK symbol. The 120 bit scrambling pattern in hex notation is as follows:

131BC4250F8C15EFCD6AEC996E2368 hex

where the most significant bit of the left most hex number is the first digit of the scrambling pattern.

COMMENTARY

This binary scrambling pattern can be derived by taking the first 120 bits of a 15 stage shift register with coefficient generator polynomial $1 + X + X^{15}$. The initial state of the shift register should be 6959 Hex where the least significant bit (LSB) is coincident with element X^{15}.

4.2.3.3 TDMA Transmit Slot Time Synchronization

The HF Data Link air/ground protocols employ a slotted Time Division Multiple Access (TDMA) protocol (see Section 5.2.1). The HF Data Link ground stations maintain slot synchronization. Each aircraft should synchronize its slot timing clock to that of the ground station from an indication of the reception time of each uplink transmitted by the ground station as defined in Section 4.2.2.6. To ensure that slot synchronization is maintained throughout the network, each HF Data Link modulator should begin transmitting the prekey at the beginning of a time slot which should coincide with the time specified by the Ph-Tx_TIME.request service primitive to within an accuracy of ±10 milliseconds.

4.2.4 Service Primitives

Service primitives are short status and control information that are available to the receiving entity to properly process incoming information. All primitive parameters are mandatory (M) for the correct operation of the protocol state machine. No specific primitive implementation is implied.

Primitives passed from the Physical Service User (Ph_User) to the Physical Service Provider (Ph_Provider) are Request primitives. Primitives passed from the Ph_Provider to the Ph_User are Indication primitives. See Attachment 2-1.

The service primitives provided by the physical layer to the link layer and their parameters are as follows:

a. Ph-DATA.request (User Data). This primitive consists of the data (MAC Packet Data Unit) to be transmitted by the HF modem.

4.0 AIR/GROUND INTERFACES AND PROTOCOLS FOR LAYER 1 - THE PHYSICAL LAYER

b. Ph-DATA.indication (User Data). This primitive consists of the received data (MAC Packet Data Unit) passed to the link layer.

c. Ph-FREQUENCY.request (frequency). This primitive consists of the carrier frequency in kHz to which the HF transmitter/receiver is to be tuned.

d. Ph-Tx_DATA_RATE.request. This primitive selects the data rate at which the next data packet is to be sent.

e. Ph-Tx_INTERLEAVER.request. This primitive selects the interleaver duration to be used with the next packet transmission.

f. Ph-Tx_TIME.request. This primitive selects the precise time at which the prekey part of the next packet transmission is to begin.

g. Ph-ANTENNA_TUNE.request. This primitive is the tuning command sent to the antenna coupler before the first transmission at a new frequency.

h. Ph-Rx_DATA_RATE.indication. This primitive indicates the data rate at which the data packet was received.

i. Ph-Rx_INTERLEAVER.indication. This primitive indicates the interleaver duration of the received packet.

j. Ph-Rx_TIME.indication. This primitive provides the precise time at which the first PSK symbol in the data segment of the received packet was received.

k. Ph-SIGNAL_QUALITY.indication. This primitive provides the effective average signal-to-noise ratio measured during the reception of the packet.

l. Ph-TUNE_IN_PROGRESS.indication. This primitive provides an indication during antenna coupler tuning and it is extinguished when it has completed successfully or not.

m. Ph-TUNE_FAIL.indication. This primitive indicates that the antenna coupler tuning has failed.

c-1

n Ph-HFDL_ENABLE-DISABLE.request. This request indicates to the HFDL whether or not the HFDL is enabled for data operations.

o. Ph-BITE.requests. This primitive initiates the reporting of built-in-test data.

p. Ph-BITE.indication. This primitive reports built-in-test data.

4.2.4.1 Physical Layer Data Request

Ph_DATA.request is the service primitive generated by the Ph_User and passed to the Ph_Provider to request user data transmission. The receipt of this primitive by the local Ph_Provider causes the Ph_Provider to transmit user data. This primitive is usually in the form of clock and data.

Note that the use of the Ph-DATA.request and Ph-Tx_TIME.request service primitives are properly synchronized by the Ph_User taking into account the variable processing delay (message length dependent) introduced by the interleaving function defined in Section 4.2.3.2.2.2.

Note also that the number of user data bits sent by the Ph_User to the Ph_Provider should not exceed the maximum number of bits allowed by the data rate and interleaver duration (see table in Section 4.2.3.2.2) specified by the Ph-User.

Parameters: User data (M)

4.2.4.2 Physical Layer Data Indication

Ph_DATA.indication is the service primitive generated by the Ph_Provider and passed to the Ph_User to transfer received user data. This primitive is usually in the form of clock and data.

Parameters: User data (M)

4.2.4.3 Physical Layer Frequency Request

Ph_FREQUENCY.request is the service primitive generated by the Ph_User and passed to the Ph_Provider to select the HF frequency. The receipt of this primitive by the Ph_Provider causes the local Ph_Provider to select the HF frequency requested by the Ph_User.

Parameters: Desired frequency (M)

4.2.4.4 Physical Layer Signal Quality Indication

Ph-SIGNAL_QUALITY.indication is the service primitive generated by the Ph_Provider and passed to the Ph_User to indicate the current signal quality.

Note that this primitive is usually generated once per received transmission and applies to the entire transmission.

Parameters: Signal quality parameter (M)

4.2.4.5 Physical Layer Transmit Data Rate Request

Ph-Tx_DATA_RATE.request is the service primitive generated by the Ph_User and passed to the Ph_Provider to select the transmit data rate. The receipt of this primitive by the Ph_Provider causes the local Ph_Provider to set the physical link transmit data rate, convolutional encoder code rate and modulation for the requested speed. The table in Section 4.2.3.2 defines the available data rates and modulation schemes. The tables in Section 4.2.3.2.2.1 define the corresponding convolution encoder code rate.

Parameters: Data rate parameter (M)

4.2.4.6 Physical Layer Receive Data Rate Indication

Ph-Rx_DATA_RATE.indication is the service primitive generated by the Ph_Provider and passed to the Ph_User to indicate the data rate at which the most recent air/ground transmission was received.

Note that this primitive is usually generated once per received transmission and applies to the entire transmission.

Parameters: Data rate parameter (M)

4.0 AIR/GROUND INTERFACES AND PROTOCOLS FOR LAYER 1 - THE PHYSICAL LAYER

4.2.4.7 Physical Layer Transmit Interleaver Setting Request

Ph-Tx_INTERLEAVER.request is the service primitive generated by the Ph_User and passed to the Ph_Provider to select the interleaver setting. The receipt of this primitive by the Ph_Provider causes the local Ph_Provider to set the interleaver duration to the requested setting.

Parameters: Interleaver duration parameter (M)

4.2.4.8 Physical Layer Receive Interleaver Setting Indication

c-1 Ph-Rx_INTERLEAVER.indication is the service primitive generated by the Ph_Provider and passed to the Ph_User to indicate the interleaver setting at which the most recent air/ground transmission was received.

Note that this primitive is usually generated once per received transmission and applies to the entire transmission.

Parameters: Interleaver duration parameter (M)

4.2.4.9 Physical Layer Transmit Time Request

Ph-Tx_TIME.request is the service primitive generated by the Ph_User and passed to the Ph_Provider to initiate a transmission. The receipt of this primitive by the Ph_Provider causes the local Ph_Provider to begin the transmission of the prekey followed by the preamble.

Note that the use of the Ph-DATA.request and Ph-Tx_TIME.request service primitives are properly synchronized by the Ph_User taking into account the variable processing delay (message length dependent) introduced by the interleaving function defined in Section 4.2.3.2.2.2.

Parameters: Time parameter (O)

4.2.4.10 Physical Layer Receive Time Indication

Ph-Rx_TIME.indication is the service primitive generated by the Ph_Provider and passed to the Ph_User to indicate the beginning of a data packet reception as defined in Section 4.2.2.6.

Note that this primitive is usually generated once per received transmission and applies to the entire transmission.

Parameters: Time parameter (O)

4.2.4.11 Physical Layer Antenna Tuning Request

Ph-ANTENNA_TUNE.request is the service primitive generated by the Ph_User and passed to the Ph_Provider to initiate the tuning of the antenna. The receipt of this primitive by the Ph_Provider causes the local Ph_Provider to begin the process of tuning the antenna.

Note that this service primitive is generated prior to initiating the first transmission after a frequency change.

Parameters: None

4.2.4.12 Physical Layer Tuning in Progress Indication

Ph-TUNE_IN_PROGRESS.indication is the service primitive generated by the Ph_Provider and passed to the Ph_User to indicate that antenna tuning is in progress.

Note that this primitive is usually generated in response to Ph-ANTENNA_TUNE.request.

Parameters: None

4.2.4.13 Physical Layer Tuning Failure Indication

Ph-TUNE_FAIL.indication is the service primitive generated by the Ph_Provider and passed to the Ph_User to indicate that antenna tuning has failed.

Note that this primitive is usually generated when antenna tuning initiated in response to Ph-ANTENNA_TUNE.request has failed.

Parameters: None

4.2.4.14 Physical Layer HFDL Enable-Disable Request c-1

Ph-HFDL_ENABLE-DISABLE.request is the service primitive generated by the Ph_User and passed to the Ph_Provider to select the HF Data Link mode of operation. The receipt of this primitive causes the Ph_Provider to switch from the voice mode of operation to the HF Data Link mode, or vice-versa. c-1

Parameters: Mode(M) c-1

4.2.4.15 Physical Layer BITE Request

Ph-BITE.request is the service primitive generated by the Ph_User and passed to the Ph_Provider to initiate and/or request the reporting of Built-In-Test data. The receipt of this primitive causes the Ph_Provider to check and report its status data.

Parameters: None

4.2.4.16 Physical Layer BITE Indication

Ph-BITE.indication is the service primitive generated by the Ph_Provider and passed to the Ph_User to report the results of Built-In-Test. This primitive may be initiated in response to the Ph-BITE.request.

Parameters: BITE data (O)

5.0 AIR/GROUND INTERFACES AND PROTOCOLS OF LAYER 2 - LINK LAYER

5.1 Introduction

The HF Data Link (HFDL) system operates on groups of HF RF frequencies assigned to ground stations around the world. The system operates in a simplex mode, either transmitting or receiving, but not both at the same time. The protocols are based on a byte and code independent basis to communicate bit or character protocols without discriminating based on user data contents. The protocols fully support the Aeronautical Telecommunications Network.

This section defines the air/ground Link Layer protocols and the actions to be taken by the HFDL to transfer the user data and signaling necessary for reliable communications. The user data is defined here to mean Air Traffic Services (ATS) and Airline Operational Control messages. While the HFDL system can support other forms of messages, external factors may preclude the communications of other than ATS or AOC messages.

5.2 Link Layer Service Definition

The functions of the Data Link layer are:

a. Channel access protocol (assignment of time slots by ground station, selection of time slots by aircraft, and transmission of Medium access Protocol Data Units in assigned/selected time slots)

b. Segmentation of user packets or HF Network Protocol Data Units (HFNPDUs) into Link Protocol Data Units (LPDUs) and reassembly of LPDUs into HFNPDUs

c. LPDU prioritization and preemption, and encapsulation of one or more LPDUs in MPDUs

d. LPDU error detection, retransmission and flow control using unacknowledged (direct link service) and acknowledged (reliable link service) modes of operation

e. Link Management (selection of frequency/ground station and log-on procedures followed by aircraft, active frequency scheduling and log-on process management by the ground station)

Attachment 2-1 illustrates a sublayer partitioning of these functions and their interfaces to the Physical and HF Subnetwork layers defined in Sections 4 and 6, respectively, of this document.

COMMENTARY

> An LPDU is the smallest packet unit employed by the Data Link layer and it encapsulates a complete user packet (HFNPDU) or a segment of an HFNPDU. An MPDU may encapsulate one or more LPDUs and it designates the group of LPDUs transmitted in a single burst (single or double time slot).

5.2.1 Channel Access Protocol

The channel access protocol to be used in the HF Data Link system is a combination of Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA). The TDMA slots are assigned on a dynamic basis using a combination of reservation, polling and random access assignments.

This protocol works as follows. A number of frequencies (channels) are available for HF Data Link users. Each of the active frequencies is divided into frames with 13 slots as shown in Attachment 2-6. The frame duration is 32 seconds and the slot duration is 2.461538 seconds.

The first slot of each frame is reserved for use by the ground station to broadcast link management data in squitter packets. The remaining slots may be designated either as uplink slots, downlink slots reserved for specific aircraft, or as downlink random access slots for use by all aircraft on a contention basis. The assignment of slots to uplinks and downlinks for the upcoming frame is broadcast in the squitter. Each squitter also contains data which identify the active frequencies at the ground station and the IDs and active frequencies of up to two neighboring HF ground stations providing coverage in the same general area. The squitters also contain acknowledgments to all downlinks received in the previous frame and channel utilization data. The squitter packet format is defined in Attachments 2-8A and 2-8B, and in Section 5.2.1.7.

5.2.1.1 Data Rate Negotiations

Both the aircraft and the ground station make signal to noise ratio estimates of all transmissions received at the physical layer. These estimates are passed to the Data Link layer in a Ph-SIGNAL_QUALITY.ind primitive. Before logging onto a ground station an aircraft receives one or more squitters from the intended Log-On ground station on the intended Log-On frequency.

When the aircraft logs on to a frequency, the aircraft reports the maximum uplink transmit rate to the ground station based on the uplink signal-to-noise ratio measured.

The subsequent Log-On ACK sent by the ground station contains the maximum downlink transmit rate based on the ground stations received Ph-SIGNAL_QUALITY.indication.

COMMENTARY

> Since the signal-in-space defined in Section 4 allows the receiving side to determine the transmission rate of each individual burst, there is no need for the ground station and the aircraft to negotiate on a transmission rate before exchanging data. Instead, the receiving side informs the transmit side the quality of the received signal or in this case the suggested maximum data rate.

After logon, both the aircraft and the ground station continue measuring the received signal-to-noise ratio of each reception and use it to update the maximum transmission rate. The aircraft reports the maximum uplink transmission rate in the header of each downlink transmission. The ground station reports the maximum downlink transmission rate in the header of each uplink transmission addressed to the aircraft.

5.0 AIR/GROUND SERVICES AND PROTOCOLS OF LAYER 2 - LINK LAYER

5.2.1.2 Assignment of Slots by the Ground Station

The ground station associated with any active HF Data Link frequency broadcasts the slot assignments for each frame in the squitter transmitted in the first slot (slot 0) of the frame. A 12 byte Slot Assignment Field in the squitter contains the assignments for slots 3 to 12 in the current frame and for slots 1 and 2 of the following frame (see Section 5.2.1.7). Slots are designated for uplinks, downlinks from specific aircraft (reserved downlink slots), or downlinks from any aircraft (random access downlink slots) based on the number of uplinks queued, and downlink slot assignment requests as follows.

The ground station maintains a table of aircraft ID versus outstanding downlink slot reservation requests and the priority of the slot request - high, medium, or low (see Section 5.2.2.c2). When preparing the slot assignments for an upcoming frame, the ground station determines the number of slots needed to transmit high, medium, and low priority uplink LPDUs (see Section 5.2.3) queued for transmission, and the number of high, medium, and low priority downlink slot reservation requests. Slots are then assigned in the following order:

a. Slots are first assigned to aircraft that have requested reservations for high priority traffic, and then slots are assigned to queued high priority uplink LPDUs.

b. Slots are next assigned to aircraft that have requested reservations for medium priority traffic, and then slots are assigned to queued medium priority uplink LPDUs.

c. Slots are next assigned to aircraft that have requested reservations for low priority traffic, and then slots are assigned to queued low priority uplink LPDUs.

d. Three fourths of the remaining slots (rounded to the next smallest integer) are assigned for random access downlinks from any aircraft and one fourth are assigned to poll aircraft starting with aircraft that have not been heard from the longest.

c-3 When assigning multiple slots to an aircraft, the ground station should assign successive slots in a single squitter. When slots 2 and 3 are assigned to the same aircraft, they should be treated as two single slots. If two consecutive slots are reserved for an aircraft, the aircraft should transmit one MPDU in the assigned double slot using the 4.2 second interleaver block.

5.2.1.2.1 Transmission of MPDUs in Assigned Uplink Slots

The ground station uses each assigned uplink slot to transmit an uplink MPDU. Contiguous uplink slot assignments are used to transmit a double-slot MPDU. Each MPDU may encapsulate up to 64 uplink LPDUs addressed to up to eight different aircraft (see Section 5.2.2). The encapsulation of LPDUs into MPDUs is done based on priority as follows:

c-3

a. LPDUs are first encapsulated based on priority, sending the LPDUs with highest precedence first and continuing to the lowest precedence.

b. Within each priority level, LPDUs are encapsulated within an MPDU in a FIFO order. This FIFO ordering should be preserved as LPDUs are retransmitted. Note that only Numbered Data LPDUs are retransmitted by the Link Control sublayer.

c. The maximum uplink data rate associated with the first LPDU to be encapsulated within the MPDU is used to determine the maximum allowed size of the single or double slot MPDU (see Section 5.2.1.6). There may be times when a high precedence LPDU is encapsulated into an MPDU designated for transmission in a single or double uplink slot at a high data rate. If there is room in this same slot (or double slot) for additional information and no other LPDUs of this precedence can be sent at this high data rate, then it is admissible to fill out the slot with an LPDU of a lower precedence provided the LPDU can be sent at the same data rate or lower. This may cause HFNPDUs to be received out of precedence order.

5.2.1.3 Selection of Downlink Slot by Aircraft

After reception of each squitter containing slot assignments, each aircraft tuned to the frequency should determine whether it has any LPDUs queued for transmission.

If an aircraft has one or more downlink LPDUs queued for transmission and the ground station has assigned one or more slots to the aircraft, the aircraft should send as many of the downlink LPDUs in the assigned slot or slots (see paragraph below).

If the ground station has not assigned the aircraft a slot, the aircraft should use a random access slot to send an LPDU. The slot should be selected at random from among all the random access slots available in the frame, as defined in Section 5.2.1.3.1, in order to minimize potential collisions with downlinks from other aircraft attempting to log-on the ground station or send a random access downlink. A request for additional slot assignments may be sent with the downlink (see Section 5.2.1.4) should there be more LPDUs queued than can be transmitted in the random access slots.

If the slot is assigned to an aircraft and the aircraft has nothing in its queue to send, the aircraft should send an MPDU with an LPDU containing a performance data HFNPDU. c-3

The encapsulation of LPDUs into MPDUs is done based on priority as follows:

a. LPDUs are first encapsulated based on priority, sending the LPDUs with highest precedence first and continuing to the lowest precedence.

b. Within each priority level, LPDUs are encapsulated within an MPDU in a FIFO order. This FIFO ordering should be preserved as LPDUs are retransmitted. Note that only Numbered Data LPDUs and Unnumbered Acknowledged Data LPDUs are retransmitted by the Link Control sublayer. c-2

c. The maximum downlink data rate indicated by the ground station is selected. An MPDU of the appropriate size is chosen based on the downlink data rate indicated by the ground station. This MPDU is filled with LPDUs as described above. Once the MPDU has been filled with LPDUs, it is transmitted to the ground station at the lowest possible data rate. c-4 c-4 An MPDU is transmitted at a data rate lower than the maximum by the ground station if the size of the completed MPDU can be fit into the slot at a lower transmission rate. There may be times when a high precedence LPDU is encapsulated into an MPDU designated for transmission in a single or double downlink slot at a high data rate. If there is room in this same slot (or double slot) for additional information and no other LPDUs of this precedence can be sent at this high data rate, then it is admissible to fill out the slot with an LPDU of a lower precedence provided the LPDU can be sent at the same data rate or lower. This may cause HFNPDUs to be received out of precedence order.

When assigning multiple slots to an aircraft, if possible, the ground station should assign successive slots. If two consecutive slots are reserved for an aircraft, the aircraft should transmit one MPDU in the assigned double slot using the 4.2 second interleaver block.

5.2.1.3.1 Contention/Random Access Slot Selection

Ground stations may designate, by each squitter, one or more slots to be used by HFDL aircraft terminals on a random access basis. When no random access slot contention existed in the previous frame, an HFDL aircraft terminal may select a random access slot in accordance with the following:

a. An HFDL aircraft terminal may transmit in one random access slot if there is no other slot designated, in the same frame, as reserved for that aircraft terminal.

b. If multiple random access slots are designated in a single frame, an HFDL aircraft terminal should transmit in the next appropriate random access slot following receipt of a transmit request.

COMMENTARY

c-2 A uniform distribution of random access slot assignments throughout a frame permits minimal transmission queuing delays. The selection of the appropriate random access slot for downlink transmission should minimize the possibility of simultaneous transmissions by multiple aircraft using the same contention slot. Since it is possible for more than one aircraft to be addressed in an uplink MPDU, multiple aircraft may concurrently need to use a downlink contention slot to issue a response or acknowledgment. A uniform distribution of random access slot assignments throughout the frame by the ground station and a distribution of slot selection by multiple aircraft improves the probability of successful downlink transmissions by avoiding collisions.

There is a potential for multiple simultaneous transmissions in the same random access slot. A slot contention condition may be detected by the receiving ground station. Since no useful data is received in a slot where contention exists, the subsequent squitter contains in the Acknowledgment Codes Field a NAK, 000_h, for all LPDUs in the slot where contention occurred. A contention resolution method is provided by way of a transmission attempt Backoff Algorithm. An HFDL aircraft terminal is considered to be operating in the Backoff Mode while continuing to attempt transmissions using random access slots following detection of a contention condition for its prior transmission. Attachment 2-14 provides a state machine representation of the Backoff Algorithm. While operating in the Backoff Mode, an HFDL aircraft terminal should make a uniform random pre-selection of one random access slot from all available random access slots designated by each squitter.

COMMENTARY

Note that random access slot selection, from multiple available random access slots, differs between the general contention-free case and the case of operation in Backoff Mode. The incorporation of randomized pre-selection of a random access slot during operation in Backoff Mode is intended to reduce the probability of persistent contention for the same slot(s) by multiple aircraft terminals. c-2

The Backoff Mode of an HFDL aircraft terminal becomes active when all of the LPDUs encapsulated in a MPDU that it transmitted in a random access slot are indicated as NAK in the acknowledgment code of the corresponding squitter. An HFDL aircraft terminal exits the Backoff Mode upon any of the following conditions, as reflected in the transitions to the idle state shown in Attachment 2-14.

a. At least one LPDU that was encapsulated in an MPDU transmitted in a random access slot is positively acknowledged, or

b. A squitter is received that assigns a reserved downlink slot to this HFDL aircraft terminal, or

c. A condition that necessitates a new frequency search is detected.

5.2.1.4 Downlink Slot Reservation Requests

With each downlink transmission, the aircraft may request slot assignments for future transmissions as described in Section 5.2.2(c2).

COMMENTARY

A feature which allows requests for reservation n frames in the future is also available in addition to that defined in Section 5.2.2(c2). This feature could be used, for example, if the HFDL system had the means to identify periodic traffic. If the downlink being sent contained a periodic position report with period $n-1 < p/D$ seconds $< n < 128$, where p is the period of the position report in seconds and D is the frame duration in seconds, the aircraft could request that a slot be reserved n frames later. The eighth bit in the reservation request field should be set to 1 (see Section 5.2.2(c2). HF Data Link supports ADS periodic reporting at intervals greater than 32 seconds and up to 4096 seconds in multiples of 32 seconds. See Section 3.5.4.

5.2.1.5 Maximum MPDU Size Adjustment

HF Data Link supports transmission of MPDUs with up to 405 bytes in a single slot at a data rate of 1800 bps and with up to 945 bytes in a double slot also at a data rate of 1800 bps. However, when the signal quality cannot support operation at 1800 bps, the aircraft should adjust the maximum downlink MPDU size to match the maximum downlink data rate supported by the channel according to Table 5-1 shown below. The ground station should also adjust the maximum uplink MPDU size to match the maximum uplink data rate supported by the channel according to Table 5-1 below.

Table 5-1
Maximum MPDU Size vs. Maximum Data Rate

Max. Data Rate	Maximum MPDU Size	
	Single Slot	Double Slot
1800 bps	405 bytes	945 bytes
1200 bps	270 bytes	630 bytes
600 bps	135 bytes	315 bytes
300 bps	67 bytes	157 bytes

Each uplink includes the maximum downlink data rate proposed by the ground station derived from the downlink signal quality measured. The aircraft should use this data to determine the maximum downlink MPDU packet size to use. The aircraft HFDR should default to maximum downlink bps rate of 300 bps when not logged on (this includes a pending logon resume).

Each downlink includes the maximum uplink data rate proposed by the aircraft derived from the uplink signal quality measured. The ground station should use this data to determine the maximum uplink MPDU packet size to use.

5.2.1.6 Data Rate and Interleaver Selection

The aircraft and ground station should select the interleaver size based on the slot duration, and data rate based on the MPDU or SPDU size as shown in Table 5-2 below.

Table 5-2 Data Rate & Interleaver Size Selection

MPDU/SPDU Size	Data Rate	Interleaver Duration	Single/ Double Slot
1- 67 bytes	300 bps	1.8 sec	single
68-135 bytes	600 bps	1.8 sec	single
136-270 bytes	1200 bps	1.8 sec	single
271-405 bytes	1800 bps	1.8 sec	single
1-157 bytes	300 bps	4.2 sec	double
158-315 bytes	600 bps	4.2 sec	double
316-630 bytes	1200 bps	4.2 sec	double
631-945 bytes	1800 bps	4.2 sec	double

5.2.1.7 Squitter SPDU Format

Squitters are packets broadcast to all aircraft in order to provide the means to synchronize uplink and downlink transmissions and to provide the means for frequency and time slot selection by the aircraft. The format of the squitter packet (SPDU) is defined in Attachments 2-8A, 2-8B, and 2-8C. Squitter SPDUs have 67 octets. Hence, they are transmitted at 300 bps.

COMMENTARY

> The fields of each SPDU or MPDU are transmitted within the bit stream as per the layout specified in Attachments 2-8A, 2-8B, and 2-8C. All fields are transmitted contiguous in the bit stream. For fields containing numeric values, the least significant bit of the least significant byte is transmitted first continuing to the most significant bit of the most significant byte.

a. **SPDU ID**. The first bit in the first byte of the SPDU is used to differentiate between squitters and uplink/downlink MPDUs. If the first bit is 0, then the packet is an SPDU; otherwise it is an MPDU. The second bit indicates the RLS Capability of the ground station. If the bit is set to 1 (binary), the ground station is RLS capable. If the bit is set to 0 (binary), the ground station is NOT RLS capable. Bits 3 and 4 contain the squitter format version which should be used in decoding the rest of the squitter.

COMMENTARY

> Initially the version field should be set to 00 (binary). Ideally all ground stations should broadcast squitters with the same initial version. However, if a significant change is ever deemed necessary after initiation of the service the squitter version should be changed. The squitter version field provides the means to indicate that a significant change in the format of the squitter has been introduced. If a change should ever be needed, some ground stations may continue to use the older version in order to allow for a gradual update of all aircraft software.

Bit 5 is a frequency utilization flag C which is set to 0 when the frequency is not heavily utilized. Bit 5 set to 1 indicates the frequency is heavily utilized and aircraft seeking to log-on the ground station should tune to another frequency.

The ground station should regard a frequency as heavily utilized when predicted performance indicates that more than 5% of messages received from the aircraft are likely to experience a transit delay longer than a minute.

The aircraft should only log on to a heavily loaded frequency if after searching all other active frequencies, it can not find a propagating frequency that is not heavily loaded.

COMMENTARY

> When the aircraft logs on to a heavily loaded frequency, the aircraft should indicate this to the CMU as per ARINC Characteristic 753 Section 10.3.1. The CMU may use this information to route data through other downlink mediums.

Bit 6 is a flag P used to indicate whether the ground station currently supports the ISO 8208 Subnetwork Access Protocol defined in Section 6. A setting of P to 0 indicates that the ground station supports the delivery of enveloped messages only. An aircraft requiring delivery of ISO 8208 messages should search for a frequency active at a different ground station. A setting of P to 1 indicates that the ground station supports the delivery of both ISO 8208 and enveloped messages.

The last two bits (7 and 8) are a Change Notice code which indicates the ground station status. The encoding of these two bits to announce changes in the ground station is defined in Attachment 2-8A. A 00_b code indicates both normal operation and continued operation on the same frequency for at least two more frames. When the Change Notice code is not 00_b, the aircraft logged on the channel should initiate a search for a new frequency.

COMMENTARY

> The ground station broadcasts a code other than 00_b in the following situations:
>
> A 01_b code is broadcast whenever the frequency on which the squitter is being transmitted changes in four frames or fewer. The aircraft should initiate a search for a new frequency, trying the current ground station frequencies first.
>
> A 10_b code is broadcast when a failure in the current frequency receiver has been detected. The aircraft should initiate a search for a new frequency, trying the current ground station frequencies first.
>
> A 11_b code is broadcast when the ground station connection to the ground network is down. The aircraft should initiate a search for a new frequency, excluding the current ground station frequencies.

c-1 The aircraft HF Data Link function should randomize the selection of a random access downlink slot used for a Log-on Request after a frequency change notice has been received in a squitter. This may reduce contention delays produced by all of the aircraft HF Data Link functions attempting to use the first random access slot available after the frequency change notice flag is set.

c-2 b. **Ground Station Address**. An 8-bit ground station (GS) address identifies the ground station and whether the ground station squitter transmission is synchronized to Universal Coordinated Time (UTC) or not. The first seven bits (bits 1 through 7) are used to identify the ground station. The last bit (bit 8) is set to 1 (binary) if the squitters are synchronized to UTC, and set to 0 (binary) if they are not.

c. **Frame ID**. This is a 16 bit field. The first twelve bits identify the current Frame Index in a superframe with a 24 hour period. The Frame Index is defined as the integer part of the UTC (in seconds since midnight) at the beginning of the first slot (squitter) in the frame divided by the frame period (also in seconds). Frames are numbered 0 to 2699 when the frame period is 32 seconds. The initial Frame Index after a frequency change is determined from the UTC at the time of transmission of the first squitter. The Frame Index increments by 1 every time a new squitter is transmitted.

The last 4 bits in the Frame ID indicate the Frame Offset relative to a superframe starting exactly at 0000 UTC. It is defined as the integer part of the remainder of the Frame Index calculation multiplied by the number of slots per frame. See the following example:

Squitter at 01:20:7.38 = 4807.38 seconds

Frame Index = 4807.38/32 = 150.23

Slot Offset = (0.23*32)/2.46 = 3

Thus, the Frame Offset for frequencies whose first frame starts exactly at 0000 UTC plus a fraction of a slot duration, is 0. The maximum Frame Offset for a frame with 13 slots is 12.

COMMENTARY

> Aircraft may use the Frame Index and Frame Offset to derive a UTC clock synchronized to that of the ground station.

d. **Slot Acknowledgment Codes**. Thirty-six octets (288 bits) are used to broadcast a 12-bit acknowledgment field for 24 non-squitter previous slots. The relationship between each 12-bit acknowledgment field and the slot being acknowledged is defined in Section 5.2.4.2.4.1 and Attachment 2-8B.

COMMENTARY

> Acknowledgments to the two slots immediately before the squitter slot are not included in this squitter, but should be included in the next two squitters.

A positive acknowledgment to a downlink is indicated in the 12-bit acknowledgment field when the first 8 bits contain the unique 8-bit Aircraft ID. The next four bits indicate the error status of the first, second, third and fourth LPDUs as determined by the CRC Frame Check Sequence (FCS) test. A bit set to one indicates that the LPDU passed the CRC test. Acknowledgment of received LPDUs is provided for all LPDU types. c-1

COMMENTARY

> Up to eight Link Protocol Data Units (LPDUs) may be sent in a single downlink slot (see Section 5.2.2(e)). c-3

A negative acknowledgment, no reception or transmission of an uplink in the slot is indicated by all 0's.

e. **Slot Assignment Codes**. Twelve octets are used to broadcast slot assignments for 12 non-squitter future slots. The relationship between each slot assignment and the slot position relative to the current squitter slot is defined in Attachment 2-8B. Assignments for the two slots immediately after the squitter are not assigned in this squitter, but were assigned in the previous squitter.

A 00_h setting in any of the slot assignments indicates that the slot is reserved for uplinks. A FE_h setting indicates the slot is assigned for random access. A 01_h to FD_h setting indicates assignment to the aircraft assigned that particular Aircraft ID. The FF_h setting is reserved.

5.0 AIR/GROUND SERVICES AND PROTOCOLS OF LAYER 2 - LINK LAYER

5.2.1.7 Squitter SPDU Format (cont'd)

c-1 f. **Minimum Priority Accepted**. Bits 1 through 4 contain the lowest packet priority level accepted by the ground station. The aircraft may select a contention slot for use (following the algorithm specified in Section 5.2.1.3) when data greater than or equal to the minimum priority indicated by the ground station is available for transmission. The aircraft, having been allocated a downlink slot, should generate a downlink MPDU for transmission.

An aircraft, having selected a slot for downlink, should construct an MPDU downlink. When an MPDU downlink is being constructed for transmission, data of any priority can be included up to the capacity of the MPDU. Data having the highest priority should be included first, continuing to the lowest priority data available.

c-2 COMMENTARY

The minimum priority field of the uplink squitter is used by the ground station to control the use of downlink contention slots, thereby increasing the chances of successful downlink transmission. Since the aircraft is allowed to include data having any priority when making a downlink MPDU, the overall throughput of the HF Data Link system should be improved. This additional downlink throughput does not come at the expense of additional bandwidth usage, since only one slot is used.

Uplink and downlink HFNPDUs and LPDUs are assigned different priorities (0 to 15) depending on their type with packets assigned priority 0 having the lowest priority and packets assigned priority 15 having the highest priority (see Section 5.2.3 and Attachment
c-1 3-1). Since the HF Data Link is intended to provide only ATS and AOC Services on AM(R)S frequencies, the priority parameter should be set at a value no lower than 5.

Bits 5-8 are reserved for future definition and are set to 0000_b.

g. **Ground Station Active Frequency Bits**. Eleven bytes (88 bits) are used to broadcast active frequency information for the current ground station and two alternate ground stations. The first 12 bits contain the data base version for the service provider operating the ground stations encoded as defined in Section 5.2.2.5.1(g). The next 20 bits contain
c-3 the Active Frequency Bits for the current ground station. The next 28 bits contain the ground station ID (8 bits) and Active Frequencies Bits (20 bits) for a second ground station. The last 28 bits contain the ground station ID (8 bits) and Active Frequencies Bits (20 bits) for a third ground station. In each 20-bit field containing the Active Frequency Bits, bit 1 indicates whether the highest frequency assigned to the ground station is on-the-air (bit set to 1) or off-the-air (bit set to 0). Bit 2 provides the same information for the next highest frequency and so on. If the ground station has fewer than 20 frequency assignments, the bits corresponding to the unassigned frequencies are set to 0.

COMMENTARY c-1

The data base version broadcast in the Active Frequency Field of the squitter corresponds to the data base version of the service provider's HFDL System Table (see Section 5.2.5.4). It is updated by the service provider whenever a change in frequency assignments to any of its ground stations occurs or when a new ground station is added to the service provider's HFDL network. The specific list of ground stations operated by the service provider and frequency assignments in tenths of kilohertz are broadcast in response to a request. If an aircraft tunes to a frequency broadcasting squitters with data base version in the Active Frequency Field which does not match the aircraft's data base version for the service provider's HFDL System Table, the aircraft should send a request for a broadcast of the HFDL System Table with the Log-On c-3
Request (see Sections 5.2.2.2 and 5.2.2.5.2). Note that if the aircraft does not have the latest data base version, the aircraft can log-on and transmit on any frequency it can receive a squitter, but it may not be able to make effective use of the active frequency information broadcast in the active frequency field of the squitters.

The active frequency bits are updated during the Frequency Change process as follows: The first squitter, containing the frequency change notice (bits 7 and 8 of the SPDU ID set to 01_b), includes the active frequency bits for any other active frequencies in the ground station and the next active frequency for the current channel. The airborne HFDL function should use this knowledge of the next active c-1
frequency in the search algorithm and take into account the ground station does not start propagating on the next active frequency until the completion of the frequency change process.

Active frequency bits for other squitters on this ground station and active frequency bits for squitters from all other ground stations are not updated until the first squitter on the new frequency has been transmitted.

h. **Frame Check Sequence (FCS)**. A 16-bit Cyclical Redundancy Code (CRC) FCS computed starting with the first bit of the first byte in the SPDU and ending with the last bit in the Active Frequency Bits field is appended at the end of the SPDU. The CRC encoder should be the International Telegraph and Telephone Consultative Committee (CCITT)-16 generator

$$P(x) = x^{16} + x^{12} + x^5 + 1$$

seeded with all 1's.

COMMENTARY

The complete description of the Encoding of the CRC is defined in the common reference ARINC Specification 429, Section 2.5.12.1. Implementers are urged to use the common reference to assure commonality of understanding.

i. **Flush.** Eight 0's are appended after the FCS to flush the HF modem convolutional encoder.

5.0 AIR/GROUND SERVICES AND PROTOCOLS OF LAYER 2 - LINK LAYER

5.2.1.7.1 Intra-Ground Station Synchronization

The HF Data Link system design is based upon the use of ground station transmitted squitters. These squitters are used to mark the beginning of a 32.0 second frame, allow the airborne receiving system to determine availability of a communications channel, and transmit system management information.

COMMENTARY

Each ground station may be assigned as many as 20 frequencies. Not all frequencies are likely to be actively used by the ground station at a given time of day. The activation of frequencies at a ground station may be according to a schedule which may be fixed or dynamically updated on an hourly basis using real time propagation data.

c-1 The airborne HFDL function should use the actual aircraft position, if known, to determine the distance to each ground station in the HFDL System Table. The distance should be used to identify all ground stations within 3000 kilometers (km). The initial ground station should be selected at random from all of the ground stations within this 3000 km range. The airborne HFDL function should then listen for a squitter for 35 seconds on each of the frequencies assigned to the ground station.

Each ground station should transmit the squitters on an assigned frequency, when that frequency is being actively used, in a synchronized manner by defining a Master Frame with 13 slots starting at T_{Ref} and repeating at 32 second intervals. Each of the frequencies assigned to the ground station is also assigned a slot transmission time in the Master Frame as illustrated in Table 5-3 below where it has been assumed that the ground station is assigned 20 frequencies, grouped into 5 families. The frequency ID associated with each assigned frequency, shown in parenthesis, is derived by listing the frequencies from highest to lowest. As an airborne station is initializing, it should listen to each frequency that the selected ground station should be transmitting on before initiating a Log-On Request. When the airborne system receives a squitter on any frequency, it can determine the time of all other squitters from that station, thus allowing the system to synchronize receiver tuning with the expected squitter transmissions.

Table 5-3
Squitter Slot Assignments vs Frequency Assignments

Master Frame Slot	Freq. Group 1	Freq. Group 2	Freq. Group 3	Freq. Group 4
1	21.9xx(1)		15.5xx(3)	
3	13.3xx(4)	10.0xx(6)	8.9xx(8)	17.9xx(2)
5	10.0yy(7)	8.9yy(9)	5.5xx(13)	13.3xx(5)
7	6.6xx(11)	5.5yy(14)	4.5xx(16)	8.9xx(10)
9	5.5zz(15)	4.5yy(17)	3.9xx(19)	6.6yy(12)
11		3.9yy(20)		4.5zz(18)

The slot each squitter is broadcast in is specified in the Broadcast HFDL System Table uplinked to all aircraft. There is a single HFDL System Table supporting the operation of the HFDL subnetwork. As the list of assigned frequencies changes, the Broadcast HFDL System Table may change, and the squitter slot offset for each frequency in the table may change. The squitter slot offset for a frequency to which an aircraft is currently logged on should never change. c-1

In Attachment 2-8D, a depiction of the squitter timing within a station is shown. The Master Frame started at T_{Ref} is used to synchronize all station squitters. Squitters on frequencies designated for transmission in slot 1 of the Master Frame are transmitted starting at T_{ref} (either 21.9xx or 15.5xx MHz in Table 5-3). These are followed two slots later by transmission of squitters on frequencies timed to fall in slot 3 of the Master Frame. Transmission of squitters on frequencies timed to fall in slot 5 of the Master Frame follow two slots later. This sequence is followed until all squitters have been transmitted in the 32 second frame period. The squitters are transmitted according to the sequence shown relative to the Master Frame. If an assigned frequency is not currently operational, no squitter is to be expected by the airborne receiver. All squitter slot transmit times are assigned relative to the Master Frame reference time T_{ref}. However, squitter slots are always designated as the first slot in the Local Frame defined for each frequency and all other slots are numbered relative to the squitter slot for the purpose of assigning slots and acknowledging downlink LPDUs.

COMMENTARY

The use of staggered squitters allows the HFDL System to rapidly determine which frequencies from the selected ground station are propagating. If the aircraft has no knowledge of which frequencies are propagating from a selected ground station, it may begin the search starting at the highest frequency. Because of the potential length of the initial squitter search, the airborne HFDL function should be initialized as early in the flight as practical. If possible, the airborne HFDL function should consider using the time of day to select a probable frequency search start point. For example, during the day, the frequencies should be searched from highest to lowest. At night, the frequencies should be searched from lowest to highest. During sunrise and sunset, the frequency search should start in the middle of the list of available frequencies. Once logged on to an HFDL ground station, the airborne HFDL function should use any available HF radio time to continuously scan the HFDL frequencies and rank order any ground stations heard. This information should be used to reduce the time to transition between active frequencies. c-1

5.2.1.7.2 Inter-Ground Station Synchronization

With a well established intra-ground station synchronization, the ability of the airborne receiving system to know when to expect a squitter improves the acquisition time. This process should be carried over to the entire network of ground stations to improve the re-acquisition performance in case a ground station is lost or operational

5.2.1.7.2 Inter-Ground Station Synchronization (cont'd)

conditions dictate a change by the HFDL System. Once timing is established from any squitter, all other squitter transmission times are known within a few milliseconds for that ground station. By synchronizing the start of the Master Frame of every ground station, T_{Ref} in Attachment 2-8E, the airborne receiving system can monitor other ground stations while not interfering with normal communications, or can quickly determine which frequencies are propagating from another ground station when the need arises.

Ground stations should start their Master Frame at 00:00:00.0 UTC each day. The ground stations can synchronize to UTC only during a scheduled frequency change or if no aircraft are logged on to the ground station via the frequency in question. The ground stations should not allow synchronization to have an error greater than 25 ms.

COMMENTARY

The use of a 32 second frame produces exactly 2,700 frames per 24 hour period. The only adjustments occurs when a "leap second" is added occasionally.

5.2.1.7.3 Ground Station Synchronization Status

The airborne receiver should obtain knowledge of the operating state of the ground station synchronization status.

This information is transmitted in the high order bit position of the Ground Station Address bytes. See Attachment 2-8A. The high order bit indicates if the broadcasting station is synchronized to UTC. Likewise, the synchronization status of GS 2 and GS 3 in Attachment 2-8A, are also indicated. A "1" or true state indicates the stations are synchronized to UTC at 00:00:00.0.

c-1 A "0", or false state, indicates the ground station is not synchronized to UTC and that a failure in the external time source has occurred. The airborne HFDL function should not use the squitter from this station to establish a Master Frame reference for monitoring of other frequencies.

5.2.2 Data Link Layer Packet Encapsulation

The Data Link layer performs three levels of encapsulation. First user packets, that is HF Network Protocol Data Units (HFNPDUs), are segmented into Basic Data Units (BDUs) when the HFNPDU is to be delivered using the Reliable Link Service. Each segment of the HFNPDU is encapsulated into a Link Protocol Data Unit (LPDU) and then one or more LPDUs are encapsulated into a single Media Access Control (MAC) Protocol Data Unit (MPDU) to make efficient use of the slot. The maximum length of an MPDU which occupies a single 2.47 second slot is 405 bytes which is the maximum number of bytes that can be transmitted by the physical layer in 1.8 seconds at a data rate of 1800 bps. The maximum length of an MPDU which occupies two contiguous slots is 945 bytes which is the maximum number of bytes that can be transmitted by the physical layer in 4.2 seconds at a data rate of 1800 bps.

c-1 Each MPDU consists of a variable length MPDU header, 0 to L LPDUs where L is 15 for downlinks and 64 for uplinks, and a one byte trailer. The maximum length of an LPDU is 256 bytes and the minimum size is 3 bytes. Each uplink MPDU can contain only one Aircraft Address which is addressed to any one aircraft. c-1

COMMENTARY

HF Data Link uses length fields to identify boundaries of LPDUs rather than flags because bit stuffing techniques cannot be used due to the strict packet size limitations imposed by the HF Data Link signal-in-space block interleaver. A single additional bit beyond the maximum interleaver block size would result in either reception of an incomplete frame which would not pass the CRC check, or the transmission of two full interleaver blocks which would occupy two slots rather than one.

COMMENTARY

The fields of each SPDU or MPDU are transmitted within the bit stream as per the layout specified in Attachments 2-7A, 2-7B, 2-7C, 2-8C, and 2-10A through 2-10G. All fields are transmitted contiguous in the bit stream. For fields containing numeric values, the least significant bit of the least significant byte is transmitted first continuing to the most significant bit of the most significant byte. c-3

The MPDU header and trailer for downlinks are defined in Attachments 2-7A, and 2-7C and below. The MPDU header and trailer for uplinks are defined in Attachment 2-7B.

a. **MID.** The first byte of the downlink MPDU header contains four fields. The first bit, labeled M, which is used to identify and differentiate between squitter SPDUs and MPDUs, should be to set to 1. The second bit, labeled T, is used to identify and differentiate between uplinks (T = 0) and downlinks (T = 1). The other 6 bits (3 through 8) have different uses in downlinks and uplinks.

In downlinks, bits 3 through 6 of the first byte, labeled NLP, indicate the number of LPDUs that are encapsulated in the MPDU. Downlink MPDUs may contain 0 to 8 LPDUs if the MPDU occupies a single slot and 0 to 15 LPDUs if it occupies a double slot. A downlink MPDU with no LPDUs is sent when the aircraft has been assigned a slot and the aircraft has no downlink data to send. Bit 7 is reserved for future use and should be set to 0. Bit 8 is an odd parity bit that should be set so that the number of 1's in the octet, including the parity bit, is odd.

COMMENTARY

The parity bit in the first octet and the restrictions on the maximum value for NLP for single and double slot downlink MPDUs should be used to flag errors in the size of the header. The header FCS should provide additional protection against errors not detected by the parity bit.

In uplinks, bits 3 and 4 are reserved and set to 0. The next 3 bits (5 through 7), labeled NAC, are used to identify the number of different Aircraft Address Fields less one included in the uplink MPDU header. For example, if NAC = 3 (bits 5 and 6 set to 1), then the MPDU header contains 4 Aircraft Address Fields. Every uplink MPDU includes at least one Aircraft Address Field. A variable length address field for each aircraft follows the Ground Stations Identifier (GSID) byte. Bit 8 is an odd parity bit that should be set so that the number of 1's in the octet, including the parity bit, is odd.

COMMENTARY

The parity bit in the first octet should be used to flag errors in the size of the header of uplink MPDUs. The header FCS should provide additional protection against errors not detected by the parity bit.

c-3 b. **Ground Station ID.** The second byte in the downlink and uplink MPDU header contains the ground station identifier. It is encoded as defined in Section 5.2.1.7(b) c-3 except that the value encoded in bit 8, UTC synchronization field, is immaterial.

c. **Aircraft Address Field.** The downlink MPDU header contains a variable length Aircraft Address (AA) field c-3 following the GS ID. The AA field consists of a 1 byte Aircraft ID (AID), a 1 byte Reservation Request (RR) Field, a 2 byte ACK field, and a variable length LPDU Sizes field follows the GS byte in the downlink MPDU header.

The uplink MPDU header contains 1 to 8 (i.e. NAC plus one) AA fields, one for each aircraft addressed by the uplink. Each AA field contains a 1 byte Aircraft ID (AID) followed by a 1 byte MDF field, and a variable length c-1 LPDU Sizes field. Each uplink MPDU can contain only one Aircraft Address which is addressed to any one aircraft.

c1. **AID.** The first byte in the AA field is an 8-bit Aircraft ID (AID) defined in Attachment 2-7C. The Aircraft ID is an 'Alias Address' uniquely assigned to each aircraft when the aircraft logs onto a new frequency. The AID is allocated by the ground station when confirming a logon to an aircraft. The AIDs are unique per frequency. The AID allocated to aircraft range from 1 to FD_h. Two aircraft using the same frequency should never be allocated the c-1 same AID. The value FE_h is reserved and is not presently permitted as an AID value.

MPDU downlinks containing an initial Log-On Request or Log-On Resume LPDU sent to the ground station by an aircraft should use FF_h for an Aircraft ID. MPDU uplinks containing a Log-On Confirm, Log-On Resume-Confirm or a Log-On Denied LPDU, sent to an aircraft in response to a Log-On Request or Log-On Resume downlink LPDU should set the Aircraft ID associated with the Log-On uplink LPDU to FF_h.

If the aircraft Log-On Request or Log-On Resume has been confirmed, all subsequent downlink MPDUs sent by the aircraft and uplink MPDUs containing Data LPDUs sent to the aircraft should use the assigned Aircraft ID.

The 00_h AID value should be used in uplink MPDU header Aircraft Address fields to indicate that a group of uplink c-1 LPDUs associated with the Aircraft ID field are broadcast to all aircraft. The number of LPDUs in the broadcast group is conveyed by the Number of LPDUs (NLP) value in the MDF field that follows each AID field.

c2. **Reservation Request**. In downlink MPDUs the second byte of the AA field contains a request for slot assignments (refer to Attachment 2-7A). The byte is broken into four fields called Pos, HI, MED, and LOW.

1) Subfields of the 'RES REQ' Field

bit 8	Periodic Request Indicator
bit 7	Request Field Usage Indicator (if bit 8=0)
bit 4-6	Request Field 2 (if bit 8=0)
bit 1-3	Request Field 1 (if bit 8=0)
bit 1-7	Periodic Request Field (if bit 8=1)

2) Mapping of Priorities to Low, Medium, and High Priority Ranges

High Priority	14-15
Medium Priority	8-13
Low Priority	0-7

3) Aircraft Calculation of the Number of Required Reserved Downlink Slots

The aircraft should calculate the number of additional downlink slots required as a function of the amount of data held for transmission. When making this calculation, data which is to be sent in slots currently assigned should not be included. Therefore, for example, if an aircraft is currently building an MPDU for transmission in a slot, and has 2 additional slots assigned, but has 7 slots worth of data to send (including the data being sent in the current slot), then the aircraft should request 4 slots (7{total data} - 1{current slot} - 2{assigned slots}=4). This logic is applicable independently for low, medium, and high priority level data".

4) Aircraft Setting Algorithm for 'RES REQ' Field c-1

The periodic Request Indicator should be set to 1 if a periodic reservation request is to be made, otherwise it should be set to 0. If bit 8 = 1, then bits 1-7 represent the Periodic Request Field, otherwise they represent Request Field 1 and Request Field 2.

The Periodic Request Field should be set to a value indicating the frame offset from the current frame in which one slot is requested.

COMMENTARY

The periodic position report field is not fully specified at this time. Further explanation of rules governing the setting of this field will be required before it can be supported.

The aircraft should set the Request Field Usage Indicator = 0 when it has no high priority data to transmit, otherwise it should be set to 1.

Request Field 2 should be set as follows: if the Request Field Usage Indicator = 0 then the aircraft should set this field to the number of medium priority level slots required for transmission. If the Request Field Indicator = 1, then the aircraft should set this field to the number of high priority level slots required for transmission.

Request Field 1 should be set as follows: if the Request Field Usage Indicator = 0 then the aircraft should set this field to the number of remaining medium priority level slots, plus low priority level slots required for transmission. If the Request Field Indicator = 1, then the aircraft should

5.0 AIR/GROUND SERVICES AND PROTOCOLS OF LAYER 2 - LINK LAYER

5.2.2 Data Link Layer Packet Encapsulation (cont'd)

set this field to the number of remaining high priority level slots, plus medium priority slots, plus low priority level slots required for transmission.

5) Ground Station Keeping Track of the Number of Requested Slots

The ground station should keep track of the number of low, medium, and high priority slots requested by each aircraft. Each time the ground station prepares the slot assignments for a squitter, the number of requested low, medium, and high priority slots should be reduced by the number assigned to each aircraft. Each time the ground station receives a downlink MPDU from an aircraft, the current requested amount of slots should be replaced by the updated amount indicated in the reservation request field.

c-1 6) Ground Station Parsing 'RES REQ' Field

If the Periodic Request Indicator = 1, then the GS should read bits 1-7 as the Periodic Request Field = n, and schedule a slot reserved for the requesting aircraft n frames from the current frame.

If the Periodic Request Indicator = 0, then the GS should read Field Request Field Usage Indicator (bit 7).

If bit 7 = 0, then the GS should use the value in Request Field 1 to set the number of low priority slots to be assigned to that aircraft, and use the value in Request Field 2 to set the number of medium priority slots to be assigned to that aircraft.

If bit 7 = 1, then the GS should use the value in Request Field 1 to set the number of medium priority slots to be assigned to that aircraft, and use the value in Request Field 2 to set the number of high priority slots to be assigned to that aircraft.

7) Aircraft Delay for Next Use of Random Access Downlink Slot

The aircraft HFDL avionics should wait 3 frames after receiving the acknowledgment of the MPDU containing slot reservation request before using another random access slot. The aircraft, having transmitted an MPDU requesting zero additional slots, should no longer wait before applying the normal contention slot selection rules (see Section 5.2.1.3.1). A description of a possible wait process is shown below:

Frame 0: Random Access Slot used to send slot reservation request.

c-2 Frame 1: HFDL Ground Station Acknowledges successful receipt of MPDU (by acknowledging individual LPDUs in squitter Acknowledgment field). Set counter = 3.

Frame 2: Decrement counter, counter = 2, If counter = 0, enable use of Random Access downlink slots.

Frame 3: Decrement counter, counter = 1, If counter = 0, enable use of Random Access downlink slots.

Frame 4: Decrement counter, counter = 0, If counter = 0, enable use of Random Access downlink slots. Aircraft can now use Random Access Slots again.

c3. **MDF.** The second field in each AA field of uplink c-1
MPDUs is referred to as the MDF. The second byte in each AA field of uplink MPDUs contains three fields. The first bit is an odd parity bit that should be set so that the number of 1's in the MDF octet, including the parity bit, is odd. The next 3 bits (2 through 4), labeled DDR, are used to inform the addressed aircraft what the maximum downlink data rate should be set to based on downlink signal quality measured by the ground station. If an aircraft address in an uplink c-1
MPDU is used to broadcast uplink LPDUs (AID set to 0000 0000_b), the DDR field should be set to 000. The last 4 bits (5 through 8), labeled NLP, indicate the number of consecutive LPDUs encapsulated within the uplink MPDU which are addressed to the aircraft. Each uplink MPDU c-1
may contain 0 to 15 LPDUs addressed to each aircraft. NLP is not expected to be set to 0 since at least one LPDU is to be addressed to each aircraft for which an AA field is included in the MPDU header.

COMMENTARY

The parity bit in the MDF octet should be used to flag errors in the size of the header of uplink MPDUs. The header FCS should provide additional protection against errors not detected by the parity bit.

c4. **ACK.** Two ACK bytes follow the Reservation Request field in the AA field of every downlink MPDU. The ACK bytes in downlinks contain a 13-bit Uplink Acknowledgment Field and a 3-bit UDR field. Bits 1 through 3 of the first byte, labeled UDR, are used to inform the ground station what the maximum uplink data rate to the aircraft should be set to, based on uplink signal quality measured at the aircraft. The last 5 bits (bits 4 through 8) of the first byte and the second byte are the Uplink Acknowledgment Field consisting of a 5-bit sequence number, U(R), which indicates the lowest uplink Numbered Data LPDU sequence number expected by the aircraft, and an 8-bit Boolean vector, U(R)vect, defined in Section 5.2.4.2.3. Bits 4 through 8 of the first byte are U(R) while bits 1 through 8 of the second byte are U(R)vect.

c5. **LPDU Sizes**. This field has variable length and contains NLP bytes, one byte per encapsulated LPDU addressed by (in downlinks) or to the aircraft (in uplinks).

The first byte contains the length of the first LPDU less one. The next byte contains the length of the second LPDU less one, etc. For example, if an LPDU has length 5, then the byte value is 4. If no LPDUs are addressed by or to the aircraft (NLP = 0), then this field is not present.

d. **FCS**. The final 16 bits in the MPDU header are used for a header CRC Frame Check Sequence (FCS) computed starting with the first bit in the MPDU Header and ending with the last bit in the LPDU Sizes field of the last AA field. The CRC encoder should be the CCITT-16 generator

$$P(x) = x^{16} + x^{12} + x^5 + 1$$

seeded with all 1's.

c-1 e. **Data Field**. The data field of uplink MPDUs should consist of 1 to 64 LPDUs, each formatted as specified in Section 5.2.2.1. The data field of downlink MPDUs should consist of 0 to eight LPDUs formatted as specified in Section 5.2.2.1 if the MPDU uses a single slot and up to 15 LPDUs if it uses two contiguous slots (double slot).

f. **Flush**. The MPDU trailer consists of eight 0's that are used to flush the convolutional encoder in the HF modem.

5.2.2.1 LPDU Encapsulation

c-1 Link Protocol Data Units (LPDUs) contain data packets or link control packets. Uplink and downlink data packets (HFNPDUs or segments of HFNPDUs) of up to 253 bytes are encapsulated into LPDUs with up to 256 bytes. The LPDU format and types of LPDUs are defined in Attachment 2-9A, and below.

c-1 a. **LPDU Type**. An 8-bit LPDU Type (LT) field is used to indicate the type and contents of the LPDU, also referred to as a frame. The LT contents for each LPDU type are defined in Attachment 2-9A. c-1 HF Data Link supports acknowledged Reliable Link Service (RLS), acknowledged Direct Link Service (DLS) and unacknowledged Direct Link Service (DLS) link control protocols.

The RLS protocol makes use of Numbered Data LPDUs to send downlink and uplink data.

c-1 The acknowledged DLS protocol makes use of Unnumbered Acknowledged Data LPDUs to send downlink ACARS blocks.

c-2 The unacknowledged DLS protocol makes use of Unnumbered Data LPDUs to send downlink and uplink data which need not be acknowledged such as broadcast data. All downlink LPDUs are either positively or negatively acknowledged in the squitter acknowledgment codes.

The Log-On Request, Log-On Confirm, Log-On Denied, Log-On Resume, Log-On Resume-Confirm and Log-On Denied LPDUs are used to establish or resume an air/ground link connection between the aircraft and the ground station.

The Log-Off Request LPDU is used to terminate an air/ground link connection.

c-1 b. **Payload Field**. All LPDUs defined in Attachment 2-9A contain additional fields (data) in the payload field. c-1 The contents of the payload field for each type of LPDU are defined in Attachments 2-10A through 2-10G and Sections 5.2.2.2 through 5.2.2.7.

c. **FCS**. The two bytes following the length are CRC frame check sequence bytes which are generated starting with the first bit of the CS field and ending with the last bit of the payload field. The CRC encoder should be the CCITT-16 generator

$$P(x) = x^{16} + x^{12} + x^5 + 1$$

seeded with all 1's.

5.2.2.2 Log-On Request and Log-On Resume LPDUs

The format and contents of the Log-On Request and Log-On Resume downlink LPDUs are shown in Attachment 2-10D. The Log-On Request LPDU is used by the aircraft to initially log-on a ground station. The Log-On Resume LPDU is used by the aircraft to resume log-on the same ground station after a frequency change or when returning from voice to data on the same previous data frequency. The payload field of the Log-On Request and Log-On Resume LPDUs contain an ICAO 24-bit aircraft address which is unique to each aircraft.

Reference Section 5.2.2.5.3(e), ICAO 24-bit Aircraft Address. c-3

5.2.2.3 Log-On Confirm and Log-On Resume-Confirm LPDUs c-1

The format and contents of the Log-On Confirm and Log-On Resume-Confirm uplink LPDUs are shown in Attachment 2-10E. The Log-On Confirm LPDU is used by the ground station to accept a Log-On Request. The Log-On Resume-Confirm LPDU is used by the ground station to accept a Log-On Resume request. The payload field of both the Log-On Confirm and Log-On Resume-Confirm LPDUs contain the unique 24-bit ICAO address of the aircraft, followed by the 8-bit Aircraft ID assigned to the aircraft, followed by an 8-bit field which defines the transmit window size k parameter, and a 16-bit field which defines the downlink acknowledgment D(R) and D(R)vect settings. The k window size is calculated as follows: k = 4-bit field value + 1. Therefore the window size k parameter can range from 1 to 16. D(R) and D(R)vect are set to all binary zeroes in the Log-On Confirm and to the current settings at the ground station in the Log-On Resume-Confirm. c-1

5.2.2.4 Log-On Denied and Log-Off Request LPDUs

The format and contents of the Log-on Denied uplink LPDU are shown in Attachment 2-10F. The Log-on Denied LPDU is used by the ground station to reject a Log-on Request or Log-on Resume request. c-1 The Log-on Denied LPDUs contain the unique ICAO 24-bit Aircraft Address c-3 followed by a 1 byte reject code indicating the reason for denying the Log-on Request. The Log-on Denied 1 byte reject codes are shown below:

a. Aircraft ID numbers not available (reject code 01_h). The HF Data Link ground station does not have any available aircraft ID numbers. On receipt of a Log-On Denied LPDU with this reject code, the aircraft HF Data Link function should look for another frequency to attempt a Log-on. c-1

b. Ground station does not support RLS Mode (reject code 02_h). The DLS/ACARS HF Data Link ground station receives a normal Log-on Request LPDU and does not support the RLS mode. On receipt of a Log-on Denied LPDU with this reject code, the aircraft HF Data Link function should look for another frequency to attempt a Log-on.

5.0 AIR/GROUND SERVICES AND PROTOCOLS OF LAYER 2 - LINK LAYER

5.2.2.4 Log-On Denied and Log-Off Request LPDUs (cont'd)

c-3 c. Other (reason code 03_h). On receipt of a Log_On Denied LPDU with this reason code, the aircraft HF Data Link function should look for another frequency to attempt a Log-On.

The format and contents of the Log-off Request LPDU are shown in Attachment 2-10F. The aircraft HF Data Link function is not required to log-off of the HF Data Link Ground Station. The Log-Off Request LPDU is used by the ground station to terminate an abnormal air/ground link connection. A Log-Off Request LPDU is issued with a one byte reason code for the following cases:

a. System disruption/not within slot boundaries (reason code 01_h). The aircraft HF Data Link function is disrupting operation of the HF Data Link System by not operating within slot boundaries. On receipt of a Log-Off Request LPDU with this reason code, the aircraft HF Data Link function should move to a non-operational state. The aircraft HF Data Link function should not be used until the unit has been inspected/repaired by maintenance staff.

b. System disruption/sending downlinks in uplink slots or within slots assigned to another aircraft (reason code 02_h). The aircraft HF Data Link function is disrupting operation of the HF Data Link System by sending downlinks in uplink slots or within slots assigned to another aircraft. On receipt of a Log-Off Request LPDU with this reason code, the aircraft HF Data Link function should move to a non-operational state. The aircraft HF Data Link function should not be used until the unit has been inspected/repaired by maintenance staff.

c-1

c. RLS protocol error (reason code 03_h). The aircraft and ground HF Data Link functions have lost link layer synchronization. On receipt of a Log-Off Request LPDU with this reason code, the aircraft HF Data Link function should terminate the session in progress and initiate the log-on process.

d. Invalid aircraft ID (reason code 04_h). The aircraft HF Data Link function is using an unassigned Aircraft ID. On receipt of a Log-Off Request LPDU with this terminate the session in progress and initiate the log-on process.

e. Ground Station does not support RLS Mode (reason code 05_h) The DLS/ACARS HF Data Link ground station received a Numbered Data LPDU. On Receipt of a Log-Off Request LPDU, the aircraft HF Data Link function should terminate the session in progress and initiate the log-on process.

f. Other (reason code 06_h) On receipt of a Log_Off Request LPDU with this reason code, the aircraft HF Data Link function should terminate session in progress and initiate the log-on process.

c-3

g. Temporary Transceiver Shutdown (reason code 07_h). On receipt of a Log-Off Request LPDU with this reason code, the aircraft HF Data Link function should move to a non-operational state. The aircraft HF Data Link function should not be used until the unit has been powered off and on again, or until the unit is switched to Voice mode and subsequently to Data mode, or until the next flight leg. c-3

5.2.2.5 Unnumbered Data LPDU

Unnumbered Data LPDUs are used in the DLS mode to send downlink and uplink data packets which do not need to be acknowledged at the Link layer level. The format and contents of the Unnumbered Data LPDU are shown in Attachment 2-10A. The types of HFNPDUs that may be sent encapsulated in Unnumbered Data LPDUs are also defined in Attachments 2-10A, 2-10C and 2-10D and in Sections 5.2.2.5.1 to 5.2.2.5.4. c-3

5.2.2.5.1 HFDL System Table

The HFDL System Table HFNPDUs are uplinks sent in response to reception of HFDL System Table Request downlink HFNPDU (see Section 5.2.2.5.2). When transmitted in DLS mode, HFDL System Table uplink HFNPDUs are always addressed to all aircraft (broadcast) and delivered using the Unnumbered Data LPDU Type designation, whether initiated independently by a Ground Station or in response to a downlinked request. The Aircraft ID set to 00_h is used to differentiate between a broadcast uplink addressed to all aircraft listening on the frequency and any other uplink addressed to a specific aircraft sent using the Unnumbered Data LPDU Type. c-1

The HFDL Ground Station may broadcast a new HFDL System Table at any time. The aircraft HFDL function detects whether the most recently received HFDL System Table has a larger version number than the current HFDL System Table. If the new HFDL System Table has a larger version number, the aircraft HFDL System Table should replace the current HFDL System Table with the new HFDL System Table. The current HFDL System Table should not be replaced with the new HFDL System Table until all of the HFNPDUs for the new HFDL System Table have been received. The aircraft HFDL function should then begin to use the new HFDL System Table, regardless of whether the squitter has been updated with the new data base version. Once the new HFDL System Table has been broadcast over the channel, the HFDL Ground Station updates the data base version in the squitter to match the version of the new HFDL System Table. c-1

Broadcasting of the entire HFDL System Table may need to be delivered using multiple HFNPDUs. The ground station function responsible for delivery of the HFDL System Table determines the number of HFDL System Table HFNPDUs to be used based on the size of the table. The HFDL System Table should always be broadcast at 300 bps and the HFDL System Table HFNPDUs should be sized to fit within a double slot operated at 300 bps. c-1

COMMENTARY

A service provider may choose to implement the delivery of the HFDL System Table using the RLS mode. However, in that case the HFDL System Table HFNPDU and the Numbered Data LPDUs encapsulating each segment of the HFNPDU are to be addressed to the aircraft that requested the HFNPDU System Table. The maximum size of each HFNPDU is 424 octets in this case. c-1

The format of the HFDL System Table HFNPDU transmitted by the ground station using the DLS mode and the all-aircraft broadcast address is defined in Attachment 2-10C and Below. The HFDL System Table is segmented to fit the available number of user bytes in each HFNPDU and minimize the number of HFNPDUs used for the broadcast. The HFDL System Table should be segmented along both field and octet boundaries.

a. **MID**. See Section 5.2.2(a).

b. **Ground Station ID**. See Section 5.2.2(b).

c. **Aircraft Address**. See Section 5.2.2(c), except the Aircraft ID is set to 00_h to indicate that a broadcast LPDU is encapsulated by the MPDU.

c1. **MDF**. See Section 5.2.2(c3). The DDR field is set to zero since this MDPU encapsulates a general broadcast LPDU.

c2. **LPDU Size**. The field is fixed at one octet. The LPDU size value is the number of octets beginning with the LPDU Type field and terminating with the last octet of the FCS field less one. The Flush field in not included.

c3. **FCS**. See Section 5.2.2.1(c).

d. **LPDU Type**. The LPDU Type is Unnumbered Data and is set to $0D_h$.

e. **HFNPDU Type**. The first octet is fixed at FF_h and the second identifies it as an HFDL System Table broadcast by setting it to $D0_h$.

f. **PDU Sequence Number**. The PDU Sequence Number is used to identify the PDU within the various HFNPDUs used to broadcast an entire HFDL System Table. An entire sequence of PDUs should be concatenated to form the complete HFDL System Table. The PDU Sequence Number has two subfields defined next.

f1. **Sequence Number**. The least four significant bits of the PDU Sequence Number contain a sequence number (0 to 15) that identifies the order of the HFNPDU within the sequence of HFNPDUs used to broadcast the entire table.

f2. **Number of Packets.** The most four significant bits of the PDU Sequence Number identify the total number of HFNPDUs (1 to 16) minus one used to broadcast the entire table.

g. **PAD and Dbase Version**. A two octet field consisting of 4 bits of padding and a 12 bit Dbase Version field are used to uniquely identify the HFDL System Table contents from all others within the range 0 to 4095. The Dbase Version number is incremented by one each time a revision is made to the contents of the HFDL System Table. The revision that follows 4095 resets the field to zero. (This happens in 341 years if one change is made per month, or in 11 years if a change is made every day). Each time a new System Table is released the DBASE Version number increases by one. This allows aircraft to detect the relative age of DBASE numbers and System Tables. The 4 bit PAD field (0_h) is transmitted first followed by the Dbase Version encoded as three hex digits (000_h to FFF_h). The least significant bit of the least significant hex digit of the Dbase Version is transmitted immediately after the 4 PAD bits, followed by the LSB of the next octet and ending with the MSB of the octet. These fields are sent with each HFDL System Table HFNPDU.

h. **Ground Station Data**. The ground station data is contained in a variable length field. The field contains ground station ID, location, squitter version, list of frequencies assigned to the ground station, and squitter timing for each frequency. The various ground station data fields are as follows.

h1. **Ground Station ID**. See Section 5.2.*2* (b).

h2. **Ground Station Location**. The ground station location is encoded in a 5 octet (40 bits) field. The latitude is encoded in the first 20 bits beginning with the LSB in the first bit position and progressing upward through bit 19 plus a sign bit in the 20th position as a BNR based on a fraction of 180 degrees. A sign bit of 0 indicates a northern latitude. The longitude is encoded in the second 20 bits beginning with the LSB in the 21st bit position and progressing upward through bit 39 plus a sign bit in the 40th position as a BNR based on a fraction of 180 degrees. A sign bit of 0 indicates an eastern longitude.

COMMENTARY

The following is an example of the calculation used to determine the fractional latitude and longitude values used in the Broadcast System Table.

Attachment 2-8C contains an example of a Broadcast HFDL System Table. Octets 54, 55, and 56 (bits 1 to 4) contain a latitude value of N59° 21.70'.

The sign bit for this field is located in octet 56, bit 4. This bit has a value of 0. Therefore, this is northern latitude. Negative values are encoded using twos-complement.

The bits of octet 54 through bit 3 of octet 56 form a 19 bit unsigned number. This number has a value of $2A367_h$. The maximum value this field can hold is: $2^{20}-1 = 7FFFF_h$.

To determine the latitude value in minutes, divide the field value, by the maximum field value ($2A367_h \div 7FFFF_h = 0.329787_d$). Since this field represents a fractional value of 180°, this fractional value is multiplied by 180 ($0.329787_d * 180 = 59.36166$). The fractional portion of the degrees represents minutes (0.36166° = to 21.70').

Therefore, the 19 bit field value of $2A367_h$ represents 59° 21.70'.

h3. **Squitter Version and Number of Frequencies**. The 3 least significant bits of the next octet contain the squitter version broadcast by the ground station (see Section 5.2.1.7(a). The number of frequencies authorized for packet data service at the ground station is encoded in the 5 most significant bits. The encoded value does not exceed 20.

h4. **Frequency Fields**. The frequencies are encoded in four octet fields beginning with the highest frequency authorized for packet data service and the ground station and proceeding to the lowest frequency authorized. The

5.2.2.5.1 HFDL System Table (cont'd)

first three octets contain the frequency encoded as six 4-bit BCD digits with the first transmitted BCD digit representing the 100 Hz increment and the sixth transmitted BCD digit representing the 10 MHz increment. The 2 most significant bits of the sixth BCD digit are always set to zero. The least four significant bits of the fourth octet contain the Master Frame slot position (0 to 12) in which squitters are broadcast on this frequency. The 4 most significant bits are pad bits set to 0_h.

i. **FCS.** See Section 5.2.2.1(d).

5.2.2.5.2 HFDL System Table Request

The HFDL System Table Request HFNPDU is a four octet packet sent by an aircraft to request that the ground station uplink the current version of the HFDL System Table. The HFDL System Table Request HFNPDU payload consists of a two octet field. Each bit in this field corresponds to an HFDL System Table HFNPDU. The "first transmitted bit" in the two-byte field is a request for the first HFNPDU and the "last transmitted bit" is a request for the 16th HFNPDU. If this is the first request by an aircraft HFDL function, all of the bits in this field are 1. If an HFNPDU, or HFNPDUs, is lost on the subsequent broadcast uplink, the appropriate bit, or bits, are set to 1 in the HFDL System Table request and only those HFNPDUs would be uplinked by the HFDL Ground Station.

c-1 COMMENTARY

In order to support this capability, an HFDL System Table is parsed by the HFDL Ground Station to always generate the same HFNPDUs. Uplink HFNPDUs are rebroadcast to all aircraft, not just to the requesting aircraft. This addresses the potential problem of some atmospheric event (lightening strike) knocking out an HFNPDU for all aircraft and having all aircraft on a channel request a rebroadcast of the same HFNPDU.

The aircraft should send this downlink if the aircraft tunes to a new frequency and the Dbase Version in the Active Frequency field of the squitter does not match the aircrafts. An aircraft should not transmit an HFDL System Table request until it has logged on to the ground station. The format of the four octet HFDL System Table Request is defined in Attachment 2-10A.

5.2.2.5.3 Performance Data

The Performance Data HFNPDU is an optional HFNPDU that may be used to downlink system performance data collected by the aircraft. The aircraft HF Data Link function should send Performance Data HFNPDUs as space permits in downlink MPDUs with the exception of the Log-On Request message. The aircraft HF Data Link function should not generate a separate downlink message to send c-1 performance data unless the downlink is in response to an HF Data Link ground station poll. The aircraft HF Data Link function generates a new Performance Data HFNPDU every time a successful frequency change is made (Log-On Confirm message received). The Performance Data HFNPDU should be stored and then transmitted in the first MPDU downlink with available space. The aircraft HF Data Link function should be able to store at least 5 Performance Data HFNPDUs. c-1

At the end of each logon session the aircraft should store a Performance Data packet which reflects the statistics gathered from the previous logon session. This packet holds data collected from the previous logon session. The packet should be held in a FIFO queue. During a logon session the aircraft should send Performance Data as transmit space permits, but should not increase the downlink transmission c-3 rate above the minimum required to contain other user data (non-Performance Data) in the MPDU. The aircraft should first choose the Performance Data packet at the front of the Performance Data Queue, otherwise a Performance Data packet reflecting the current logon session accumulated data should be sent. Once a Performance Data packet from a previous session has been sent, it should be removed from the queue. The Performance Data Queue should be capable of holding 5 packets. When an insertion is to be made to the c-1 queue while the queue is full, the oldest packet should be removed and the current packet inserted.

COMMENTARY

A Performance Data HFNPDU should be generated and downlinked if the aircraft HF Data Link function is polled (assigned a downlink slot) and there is no downlink MPDU in the message queue.

The format of the Performance Data HFNPDU transmitted by the aircraft is defined below. c-2

a. **MID**. See Section 5.2.2(a).

b. **Ground Station ID**. See Section 5.2.2(b). c-3

c. **Aircraft Address**. See Section 5.2.2(c).

c1. **Reservation Request**. See Section 5.2.2(c2).

c2. **LPDU Size**. The field is fixed at one octet. The LPDU Size value is the number of octets beginning with the LPDU Type field and terminating with the last octet of the FCS field less one. The Flush field is not included. In the case where a Performance Data HFNPDU is encapsulated by the LPDU, the LPDU has 53 octets and the LPDU Size value should be set to 34_h.

d. **LPDU Type**. The LPDU Type is set to $0D_h$

e. **ICAO 24-bit Aircraft Address**. This is a 3 octet field which contains a unique 24 bit address that identifies the aircraft. The ICAO 24-bit Aircraft Address is denoted with names A1, A2, through A24 as shown in ARINC c-3 Characteristic 753, Appendix C. The transmit ordering of the ICAO 24-bit Aircraft Address should begin with A1 and continue through A24.

f. **HFNPDU Type**. The first octet is fixed at FFh and the second identifies it as a Performance Data HFNPDU by setting it to $D1_h$.

g. **Flight Number ID**. This is a 6 octet field which contains the airline flight number identifier if known. Otherwise, it may be set to all zeroes.

5.0 AIR/GROUND SERVICES AND PROTOCOLS OF LAYER 2 - LINK LAYER

The six octets of this field should be set as follows:

octet 1	most significant bit set to zero;
octet 1	lower seven bits set to character #1 (MSB of Flight ID);
octet 2	most significant bit set to zero;
octet 2	lower seven bits set to character #2;
octet 3	most significant bit set to zero;
octet 3	lower seven bits set to character #3;
octet 4	most significant bit set to zero;
octet 4	lower seven bits set to character #4;
octet 5	most significant bit set to zero;
octet 5	lower seven bits set to character #5;
octet 6	most significant bit set to zero;
octet 6	lower seven bits set to character #6 (LSB of Flight ID).

Characters 7, and 8, if available, are not included in the Flight Number ID field. The Flight Number ID may be available in specific installations in ARINC 429 Labels 233, 234, and 235.

h. **Aircraft Position**. This is a 7 octet field. The first 5 octets (40 bits) contain the current Latitude and Longitude of the aircraft encoded as defined in Section 5.2.2.5.1(h2). The other two octets contain UTC expressed in seconds with a resolution of 2 seconds (UTC divided by 2). The least significant bit of UTC is transmitted first and the most significant last. The UTC should express the time the position data was gathered, not the time the Performance Data NPDU was transmitted. When no position information is available to the HFDR, the aircraft position should be specified as +180º for both latitude and longitude.

i. **Performance Data.** This is a fixed length field whose length is dependent on the version of the performance data.

i1. **PD Version**. This is a 1 octet field which identifies the version number and contents of the performance data. This field is initially set to 01_h signifying version 1. For versions other than 1, the lower 3 bits constitute a version number ranging from 2 through 7, and 0. The upper 5 bits of the octet are allocated for vendor-specific purposes to identify hardware/software configuration information to be used to analyze performance of the aircraft units.

i2. **Flight Leg**. This is a one octet field which identifies the current flight leg. It is incremented by one every time the aircraft takes-off. When the flight leg count reaches 255, the next increment resets it to zero. The flight leg value that is in place when a performance data packet is being saved for transmission should be used in the packet. The Flight Leg value should be retained across power cycles of the HFDR.

i3. **Ground Station ID**. This is a one octet field which identifies the ground station for which the performance data applies. It is encoded as defined in Section 5.2.2(b).

i4. **Frequency ID**. This is a one octet field which identifies the frequency for which the performance data applies. Its range is 1 (highest frequency assigned to the ground station) to 20.

i5. **Frequency Search Counts**. This is a four octet field. The first two octets contain the number of 32 second frames that the aircraft HF Data Link function was out of communications during the previous flight leg. The other two octets contain the number of 32 second frames that the aircraft HF Data Link function was out of communications during the current flight leg.

COMMENTARY

The purpose of the frequency search count is to provide the means to determine the fraction of a flight leg during which the aircraft is out of range coverage from all HFDL ground stations. Therefore, the frequency search count should only be updated when the aircraft is in the air and the HF Data Link function has determined that it has lost contact with the last ground station (if any) it was logged-on and a new frequency to log-on needs to be found.

i6. **HF Data Disabled Times**. This is a four octet field. The first two octets contain the total time in seconds that HF Data was not enabled during the previous flight leg. The other two octets contain the total time HF Data was not enabled during the current flight leg.

i7. **Uplink MPDU Data**. This is an 8 octet field. The first 4 octets contain the number of uplink MPDUs received on the identified frequency at 1800, 1200, 600 and 300 bps, respectively. The other 4 octets contain the number of uplink MPDUs received with errors (errors detected in at least one of the LPDUs or the header) at 1800, 1200, 600, and 300 bps, respectively. The counts are initialized at zero when the aircraft logs on the identified frequency and ground station and the appropriate counts are incremented by one whenever an uplink MPDU (not a squitter) is received.

COMMENTARY

If an uplink is indicated in the squatter and not received in the designated slot, the 300 bps Uplink Received With Error field should be incremented. This field should be incremented for each uplink slot specified in the squitter regardless of whether or not the uplink may have occupied a double slot.

i8. **Squitter Data**. This is a three octet field. The first two octets contain the total number of squitters received error free during the time aircraft was tuned to the identified frequency. The third octet contains the number of squitters which were received with errors or were not received during the time the aircraft was tuned to the frequency. Note that squitters not received while the aircraft was in Voice mode are not included in this count.

i9. **Downlink MPDU Data**. This is an 8 octet field. The first 4 octets contain the number of downlink MPDUs transmitted on the identified frequency at 1800, 1200, 600 and 300 bps, respectively. The other 4 octets contain the number of downlink MPDUs delivered successfully on the first try (all LPDUs in the MPDU positively acknowledged by the ground station) at 1800, 1200, 600, and 300 bps, respectively. The counts are initialized at zero when the aircraft sent the Log-On Request on the identified frequency and ground station and the appropriate counts are incremented by one whenever a downlink MPDU is transmitted and when the acknowledgments are received on subsequent squitters.

5.2.2.5.3 Performance Data (cont'd)

COMMENTARY

The uplink, squitter and downlink data sent with the first Performance Data HFNPDU after a Log-On Request message contains the counts for the last frequency the aircraft was logged on during the previous flight leg.

i10. **Frequency Change Code**. This is a one octet field. The first four bits of the last octet contain a code that indicates the reason for the last frequency change. It is set to 0_h when it was the first frequency search of the current flight leg. It is set to 1_h when the change was due to too many NAKs. It is set to 2_h when the change was due to squitters no longer received. It is set to 3_h when the switch resulted due to HF Data Disabled or extended operation of the opposite side radio for voice communication. It is set to 4_h when the switch was due to a ground station frequency change notice. It is set to 5_h when the change was due to a ground station down/channel down notice. It is set to 6_h when the change is due to poor uplink channel quality. If there has been no frequency search or change since the last PD HFNPDU was sent, it is set to 7_h. If the frequency change occurs when the aircraft is on the ground, the frequency change code is set to 8_h. The upper 4 bits of the octet are allocated for vendor-specific purposes to identify hardware/software configuration information to be used to analyze performance of the aircraft units.

COMMENTARY

Vendor specific information contained in the PD Version and Frequency Change Code fields of performance data is optional. The values should be zero if unused by the vendor. If non-zero, the vendor should supply documentation of the expected values for these fields relative to the PD version from 2-7, and 0. Candidate values for these information fields are hardware version, software version, parameter version, and equipment position (L/R).

5.2.2.5.4 Frequency Data

The Frequency Data HFNPDU is an HFNPDU that may be used to downlink system propagating frequency data collected by the aircraft during the most recent frequency search. The Frequency Data HFNPDU may be delivered with every Log-On Request or Log-On Resume LPDU.

The format of the Frequency Data HFNPDU transmitted by the aircraft in the Log-On Request or Log-On Resume LPDU is defined below.

a. **MID**. See Section 5.2.2(a).

b. **Ground Station ID**. See Section 5.2.2(b).

c. **Aircraft Address**. See Section 5.2.2(c), except the Aircraft ID is set to FF_h to indicate that a Log-On LPDU is encapsulated by the MPDU.

c1. **Reservation Request**. See Section 5.2.2(c2).

c2. **LPDU Size**. The field is fixed at one octet. The LPDU Size value is the number of octets beginning with the LPDU Type field and terminating with the last octet of the FCS field less one. The Flush field in not included. In the case where a Frequency Data HFNPDU is encapsulated by the LPDU, the LPDU has either 25, 31, 37, 43, 49 or 55 bytes, and the LPDU Size value should be set to 18_h , $1E_h$, 24_h , $2A_h$, 30_h , or 36_h respectively. The size is dependent upon the size of the variable length Frequency Data described in subparagraph i, below.

d. **LPDU Type**. The LPDU Type is set to $8F_h$ if the LPDU is a Log-On Request and to $4F_h$ if the LPDU is a Log-On Resume.

e. **ICAO 24-bit Aircraft Address**. This is a 3 octet field encoded as defined in Section 5.2.2.5.3(e).

f. **HFNPDU Type**. The first octet is fixed at FF_h and the second identifies it as a Frequency Data HFNPDU by setting it to $D5_h$.

g. **Flight Number ID**. This is a 6 octet field which contains the airline flight number identifier if known. Otherwise, it may be set to all zeroes. For the format of the contents of the Flight Number ID field see Section 5.2.2.5.3 sub-section g.

h. **Aircraft Position**. This is a 7 octet field encoded as defined in Section 5.2.2.5.3(h).

i. **Frequency Data**. This is a variable length field containing 1 to 6 fields with 6 octets each. Each 6 octet field contains data which indicates which frequencies are propagating from that ground station to the current aircraft position.

i1. **GS ID**. The first octet identifies the ground station (see Section 5.2.2(b).

i2. **Propagating Frequencies.** This is a five octet (40 bits) field. The first 20 bits encoded per Section 5.2.1.7 (g) indicate which frequencies are propagating (bit set to 1 indicates squitter was received on that frequency) and which are not (bit set to 0 indicates that squitter was not received). The second 20 bits encoded per Section 5.2.1.7 (g) indicate which frequencies were tuned to during the frequency search. Bit set to 1 indicates frequency was tuned, and bit set to 0 indicates the frequency was not attempted. Encoded values should represent the most recent frequency search.

5.2.2.6 Numbered Data LPDU

The Numbered Data LPDUs are used in the RLS mode to send downlink and uplink data packets. The Numbered Data LPDU contains the following fields: RN (see Section 5.2.4.2.1a), U(S)/D(S) (see Sections 5.2.4.2.3, 5.2.4.2.3.2, 5.2.4.2.4, and 5.2.4.2.4.2), BDU (see Section 5.2.4.2.1, and the FCS (see Section 5.2.2.1.d). The format and contents of the Numbered Data LPDU are shown in Attachment 2-10B.

5.2.2.7 Unnumbered Acknowledged Data LPDU

Unnumbered Acknowledged Data LPDUs are used in the DLS mode to send downlink ACARS data blocks. Unnumbered Acknowledge Data LPDUs are retransmitted when negatively acknowledged by the ground station. The format and contents of the Unnumbered Data LPDU are shown in Attachment 2-10G.

5.0 AIR/GROUND SERVICES AND PROTOCOLS OF LAYER 2 - LINK LAYER

5.2.3 LPDU Prioritization and Preemption

HF Data Link supports up to 16 levels of prioritization of user packets. Each LPDU is assigned a priority level between 15 and 0 with the highest priority level being 15 and the lowest 0. The LPDU priority level assignment is based on the type of LPDU. The priority level of Numbered Data and Unnumbered Data LPDUs also depend on the type HFNPDUs encapsulated within the LPDU. c-1

The priority level of an LPDU encapsulating a whole or a segment of an HF Subnetwork layer HFNPDU is determined from the priority level of the logical virtual circuit connection.

The priority of an LPDU encapsulating a whole or a segment of an ACARS HFNPDU is priority 7. The procedures for prioritizing the transmission of LPDUs of different priorities are defined in Sections 5.2.1.2.1 and 5.2.1.3. c-3

The priority that should be given to LPDUs is described in Table 5-4 below.

Table 5-4 LPDU Priorities

LPDU Type	Payload	Priority Q
Log-On Request	Unsegmented HFNPDU	13
Log-Off Request	Optional	13
Log-On Resume		13
Log-On Confirm	None	13
Log-On Resume Confirm		13
Log-On Denied		13
Numbered DATA	HF Subnetwork layer HFNPDU	Priority of Virtual Circuit
	ACARS HFNPDU	7
Unnumbered DATA	HFDL System Table uplink	6*
	Performance Data downlink	6*
	HFDL System Table Request downlink	13
	Frequency Data	6*

c-3 * The priorities indicated in Table 5-4 should apply to HFNPDUs whether they are transmitted in unnumbered or numbered LPDUs.

5.2.4 Link Control Protocols

The Link Control functions of the Data Link layer provide for the orderly transmission of HFNPDUs and delivery of HFNPDUs to HF Subnetwork layer. The HF Data Link layer supports a Direct Link Service (DLS) mode, and a Reliable Link Service (RLS) mode.

5.2.4.1 Direct Link Service Mode Protocol

The DLS protocol may only be used to transfer certain types of HFNPDUs (defined in Attachment 2-10A and 2-10G and Section 5.2.2.5 and 5.2.2.7) between the airborne HFDL subsystem and an HFDL ground station. In the DLS mode, uplink or downlink HFNPDUs are not segmented by the Link layer. c-1

COMMENTARY

> However, if the application generating the HFNPDUs has knowledge of the maximum data rate supported, it may choose an HFNPDU size compatible with that data rate.

The DLS protocol supports unacknowledged transmission of uplink and downlink LPDUs, as well as acknowledged transmission of downlink (only) LPDUs. Tables 1, 2, 3B and 4 in Attachment 2-12 define the events, states, and state transitions for the acknowledged and unacknowledged DLS protocol. c-1

The acknowledged DLS protocol is used primarily for the transmission of downlink ACARS blocks as described below.

The unacknowledged DLS protocol is primarily used to send the broadcast uplink HFNPDUs (see Section 5.2.2.5), but can also be used to send other HFNPDUs not requiring automatic retransmission by the Link layer, including ACARS blocks. c-1

A whole (unsegmented) HFNPDU with up to 253 octets may be encapsulated into an unnumbered (DLS) LPDU when the physical layer (channel) can reliably support operation at the data rate needed to transmit a packet of its size.

When routing HFNPDUs received using the DLS mode, the first two octets in the HFNPDU are examined.

If the first octet is set to FF_h, and the second is set to $D0_h$, then the HFNPDU should be routed to the function responsible for processing HFDL System Table uplinks (aircraft side only).

If the first octet is set to FF_h, and the second is set to $D2_h$, then the HFNPDU should be routed to the function responsible for processing HFDL System Table Request downlinks (ground station side only).

If the first octet is set to FF_h, and the second is set to $D1_h$, then the HFNPDU should be routed to the function responsible for collecting and processing Performance Data (PD) downlinks (ground station side only).

If the first octet is set to FF_h, and the second is set to $D5_h$, then the HFNPDU should be routed to the function responsible for processing Frequency Data (FD) downlinks (ground station side only).

DLS/ACARS Implementation

It is possible to implement HF Data Link using only the DLS Mode protocol. This type of implementation may be used to support ACARS message traffic including FANS 1 c-1

15.2.4.1 Direct Link Service Mode Protocol (cont'd)

c-1 messages. In order to support the delivery of ACARS messages in the DLS Mode, the following functionality should be provided.

DLS/ACARS to ATN Transition

c-2

a. In order to provide a transition path to RLS/ATN, each squitter includes an RLS Capability bit. This bit field is set to 0 if the Ground Station is DLS/ACARS only capable. This bit field is set to 1 when the HF Data Link Ground Station is RLS/ATN capable. As DLS/ACARS HF Data Link Ground Stations are upgraded to support RLS/ATN, they should continue to be able to provide backwards compatibility with DLS/ACARS only aircraft HF Data Link functions.

b. DLS/ACARS only aircraft HF Data Link functions should generate a DLS Log-On Request using the LPDU Type 1111 1101. A unique Log-On Request for DLS aircraft enables an RLS/ATN capable HF Data Link Ground Station to be able to respond appropriately to a DLS/ACARS capable aircraft.

c-1

c. The DLS/ACARS HF Data Link Ground Station discards any Numbered Data LPDUs received from an aircraft HF Data Link function and sends a Log-Off Request message with the appropriate reason code.

Squitter Acknowledgments

The DLS/ACARS HF Data Link Ground Station acknowledges the receipt of downlink LPDUs in the squitter acknowledgment field. The aircraft HF Data Link function should be able to retransmit ACARS HFNPDUs if the downlink LPDU containing the ACARS HFNPDU is not successfully acknowledged by the HF Data Link Ground Station.

DLS Retransmission Protocol

ACARS HFNPDUs should be encapsulated into Unnumbered Acknowledged Data LPDUs for transmission to the HF Data Link Ground Station. Up to two Unnumbered Acknowledged Data LPDUs may be transmitted in a 32 second Frame.

COMMENTARY

c-2

At any one time there may be no more than two distinct downlink ACARS HFNPDUs queued for delivery to the Ground Station: one containing a downlink ACARS message and the other an ACARS ACK block acknowledging an uplink. Any other queued ACARS HFNPDUs could only be duplicates of the ACARS message. Since it is critical that both the ACARS ACK and the ACARS message be delivered promptly, the retransmission protocol allows both of them to be sent in the same Frame.

If all of the Unnumbered Acknowledged Data LPDUs sent in a Frame are positively acknowledged in the succeeding squitter, then two more Unnumbered Acknowledged Data LPDUs may be sent in the next Frame.

If one or both Unnumbered Acknowledged Data LPDUs are negatively acknowledged (NAK'ed) in a squitter, then the NAK'ed Unnumbered Acknowledged Data LPDUs should be retransmitted up to two times. If after two retransmissions the NAK'ed Unnumbered Acknowledged Data LPDUs have not been positively acknowledged, the NAK'ed Unnumbered Acknowledged Data LPDUs should be discarded.

If a new ACARS downlink is received from the MU for transmission to the ground, and it matches an ACARS downlink currently in progress, the new ACARS downlink is discarded and the retransmission counters of the ACARS downlink currently in progress are reset to zero.

If a new ACARS downlink is received from the MU for transmission to the ground, and there are two ACARS downlinks currently in progress, and the ACARS downlink does not match either of the two new ACARS downlinks in progress, the oldest ACARS downlink in progress should be discarded.

c-2

COMMENTARY

If the Unnumbered Acknowledged Data LPDU which has been transmitted 3 times without success contains a downlink ACARS message, a duplicate of it may have already been retransmitted by the ACARS MU and is probably already queued for transmission or will shortly be sent. Similarly, if the Unnumbered Acknowledged Data which has been transmitted 3 times without success contains an ACARS ACK block, the ground based ACARS Processor will probably have retransmitted the uplink block for which the acknowledgment has yet to be received, or may soon do so.

No additional Acknowledged Unnumbered Data LPDUs may be sent until previously sent Unnumbered Data LPDUs are either positively acknowledged or are discarded.

Data Rate and Slot Assignments

The DLS/ACARS protocol does not support segmentation and MPDUs larger than 157 bytes can not be sent at 300 bps using a double slot. Instead, these large MPDUs are sent at 600 bps in a double slot. If a downlink can not be sent in a single slot at the assigned data rate, the aircraft HF Data Link function requests a double slot. The aircraft sends a downlink MPDU at 300 bps requesting a double slot. Given the size of an MPDU, available data rates and slot sizes are shown below:

c-1

MPDU Size	Lowest Single Slot Data Rate (bps)	Lowest Double Slot Data Rate (bps)
up to 67 bytes	300	300
68 .. 135 bytes	600	300
136 .. 157 bytes	1200	300
158 .. 270 bytes	1200	600
271 .. 315 bytes	1800	600
316 .. 405 bytes	1800	1200
406 .. 630 bytes		1200
631 .. 945 bytes		1800

5.0 AIR/GROUND SERVICES AND PROTOCOLS OF LAYER 2 - LINK LAYER

Log-On Resume Message

c-1 The DLS/ACARS HF Data Link Ground Station generates a Log-On Confirm message on receipt of either a Log-On Request message or a Log-On Resume Confirm message.

Default Field Values

Non-implemented fields within the HF Data Link protocol should contain a default value if possible. If the use of a default value is not possible or appropriate, then the field bits are set to 0.

5.2.4.2 Reliable Link Service Mode Protocol

The RLS protocol exchanges user data packets between airborne and ground peer Link layers. The data packets are peer to peer acknowledged, and retransmitted as needed to insure a reliable link.

The HFDL RLS protocol functions consist of:

a. Segmentation of HFNPDUs into BDUs and encapsulation into Numbered Data LPDUs (Segmentation sublayer in Attachment 2-1).

b. Reassembly of BDUs into HFNPDUs (Reassembly sublayer in Attachment 2-1).

c. Transmission acknowledgment and retransmission of c-1 LPDUs, and flow control performed by a Logical Link Control sublayer. Tables 1, 2 and 3A in Attachment 2-12 define the events, states, and state transitions for the airborne and ground Logical Link Control sublayer. Table 4 in Attachment 2-12 defines timers, counters and other parameters involved in the protocol. Table c-4 5-5 summarizes the information used to conduct the RLS protocol.

Table 5-5 Information Held by the HFDR Aircraft and Ground Station

Aircraft	Ground Station
D(A) - oldest sequence number not acknowledged by the ground station	**U(A) -** oldest sequence number not acknowledged by the aircraft
D(A)vect - flag indicating if D(A)+1..D(A)+8 has been acknowledged	**U(A)vect -** flag indicating if U(A)+1..U(A)+8 has been acknowledged
c-1 c-4 **D(N)vect -** flags indicating if the GS has negatively acknowledged D(A)+1..D(A)+k	**U(N)vect -** flags indicating if the aircraft has negatively acknowledged U(A)+1..U(A)+k
D(S) - next to send	**U(S) -** next to send
U(R) - oldest not received	**D(R) -** oldest not received
U(R)vect - flags indicating if U(R)+1..U(R)+8 has been received	**D(R)vect -** flags indicating if D(R)+1..D(R)+8 has been received

5.2.4.2.1 Segmentation of HFNPDUs into BDUs and Flow Control

In the RLS mode, HFNPDUs of up to 424 bytes are broken up (segmented) into smaller Basic Data Units (BDUs). Each BDU is encapsulated into a Numbered Data LPDU as shown in Attachment 2-10B. An HFNPDU may be broken up into no more than 8 BDUs. Each BDU contains at least one byte of data and no more than 53 bytes of data.

The HFDL should discard newly arrived ACARS packets if they are simply a copy of ACARS packets already in process. c-1

COMMENTARY

The largest BDU size of 53 bytes has been chosen so that an MPDU encapsulating a single BDU, i.e. a single LPDU, can be transmitted at 300 bps using a single slot.

COMMENTARY

The largest HFNPDU size of 424 bytes supported by the link layer has been chosen so that only one byte of overhead per segment, i.e., per BDU, is sufficient to allow reassembly of the HFNPDU at the receiving end.

An HFNPDU may be broken into up to 8 BDUs depending on the size of the HFNPDU. An 8-bit BDU header, defined in Attachment 2-10B and below, is appended to each BDU prior to encapsulation into a Numbered Data LPDU.

a. **HFNPDU Reference Number and Priority**. Each segmented HFNPDU is identified by a Reference Number (RN) encoded in bits 2 and 3 of the Numbered Data LPDU Type (see Attachments 2-9A and 2-10B) and its priority Q encoded in bits 1 through 4 of the BDU header (see Attachment 2-10B).

b. **M-bit.** Bit 5 in the BDU header is used to indicate whether the BDU is the last BDU (M = 0) in the sequence of BDUs making up an HFNPDU or not (M = 1).

c. **BDU Sequence Number.** Bits 6-8 in the BDU header are the BDU Sequence Number (BSN) in the range 0 to 7. The maximum number of BDUs per HFNPDU is eight. The first BDU has BSN=0. The second BDU has BSN=1. The nth BDU has BSN=(n-1). In this way the receiving HFDL System can detect the first BDU from an HFNPDU since it has BSN=0. The last BDU making an HFNPDU can be detected since the M-bit field should not be set to 1.

COMMENTARY

The HFNPDU Reference Number (RN) and its priority Q identify the HFNPDU associated with each BSN. A pair of numbers (RN,Q) different from the LPDU sequence U(S)/D(S) which encapsulates each BDU is used to identify each HFNPDU because the need for prioritization and preemption may cause different segments of an HFNPDU to be delivered out of sequence and interleaved with the BDUs of a different HFNPDU.

When building an MPDU for transmission, Numbered LPDUs are used (among others). BDUs having the highest priority should be chosen first for insertion into the c-1 Numbered LPDUs being sent. It should be noted that the relationship between a BDU and the Numbered LPDU that

5.2.4.2.1 Segmentation of HFNPDUs into BDUs and Flow Control (cont'd)

contains it exists only until the Numbered LPDU is either ACKed or NACKed. If the BDU is ACKed, then it can be reported as successfully transmitted to the segmentation layer. If the BDU is NACKed, then it should be placed into a prioritized BDU queue for retransmission. When a BDU needs to be retransmitted, it is once again placed into a Numbered LPDU for transmission. The BDU fields RN, Q, M-bit, and BSN remain the same as the initial transmission. The U(S)/D(S) field of the Numbered LPDU may not have the same value as the Numbered LPDU that contained the BDU in the initial transmission. This is due to the possibility of introduction of BDUs at a higher priority.

When choosing sequence numbers (U(S)/D(S)) in Numbered LPDUs the following should be considered. A sequence number (U(S)/D(S)) is not eligible for use in a Numbered LPDU transmission until the Numbered LPDU that last used the sequence number (U(S)/D(S)) is either ACKed or NACKed. For a Numbered LPDU to be considered ACKed, a squitter or a U(R)/U(R)Vect (D(R)/D(R)Vect) must be received providing positive acknowledgment of the Numbered LPDU. For a Numbered LPDU to be considered NACKed, a squitter or a U(R)/U(R)Vect (D(R)/D(R)Vect) must be received at least two slots after the transmission of the Numbered LPDU providing a negative acknowledgment. If the Numbered LPDU is ACKed, then the sequence number (U(S)/D(S)) used is considered unavailable for use until the window rotation includes it again. If the Numbered LPDU is NACKed, then the sequence number (U(S)/D(S)) used is made available for transmission in another Numbered LPDU.

The transmitting Segmentation sublayer should send the BDUs associated with at most 4 HFNPDUs of a given priority to the Logical Link Control sublayer and queue any following HFNPDUs with the same priority until confirmation that the first HFNPDU has been delivered to and acknowledged by the peer Logical Link Control sublayer.

5.2.4.2.2 Reassembly of BDUs into HFNPDUs, Flow Control and Routing

Reassembly of BDUs into an HFNPDU is initiated when a BDU with a new (RN,Q) and Aircraft ID not previously active in the reassembly process is received.

The HFNPDU reassembly is completed when the BDU with the M bit set to 0 and all other BDUs with the same (RN,Q) and aircraft address are received. If any BDUs are missing, a timer is started. If the outstanding BDUs do not arrive before the timer expires, the incomplete HFNPDU is delivered to the higher layer with an error indication.

When receiving BDUs and reassembling them into HFNPDUs the RN, Q, M-bit, and BSN fields are used to correlate the BDUs. The U(S)/D(S) field of the Numbered LPDU containing the BDU can not be used as a reference to correlate BDUs. This is because a retransmitted BDU may be contained in a Numbered LPDU having a different U(S)/D(S) number than the initial transmission.

For each priority level, the receiving reassembly sublayer should deliver reassembled HFNPDUs which have been received using the RLS mode (encapsulated in Numbered Data LPDUs) to the higher layer in order. HFNPDUs received and reassembled out of order should be queued until the missing HFNPDUs have been received or a timer expires.

When routing of assembled HFNPDUs received using the RLS mode the first two octets in the HFNPDU are examined. If the first octet is not set to FF_h, then the HFNPDU should be routed to the HF Subnetwork layer.

If the first octet is set to FF_h and the second octet is also set to FF_h, then the HFNPDU should be routed to the function that processes enveloped ACARS blocks.

If the first octet is set to FF_h, and the second is set to $D0_h$, then the HFNPDU should be routed to the function responsible for processing HFDL System Table uplinks (aircraft side only).

5.2.4.2.3 Uplink Transmission of LPDUs and Flow Control

All U(S) sequence number operations should be done using modulo 32 arithmetic. To describe the RLS uplink transmission protocol, it is useful to define a number of terms and parameters.

U(S) — U(S) is the 5-bit uplink sequence number embedded in the LT field of the uplink Numbered Data LPDUs.

U(A) — U(A) is oldest uplink sequence number which has not yet been acknowledged by the aircraft U(A)vect U(A)vect is a field of bits each of which represents whether or not each of the LPDUs starting from the sequence number U(A)+1 to U(A)+k has been acknowledged by the aircraft, where k is the transmit window size.

U(A)vect — U(A)vect is a field of k bits, each of which represents whether or not each of the LPDUs starting from the sequence number U(A)+1 to U(A)+k has been acknowledged by the aircraft, where k is the transmit window size. A bit set to one (1) indicates that the LPDU has been positively acknowledged.

U(N)vect — U(N)vect is a field of k bits each of which represents whether or not each of the LPDUs starting from the sequence number U(A)+1 to U(A)+k has been negatively acknowledged by the aircraft, where k is the transmit window size. For an LPDU to be considered negatively acknowledged a U(R)/U(R)vect must be received at least three slots after transmission of the LPDU. A bit set to one (1) indicates that the LPDU has been negatively acknowledged.

COMMENTARY

The Window size k can be larger than the eight bits of the U(R)vect. Those LPDUs transmitted in the window, but not included in U(R)vect can not be considered as either ACKed or NACKed.

U(R) U(R) is the 5-bit uplink sequence number of the oldest uplink LPDU not yet received by the aircraft. This is the uplink sequence number embedded in the Uplink Acknowledgment Field of downlink MPDUs (see Section 5.2.4.2.3.1).

c-4 U(R)vect U(R)vect is an 8-bit boolean array embedded in the Uplink Acknowledgment Field of downlink MPDUs (see Section 5.2.4.2.3.1). Each bit indicates whether or not each of the LPDUs starting from the sequence number U(R)+1 to U(R)+8 has been received by the aircraft. Each bit set to one (1) indicates that the corresponding LPDU having sequence number U(R)+i, where i = 1 to 8, has been received; otherwise, it is set to zero (0).

Whenever an aircraft receives a Numbered Data LPDU from the ground, the sequence number of the received LPDU should be compared to U(R). If the sequence number is equal to U(R) the aircraft should:

a. Pass the LPDU data to the reassembly sublayer of the Link layer (see Section 5.2.4.2.2).

b. Increment U(R)

c. If U(R)vect modulo 2 is = 1, then: Divide U(R)vect by 2 discarding the remainder and repeat steps 1 and 2.

d. If U(R)vect modulo 2 is = 0, then Divide U(R)vect by 2.

If the sequence number is greater than U(R), and less than U(R)+k, where k is the transmit window size specified by the ground station in the Log-On Confirm, the aircraft should set the appropriate bit in U(R)vect. If the bit in U(R)vect was 0, then the LPDU should be passed to the reassembly area.

If the sequence number is less than U(R), but greater than or equal to U(R)-k, the aircraft should consider the received Numbered Data LPDU as a repeat and discard it. If there are no outstanding LPDU downlinks waiting to be sent, then the aircraft should send an empty downlink with the appropriate Uplink Acknowledgment Field indicating the next expected uplink sequence number U(R). Otherwise, the U(R) value is sent in the next downlink LPDU.

c-1 If the sequence number is less than U(R)-k or greater than or equal to U(R)+k, the aircraft should consider itself logged off and initiate a frequency search and log on.

5.2.4.2.3.1 Uplink Acknowledgment Field

c-3 Each downlink MPDU header contains an Aircraft Address Field (see Section 5.2.2(c)) containing an Uplink Acknowledgment Field. The Uplink Acknowledgment Field contains the three bit UDR, a five bit U(R), and an eight bit U(R)vect.

c-1 When the ground station receives a downlink transmission it should update the U(A)vect with the acknowledgment bits contained in U(R)vect and update the U(N)vect with the negative acknowledgment bits contained in U(R)vect. Those BDUs contained in the Numbered LPDUs which are not acknowledged in U(A)vect and are negatively acknowledged in U(N)vect should be scheduled for retransmission.

5.2.4.2.3.2 Uplink LPDU Sequence Number Assignment

When a ground station is sending BDUs, a Numbered LPDU is created, and a sequence number is assigned. The assigned sequence number is either a previously used sequence number or a new sequence number equal to U(S) (the next available unused sequence number). A previously used sequence number should be used when there is a bit field in U(A)vect which is zero and U(N)vect is one. In this case the sequence number has been sent, but the aircraft has indicated it was not received. If a reused number is chosen, then the bit in U(N)vect should be set to zero. A new number can be used when U(S) < U(A) + k, where k is the transmit window size specified in the Log-On Confirm uplink LPDU. If a new sequence number is used, then U(S) should be incremented. If U(S) = U(A) + k, then a new sequence number can not be assigned until U(A) is increased (note that U(S) > U(A) + k is not allowed). c-1

5.2.4.2.3.3 Request Acknowledge

In order to speed up delivery of uplink LPDUs the ground station may assign a slot to an aircraft to allow the aircraft to acknowledge uplink Numbered Data LPDUs. If the ground station does not hear a reply from the aircraft, the ground station may further elicit an acknowledgment from the aircraft by assigning another slot to the aircraft in the following squitter.

In order for the ground station to determine if an aircraft is still logged on, the ground station may poll the aircraft by assigning a downlink slot to the aircraft. If the aircraft does not respond by transmitting an MPDU in the slot provided, the ground station may poll again. If, for the second time the aircraft fails to respond, the ground station should conclude that the aircraft is no longer logged on. The two polls done by the ground station should be separated in time by at least five minutes, with no intervening downlinks received from that aircraft during this time. This time difference is needed to insure that an aircraft is not deemed to be logged off when the aircraft HF system is currently being used for voice traffic. c-1

COMMENTARY

Because the complete acknowledgment state may be determined from each downlink MPDU header, reception of an MPDU serves to positively or negatively acknowledge all uplink LPDUs.

5.2.4.2.4 Downlink Transmission of LPDUs and Flow Control

All D(S) sequence number operations should be done using modulo 32 arithmetic. c-1

To describe the RLS downlink transmission protocol, it is useful to define a number of terms and parameters.

D(S) D(S) is the 5-bit downlink sequence number embedded in the LT field of the downlink Numbered Data LPDUs.

D(A) D(A) is oldest downlink sequence number which has not yet been acknowledged by the ground station.

5.2.4.2.4 Downlink Transmission of LPDUs and Flow Control (cont'd)

D(A)vect D(A)vect is a field of k bits, each of which represents whether or not each of the LPDUs starting from the sequence number D(A)+1 to D(A)+k has been acknowledged by the ground station, where k is the transmit window size. A bit set to one (1) indicates that the LPDU has been positively acknowledged.

c-1

c-4

D(N)vect D(N)vect is a field of bits each of which represents whether or not each of the LPDUs starting from the sequence number D(A)+1 to D(A)+k has been negatively acknowledged by the ground station, where k is the transmit window size. For an LPDU to be considered negatively acknowledged a D(R)/D(R)vect or a squitter must be received at least three slots after transmission of the LPDU. A bit set to one (1) indicates that the LPDU has been negatively acknowledged.

c-1

c-4

D(R) D(R) is the 5-bit downlink sequence number of the oldest downlink LPDU not yet received by the ground station from the aircraft.

D(R)vect D(R)vect is an 8-bit boolean array used by the HFDL ground station to determine which LPDUs have been received and which have been lost in transit. Each bit indicates whether or not each of the LPDUs starting from the sequence number D(R)+1 to D(R)+8 has been received by the ground station. Each bit set to one (1) indicates that the corresponding LPDU having sequence number D(R)+i, where i = 1 to 8, has been received; otherwise, it is set to zero (0).

c-4

Whenever a ground station receives a Numbered Data LPDU from an aircraft the sequence number of the received LPDU should be compared to D(R). If the sequence number is equal to D(R) the ground station should:

a. Pass the LPDU data to the reassembly sublayer of the Link layer (see Section 5.2.4.2.2).

b. Increment D(R).

c. If D(R)vect modulo 2 is = 1, then Divide D(R)vect by 2 discarding the remainder and repeat steps 1 and 2.

d. If D(R)vect modulo 2 is = 0, then Divide D(R)vect by 2.

If the sequence number is greater than D(R), and less than D(R)+k, where k is the transmit window size used by the ground station, the ground station should set the appropriate bit in D(R)vect. If the bit in D(R)vect was 0, then the LPDU should be passed to the reassembly area.

If the sequence number is less than D(R), but greater than or equal to D(R)-k, the ground station should consider the received Numbered Data LPDU as a repeat and discard it.

If the sequence number is less than D(R)-k or greater than or equal to D(R)+k, the ground station should send a Log-Off Request LPDU with the reason code set to 'Protocol Error.'

5.2.4.2.4.1 Downlink Acknowledgment Field

Each squitter contains a 288-bit Downlink Acknowledgment Field. This field contains 24 twelve bit subfields. The 12-bit subfields each contain all acknowledgment data for one of the slots in the previous 24 non-squitter slots starting with slot 11 in the previous frame. Each 12-bit field contains an 8-bit Aircraft ID or alias (set to 0 if no reception or uplink slot) and a four bit field indicating in order which, if any, LPDUs encapsulated within an MPDU were correctly received in the corresponding slot. It is necessary for an aircraft to record the slot number and order within the MPDU transmitted in the slot in which all LPDUs are transmitted. In addition, no aircraft may transmit more than 8 LPDUs in a single slot (15 in a double slot). c-1

The frame has 13 slots, the first 12-bit field acknowledges any possible transmission in slot 11 three frames previous. The second 12-bit field acknowledges any transmission in slot 12 three frames previous. The third 12-bit field acknowledges any transmission in slot 1 two frames previous. The 15th 12-bit field acknowledges any transmission in slot 1 of the previous frame. The 24th 12-bit field acknowledges any transmission in slot 10 of the previous frame. Each 12-bit acknowledgment field contains an 8-bit Aircraft ID followed by a 4-bit field that acknowledges the LPDUs transmitted in the slot. For double slot transmissions two acknowledgment fields are used to acknowledge the LPDUs transmitted.

Acknowledgments to downlinks sent using a single slot are represented as follows:

If 1 to 4 LPDUs are transmitted in the slot, then the bits have following meaning:

Slot acknowledgment field bit 1 acknowledges LPDU 1

Slot acknowledgment field bit 2 acknowledges LPDU 2

Slot acknowledgment field bit 3 acknowledges LPDU 3

Slot acknowledgment field bit 4 acknowledges LPDU 4

If 5 to 8 LPDUs are transmitted in the slot, then the bits have the following meaning:

Slot acknowledgment field bit 1 acknowledges LPDU 1 and 2 c-1

Slot acknowledgment field bit 2 acknowledges LPDU 3 and 4

Slot acknowledgment field bit 3 acknowledges LPDU 5 and 6

Slot acknowledgment field bit 4 acknowledges LPDU 7 and 8.

Acknowledgments to downlinks sent using double slots are represented as follows:

If 1 to 8 LPDUs are transmitted in the slots, then the bits have the following meaning:

First slot acknowledgment field bit 1, acknowledges LPDU 1

First slot acknowledgment field bit 2, acknowledges LPDU 2

First slot acknowledgment field bit 3, acknowledges LPDU 3

First slot acknowledgment field bit 4, acknowledges LPDU 4

Second slot acknowledgment field bit 1, acknowledges LPDU 5

Second slot acknowledgment field bit 2, acknowledges LPDU 6

Second slot acknowledgment field bit 3, acknowledges LPDU 7

Second slot acknowledgment field bit 4, acknowledges LPDU 8.

If 9 to 15 LPDUs are transmitted in the slots, then the bits have the following meaning:

First slot acknowledgment field bit 1, acknowledges LPDU 1 and 2

First slot acknowledgment field bit 2, acknowledges LPDU 3 and 4

c-1

First slot acknowledgment field bit 3, acknowledges LPDU 5 and 6

First slot acknowledgment field bit 4, acknowledges LPDU 7 and 8

Second slot acknowledgment field bit 1, acknowledges LPDU 9 and 10

Second slot acknowledgment field bit 2, acknowledges LPDU 11 and 12

Second slot acknowledgment field bit 3, acknowledges LPDU 13 and 14

Second slot acknowledgment field bit 4, acknowledges LPDU 15.

The acknowledgment definition is shown in Attachment 2-8B.

COMMENTARY

The number of slots in a frame is 13. Slots within a frame are numbered 0 through 12 with slot 0 designated for squitter transmission. The Downlink Acknowledgment Field does not have fields for any squitter slots. Slot acknowledgment fields corresponding to slots assigned to uplinks are set to all 0's.

Any Numbered Data LPDU which is not acknowledged in a correctly received squitter should be retransmitted. If the first squitter following a downlink is not received correctly, the aircraft should wait for the second squitter.

Whenever a downlink Numbered Data LPDU is acknowledged by the squitter, the aircraft compares the sequence number of the acknowledged LPDU to D(A). If the sequence number is equal to D(A), the aircraft should:

a. Increment D(A), and delete the LPDU from its queue.

b. If D(A)vect modulo 2 is = 1, then Divide D(A)vect by 2 discarding the remainder and repeat steps 1 and 2.

c. If D(A)vect modulo 2 is = 0, then Divide D(A)vect by 2.

If the sequence number is greater than D(A), and less than D(A)+k, where k is the transmit window size specified by the ground station in the Log-On Confirm, the aircraft should set the appropriate bit in D(A)vect.

If the sequence number is less than D(A) or greater than or equal to D(A)+k, the aircraft should send a Log-Off Request LPDU with the reason code set to 'Protocol Error'.

5.2.4.2.4.2 Downlink MPDU Sequence Number Assignment

When an aircraft is sending BDUs, a Numbered LPDU is created, and a sequence number is assigned. The assigned sequence number is either a previously used sequence number or a new sequence number equal to D(S) (the next available unused sequence number). A previously used sequence number should be used when there is a bit field in D(A)vect which is zero and D(N)vect is one. In this case the sequence number has been sent, but the ground station has indicated it was not received. If a reused number is chosen then the bit in D(N)vect should be set to zero. A new number can be used when D(S) < D(A) + k, where k is the transmit window size specified in the Log-On Confirm uplink LPDU. If a new sequence number is used then D(S) should be incremented. If D(S) = D(A) + k, then a new sequence number can not be assigned until D(A) is increased (note that D(S) > D(A) + k is not allowed). c-1

5.2.5 Airborne Link Management Functions

The airborne Link Management functions are performed by a Link Management Entity (LME) and consist of:

a. HF Link establishment and management, including Voice/Data mode switching.

b. HF link quality monitoring and status indication.

c. HF Data Link (HFDL) System Table Management.

e. HFDL function built-in-test and fault indication.

5.2.5.1 HF Link Establishment and Management

The procedures to be followed to establish, re-establish and terminate an air-ground connection between an aircraft and an HFDL ground station are referred to as HF Link Establishment and Management. These procedures consist of the Log-On, Log-On Resume and Log-Off procedures defined in Sections 5.2.5.1.1 through 5.2.5.1.3, and HF Voice/Data Switching defined in Section 5.2.5.1.5. Attachment 2-13 defines the events, states, and state transitions involved in the management of the air/ground

5.2.5.1 HF Link Establishment and Management (cont'd)

link. In dual HFDL installations, the Log-On, Log-On Resume and Log-Off procedures are performed by the master HFDL installation while the slave HFDL installation performs the slave link management procedure defined in Section 5.2.5.2.

5.2.5.1.1 Aircraft Log-On Procedure

Every aircraft logs on to an HF Data Link ground station and is assigned a unique Aircraft ID (alias address) before proceeding to send any traffic. The log-on procedure is fully automatic and transparent to the crew. Each aircraft should maintain an HFDL System Table which contains a list of ground stations and their frequency assignments in non-volatile memory. Details of this table are provided in Section 5.2.5.4.

The LME of an aircraft trying to access the HF Data Link network for the first time after power on should initiate the search for a suitable frequency from the list of frequencies in the HFDL System Table.

The LME should tune the HF transceiver to the first frequency in the list of frequencies and listen for the reception of a squitter for at least 35 seconds. If a squitter is received without CRC error, the squitter format version matches that expected by the aircraft, the Signal Quality Measured (SQM) is acceptable, and one or more random access slots are available for Log-On, the LME should issue a DL_CONNECT.request to the Link Control function which in turn should send a Log-On Request downlink (refer to Section 5.2.2.2). The slot used to send the Log-On downlink should be selected at random from all the random access slots available for Log-On in the frame. If the LME fails to detect a squitter that meets the above criteria, or if no slots are available, then it should tune the HF transceiver to the next frequency in the list, and repeat the procedure until a usable frequency is found.

COMMENTARY

Several frequency search algorithms have been discussed by the HF Data Link subcommittee ranging from selecting the first frequency that meets an acceptable set of criteria (shortest outage time) to tuning to all frequencies and then selecting the frequency with the best quality (long outage time).

A compromise between these two extremes is an algorithm where the aircraft tunes to as many frequencies as possible in a period of 64 seconds and selects the best from those frequencies which meet the minimum set of criteria defined above. If none of those frequencies tried to meet the criteria, then the aircraft continues searching and selects the first frequency that meets the selection criteria. By using this search strategy the aircraft can include data indicating which frequencies are propagating from the various HFDL ground stations tried to the current aircraft position along with the Log-On Request (see Section 5.2.2.5.4).
c-3 The HF Data Link ground system may then use this information to make a better decision as to what frequencies to actively monitor.

Once the frequency search algorithm is complete and the LME has received what is considered to be a good frequency, the hardware is tuned for transmit. During this initial tuning cycle there may be a small amount of radiated energy that may be receivable by the ground c-1 station or other aircraft. Therefore, this initial tune should take place at a time other than when the squitter is being broadcast by the ground station.

If the LME cannot find a usable frequency from among all frequencies in the list, it should issue a Data Link Unavailable indication to the cockpit (see Section 5.2.5.3. c-3

A confirmation that the ground station has received the Log-On Request is provided by a positive acknowledgment using FF_h as the Aircraft ID in the appropriate slot c-1 acknowledgment field. A 'NAK' in this field indicates that the downlink was not received. The aircraft may then send a new Log-On Request downlink. If two consecutive Log-On Requests fail to be acknowledged, the Link Control function should issue a DL_DISCONNECT.indication to the LME. The LME should then try a different frequency.

COMMENTARY

It is possible that multiple aircraft may attempt to Log-On to an HF Data Link Ground Station using the same random access downlink slot. This situation could occur after a frequency change. If one of the Log-On Request messages is successfully received and a positive acknowledgment using FF_h is c-1 broadcast, all of the aircraft HF Data Link functions which sent a Log-On Request message in that slot assume the Log-On Request was successfully received. However, only one of the aircraft HF Data Link functions receives a Log-On Confirm LPDU. It is recommended that a 60 second timer be set on receipt of the positive acknowledgment to the Log-On Request message. If a Log-On Confirm LPDU is c-3 not received in the next two frames, the aircraft HF Data Link function should generate another Log-On Request.

When the ground station receives a Log-On Request, it should check for the availability of unassigned Aircraft IDs (i.e. channel loading) and respond with a Log-On Confirm c-1 uplink (refer to Section 5.2.2.3) addressed to the aircraft with the assigned Aircraft ID and maximum downlink data rate measured. If there are no Aircraft IDs available, the ground station should respond with an uplink addressed to the aircraft with the Log-Off Request/Log-On Denied Aircraft ID (refer to Section 5.2.2.4). c-3

If the aircraft receives a Log-On Confirm uplink, the Link Control function should issue a DL_CONNECT.confirm to the LME. The aircraft should then begin delivery of downlink data and continue using the same frequency and the assigned Aircraft ID as long as the squitters continue to be received without CRC error and time slots are available.

If the aircraft receives a Log-On Denied uplink, the Link Control function should issue a DL_DISCONNECT.indication to the LME. The LME should then re-start a search for a different frequency.

COMMENTARY

The HF Data Link Ground Station should implement procedures to log aircraft off of the channel and make Aircraft ID numbers available for reassignment. These procedures could include periodically polling aircraft to determine status. However, every effort should be made to identify aircraft status without adding additional air/ground HF Data Link message traffic. HF Data Link Ground Stations should share aircraft Log-On information and log off aircraft when they Log-On to another HF Data Link Ground Station.

5.2.5.1.2 Aircraft Log-On Resume Procedure

From time-to-time the aircraft may have to change frequencies as the channel quality degrades. The LME should initiate a search for a new frequency when:

a. The last squitter announced a ground station frequency change, shut down or loss of ground network connection

b. The aircraft fails to detect 2 consecutive squitters

c. 3 consecutive downlinks are not positively acknowledged

d. 5 or fewer out of 10 squitters are received without CRC error (squitter error rate)

e. The maximum uplink data rate computed by the aircraft degrades below a minimum threshold

f. The aircraft has been transmit inhibited in the air for longer than the maximum threshold

COMMENTARY

The LME may periodically order the list of frequencies in the HFDL System Table to be searched (Active Frequency Search List), using squitter data information to delete inactive frequencies from the Active Frequency Search List.

The minimum threshold for the maximum uplink data rate computed by the aircraft should be one which is sufficient to support the protocol operation (DLS/RLS). The LME may continuously monitor the received signal quality (SNR, if available) of the log-on channel, over time, to assess its suitability for continued operation. The LME may use the results of background frequency searches, conducted using the Active Frequency Search List, to select a different ground station and/or frequency for log-on, one which has been proven over time to meet or exceed the minimum threshold for the uplink data rate. The length of the time period and the computed difference in signal quality should be determined to minimize frequent frequency changes. The LME may also use downlink success or lack thereof as an indication of the suitability of the current log-on channel.

When changing frequencies the LME should implement the Log-On renewal procedures illustrated in Attachment 2-11. When the LME finds a suitable new frequency it should issue a DL_RESUME.request to the Link Control function to resume Log-On to the same ground station. Otherwise, the LME should issue a DL_CONNECT.request to Log-On to a different ground station.

If the Link Control function receives a DL_RESUME.request, it should send a Log-On Resume downlink LPDU to the ground station. The ground station may respond with one of the following uplink LPDUs.

If the aircraft was still logged on and the ground station accepts the Log-On Resume request, the ground station should respond with a Log-On Resume-Confirm LPDU. The Log-On Resume-Confirm LPDU may contain a new Aircraft ID assignment or the same previous assignment. The AID should be the same if the Log-On Resume is being done on the frequency the aircraft is currently logged on to. If, however, the aircraft is sending a Log-On Resume to the ground station it is currently logged on to using a different frequency, then the AID allocated has no relationship to the AID allocated for the other frequency. When a ground station confirms a Log-On Resume request to an aircraft on a frequency different than the current frequency in use, both the aircraft and the ground station should consider the AID used on the previous frequency for link control as unused. The aircraft Link Control function should send a DL_RESUME.confirm to the LME when it receives the Log-On Resume-Confirm LPDU.

COMMENTARY

The aircraft HFDL should save all segments of partially reassembled uplink HFNPDUs (Basic Data Units) while a Log-On Resume procedure is pending, and discard the partially reassembled uplink HFNPDU only if the ground station does not respond with a Log-On Resume-Confirm LPDU.

If the aircraft was no longer logged on the ground stations table, the ground station cannot accept the Log-On Resume request. In this case the ground station should respond with a Log-On Confirm LPDU to indicate to the aircraft that the ground station cannot resume where the aircraft left off and that the link connection is to be re-initialized and treated as a new connection. The Log-On Confirm LPDU should contain a new Aircraft ID assignment. The aircraft Link Control function should send a DL_CONNECT.confirm to the LME when it receives the Log-On Confirm LPDU and discard any partially delivered HFNPDUs. All sequence numbers should be reset to 0.

COMMENTARY

The ground station should save all partially assembled HFNPDUs for any aircraft in its Table. If the ground station cannot accept the Log-On Resume request, the ground station should respond with a Log-On Denied LPDU. The aircraft Link Control function should send a DL_DISCONNECT.indication to the LME when it receives the Log-On Denied LPDU.

5.2.5.1.3 Aircraft Log-Off Procedure

The aircraft HF Data Link function is not required to log-off of the HF Data Link Ground Station. Instead the HF Data Link Ground Station uses polling and other techniques to identify aircraft which are no longer logged on to the ground station.

5.2.5.1.4 Table of Logged Aircraft

Each HF Data Link ground station maintains a table of aircraft logged on each of its active frequencies. Each entry in the table includes the aircraft address, assigned Aircraft ID, and the last frame when the aircraft was heard from and slot reservation request information.

When the ground station receives a downlink with a slot reservation request, the ground station should update the index of the last frame the aircraft was last heard from and the downlink slot assignments requested.

5.2.5.1.5 HF Voice/Data Switching

The LME monitors a discrete from the cockpit to detect when the HF radio is being used for voice communications rather than data communications. When the discrete indicates a change from Data to Voice mode operation the LME inhibits HF Data Link downlink transmissions until the discrete returns to the data state by sending a DL-PAUSE.request to the Link Control sublayer (see Table 1 in Attachment 2-12 and Table 1 in Attachment 2-13). When the discrete returns to Data mode, the LME initiates a frequency search starting with the last frequency it was logged on.

If the ground station address associated with the frequency found is the same as that of ground station the aircraft was logged on before going into the Data Disabled (Voice) mode, then the LME may re-establish a connection by issuing a DL-RESUME.request to Link Control sublayer. Otherwise, it should issue a DL-CONNECT.request .

When the aircraft HFDL system is in Voice mode (PAUSED state), the Link layer should not accept any HFNPDUs fordelivery to the ground. HFNPDUs already accepted, but partially delivered should be held by the Link Control sublayer until a DL-RESUME.request or a DL-CONNECT.request is issued by the LME. If a DL-CONNECT.request is issued by the LME, then the Link Control sublayer should discard partially delivered HFNPDUs and reset.

c-1 The LME notifies the MU/CMU whether the HFDL is in Voice or Data mode at 1 second intervals (See ARINC Characteristic 753, Section 10.3.1). When the aircraft HFDL system indicates it is unavailable (Voice mode), the MU/CMU should stop sending data to be delivered to the ground. The MU/CMU may alert the crew when it has become evident that the crew may have forgotten to switch the HF radio back to Data mode.

5.2.5.2 Link Management in Slave Mode

If the HFDL installation is a slave in a dual HFDL installation, the Slave LME should perform a frequency search and channel quality evaluation procedure similar to that described in Section 5.2.5.1.1, except that instead of issuing a DL_CONNECT.request on the first 'usable' frequency, the LME should tune to each frequency on the list, listen for the squitter, record the signal quality measure QM, if a squitter is received, and report the c-2 current frequency tuned to and received signal quality to the Master HFDL installation**.**

If at the end of the search, the HFDL installation is still a slave installation, the Slave LME should tune to the frequency with the highest signal quality and monitor that frequency until the uplink signal quality degrades, or the list of active frequencies changes. While monitoring the 'best frequency' the LME may use the Active Frequency information in the received squitters to update the list of frequencies. If the uplink signal quality of the best frequency degrades or the list of active frequencies changes, the Slave LME should perform a new search for the 'best frequency' by tuning to all active frequencies. At the end of the search it should tune to and begin monitoring the new 'best frequency'.

5.2.5.3 HF Link Monitoring and Data Link Unavailable Indication

Once a log-on procedure is initiated and a connection with a ground station has been established (DL_CONNECT.indication received by LME), the LME in the aircraft monitors the quality of the connection and re-initiates the search for a new frequency when the quality of the link is degraded. A number of quality measures defined in Section 5.2.5.1.2 are monitored to determine the quality of the link.

When the link connection to the ground station has been lost, the LME in the aircraft should notify the user of the HF Data Link subnetwork that a link connection is unavailable and the reason for the loss of the connection as specified in ARINC Characteristic 753 Section 10.3.1.

COMMENTARY

The HF Data Link layer protocol includes features (DL_PAUSE.request and LD_RESUME.request service primitives) which allow the system not to have to reset the link connection and retransmit partially delivered HFNPDUs when a connection is re-established with the same ground station either on the same or a new frequency. In order to take advantage of this feature, the HF Subnetwork layer should not reset virtual circuits unless so requested by the LME. The user of the HFDL (i.e., the HFDL Subnetwork Dependent Convergence Function shown in Attachment 1-2) should also wait for a period of time before resetting the virtual circuit. It should also be noted that when multiple HFDL ground stations operated by the same service provider provide coverage in a given area, the HFDL system is expected to be more efficient if all these ground stations are networked together so that virtual circuit connections are maintained when switching link connections between these ground stations. The users of the HFDL (i.e., the HFDL Subnetwork Dependent Convergence Function) should make use of the Join/Leave Event messages (see ARINC Characteristic 753 Section 10.3.3) to decide when to reset the virtual circuits as the ground station address contained in these messages indicates which service provider operates the ground station.

5.2.5.4 HFDL System Table Management

The airborne HFDL function utilizes an HFDL System Table containing a list of HFDL ground station IDs and their assigned frequencies (in tenths of kHz). The table also c-1 includes the latitude/longitude of the ground station and information as to whether the ground station synchronizes the broadcast of its squitters, the Master Frame slot assigned for transmission of squitters on each of the authorized frequencies, the squitter version broadcast by each ground station, and the data base version for each service provider. The format and contents should follow the contents of the HFDL System Table broadcast (see Attachment 2-10C and Section 5.2.2.5.1).

The LME manages the uploading of the HFDL System Tables. The HFDL System Table may be initially uploaded from the MU/CMU or from a portable/airborne data loader and stored in non-volatile memory. Also, when the HFDL System Table does not match the HFDL System Table version broadcast in a squitter by the ground station, the LME manages the updating of the HFDL System Table from broadcast uplinks by the ground station. The format and contents of the broadcast uplinks are defined in Section 5.2.2.5.1.

Aircraft should only log-on to ground stations broadcasting a squitter with a compatible squitter version to that implemented in the aircraft. This prevents aircraft from accessing the ground stations that are implementing a different protocol iteration than that implemented in the aircraft. The actions to be taken by the aircraft are discussed in Section 5.2.5.1.1.

Before issuing a DL_CONNECT.request, the LME should verify that the squitter format version matches that expected by the aircraft. If the squitter format version does not match, then the aircraft will not be able to decode the squitter contents correctly. The LME should continue the search for a frequency with matching squitter version.

If the HFDL System Table version in the squitter Active Frequency bits (refer to Section 5.2.1.7) does not match that expected by the LME, a flag should be set to decode the ground station broadcast uplinks which contain current HFDL System Table ground station and frequency assignment data (refer to Section 5.2.2.5.1). The contents of these broadcast uplinks may be used to update the HFDL System Table for the ground station.

5.2.5.5 HFDL Fault Monitoring and Fault Indication

The airborne LME manages the collection, recording and reporting of built-in-test data, also referred to as Built In Test Equipment (BITE). The LME provides a fault indication to the cockpit when a fault condition has been detected by the BITE function.

5.3 Service Primitives

5.3.1 Data Link Layer Service Primitives

The Data Link layer provides the following service primitives to a user of its services (i.e., the HF Subnetwork layer in the ATN, the LME sublayer and ACARS processing function):

a. DL-CONNECT.request (ICAO 24-bit aircraft address, ground station address). This primitive is used by the LME to request a connection to an HF Data Link ground station. The Data Link layer sends a Log-On Request to the indicated ground station. The aircraft and ground station addresses are mandatory parameters.

b. DL-CONNECT.confirm (ICAO 24-bit aircraft address, ground station address, aircraft ID). This primitive is used to report to the LME that a connection with the ground has been established (Log-On Confirm received). The aircraft and ground station address and the assigned aircraft ID are mandatory parameters.

c. DL-DISCONNECT.indication (ICAO 24-bit aircraft address, ground station address, reason). This primitive is used to report to the LME that either the connection request has been rejected by the ground station (Log-On Denied received) or that connection establishment with the ground station has failed (Data Link Unavailable condition). The reason parameter is used to specify why the connection request has been rejected. The aircraft and ground station address parameters and the reason code are mandatory parameters.

d. DL-DISCONNECT.request (ICAO 24-bit aircraft address, ground station address, flag). This primitive is used by the LME to request termination of the connection with the HF Data Link ground station when no more data is expected to be sent via HF Data Link. The aircraft and ground station addresses are mandatory parameters. The flag parameter is optional and indicates whether a Log-Off Request should be sent to the ground station or not.

e. DL-DISCONNECT.confirm (ICAO 24-bit aircraft address, ground station address). This primitive is used to confirm to the LME that the request to terminate the connection has been accepted.

f. DL-PAUSE.request (ICAO 24-bit aircraft address, ground station address). This primitive is used by the LME to request that data transfer to the HF Data Link ground station be stopped when changing frequencies or when HFDL operation is disabled. The aircraft and ground station address parameters are optional.

g. DL-PAUSE.indication (ICAO 24-bit aircraft address, ground station address). This primitive is used to acknowledge to the LME that a PAUSE.request has been received. Data transfer already in progress may continue. The LME should not change frequencies until a PAUSE.confirm has been received. The aircraft and ground station address parameters are optional.

h. DL-PAUSE.confirm (ICAO 24-bit aircraft address, ground station address). This primitive is used to report to the LME that data transfer has been stopped. The LME may then proceed to change frequencies. The aircraft and ground station address parameters are optional.

i. DL-RESUME.request (ICAO 24-bit aircraft address, ground station address). This primitive is used by the LME to request that the idled connection with the indicated ground station be resumed. The Data Link layer sends a Log-On Resume Request to the ground station. The aircraft and ground station address parameters are mandatory.

j. DL-RESUME.confirm (ICAO 24-bit aircraft address, ground station address, aircraft ID). This primitive is used to report to the LME that the idled connection with the indicated ground station has been restarted

5.0 AIR/GROUND SERVICES AND PROTOCOLS OF LAYER 2 - LINK LAYER

5.3.1 Data Link Layer Service Primitives (cont'd)

(Log-On Resume-Confirm received from the ground station). The aircraft and ground station address and the aircraft ID parameters are mandatory.

c-1 k. DL-DATA.request (HFNPDU, priority, period). This primitive is used by the HF subnetwork layer or the ACARS relay function to request transmission of an HF Subnetwork Layer or Enveloped ACARS HFNPDU using the 'Reliable Link Service'. The HFNPDU and the priority parameter (0 to 15) are mandatory. The period parameter is optional and may be used to indicate that the HFNPDU is periodic with the indicated periodicity. The Link layer may use the periodicity to determine the type of Reservation Request to use with each downlink.

c-1 l. DL-DATA.indication (HFNPDU, priority). This primitive is used to deliver an HF Subnetwork Layer or Enveloped ACARS HFNPDU received using the RLS mode to the HF Subnetwork layer or the ACARS relay function. The HFNPDU and the priority parameter (0 to 15) are mandatory.

c-1 m. DL-UNITDATA.request (HFNPDU, priority, period). This primitive is used to request transmission of an HFNPDU using the DLS mode. The HFNPDU and the priority parameter (0 to 15) are mandatory. The period parameter is optional and may be used to indicate that the HFNPDU is periodic with the indicated periodicity. The Link layer may use the periodicity to determine the type of Reservation Request to use with each downlink.

c-1 n. DL-UNITDATA.indication (HFNPDU, priority). This primitive is used to deliver an HFNPDU received using the DLS mode. The HFNPDU and the priority parameter (0 to 15) are mandatory.

c-1 o. DL-DATA_ACK.request (HFNPDU, priority, period). This primitive is used to request transmission of an HFNPDU using the acknowledged DLS mode. The HFNPDU and the priority parameter (0 to 15) are mandatory. The period parameter is optional and may be used to indicate that the HFNPDU is periodic with the indicated periodicity. The Link layer may use the periodicity to determine the type of Reservation Request to use with each downlink.

5.3.2 Airborne LME Service Primitives

The LME provides the following service primitives:

a. LM-HFDL_LOST.indication. This primitive is used to report an HFDL not available condition via a discrete indication.

b. LM-HFDL_FAULT.indication. This primitive is used to report a HFDL system failure via a discrete indication.

c. LM-HFDL_STATUS.indication. This primitive is used to report the HFDL link and fault status to the MU/CMU per ARINC Characteristic 753 Section 10.3.1.

d. LM_RESET_VC.indication. This primitive is used to indicate to the HF Subnetwork layer that all virtual circuit connections should be cleared or reset.

e. LM_HFDL_Enable-Disable.request. This primitive is used to enable and disable HFDL operations. c-1

6.0 SERVICES AND PROTOCOLS OF LAYER 3 - THE NETWORK LAYER

6.1 Introduction

COMMENTARY

"It is the intent of this Specification to provide a common network layer with other communications subnetworks. Since the definitions are being refined through various groups within the industry, some elements of this section may change over time. A significant area of change will likely be the DTE addressing which is being refined by the SATCOM subnetwork developers. Designers are urged to participate, or at least stay aware of activities, in the development within the aviation community with regard to Network Layer Specifications."

Layer 3 in the OSI model is called the Network Layer. It provides the upper layers with independence from the data transmission and routing functions used to connect systems. The Network Layer provides routing and relaying functions both within any subnetwork and throughout the Aeronautical Internetworking domain.

Within the Aeronautical domain the Network Layer is divided into three sublayers as specified by the Internal Organization of the Network Layer (ISO 8648). These sublayers consist of two network layer protocols and one convergence or mapping function between them. This concept is illustrated in Attachment 1-2.

The network layer protocol used across the air-ground subnetworks is referred to formally as a SubNetwork Access Protocol (SNAcP). Within this document, the SNAcP is referred to as the "SubNetwork Protocol". The network layer can also contain a common Internetwork Protocol as well as a mapping function between the Internetwork and Subnetwork protocols.

When a received frame passes through the Link Layer, the Layer 2 header and trailer which are used for frame processing, are stripped off. The remaining DLS User-data parameter is passed within a Data Link service primitive up to the Subnetwork layer. This remainder is a Subnetwork Protocol Data Unit (SNPDU) or informally "packet". All nodes within the subnetwork should support the Subnetwork Protocol and exchange SNPDUs.

Some nodes within the subnetwork act as routers out of the subnetwork. These nodes support the other two sublayers of the network layer. Any node in the subnetwork which does not support the gateway function utilizes the Subnetwork Protocol within its network layer.

6.1.1 General Operation

The subnetwork access layer protocol specified in Section 6.2 is intended to conform to the DTE-DCE X.25 Packet Level Protocol as specified by ISO 8208 (E) 1990-03-15.

6.2 Packet-Mode Data Service

This section specifies the procedures which are to be performed by the HFDL for the establishment, use and release of Switched Virtual Circuits (SVCs) within the HFDL SubNetwork, and the interworking between High Frequency SubNetwork Protocol Data Units (HFNPDUs) and packets defined in ISO 8208 Packet Layer Protocol (PLP) for providing Connection-Oriented SubNetwork Service to the High Frequency SubNetwork Service (SNS) user. The maximum length of the HFNPDU is 421 octets of user data plus 3 octets of overhead.

6.2.1 Link Layer Functions

The packet-mode data service makes use of the Reliable Link Service (RLS) for the transmission of SubNetwork protocol Data Units over the High Frequency radio channels. The HFDL should then provide the Reliability Sublayer of the link layer. The receiving Reliability sublayer receives sets of Basic Data Units (BDUs) requiring RLS quality of service, together with relevant LSUs from the Priority and Routing sublayer, checks whether the set is complete and informs the transmitting Reliability sublayer accordingly. If the set of BDUs was incomplete, the missing BDUs are retransmitted. The receiving Reliability sublayer then passes corrected sets of BDUs to the LSDU Segmentation and Reassembly sublayer. Reference Attachment 2-1 and Section 5.2.4.2.

6.2.2 HFDL SubNetwork Layer Structure

Attachment 1-2 illustrates the essential elements of the High Frequency subnetwork and their relationship to the user of the subnetwork. The user accesses the High Frequency subnetwork by means of the High Frequency SubNetwork Access (SNAc) sublayer (Interface 1 of Attachment 1-2). The HF SubNetwork Layer (HFSNL) entity both communicates with its counterpart on the ground using a peer-to-peer protocol, named HFDL SubNetwork Dependent (HFSND) protocol, and provides interworking functions between the SNAc protocol and the HFSND protocol.

6.2.3 HFSNL Protocol Definition

The HFSNL Protocol functions consist of a HF Subnetwork Dependent Protocol (HFSNDP), a HF Subnetwork Access Protocol (HFSNAcP), and an Interworking Function (IWF). c-3

The HFSNDP controls the mapping of user packets into HF Network Packet Data Units (HFNPDUs), mapping of HFNPDUs into user packets, and the peer-to-peer delivery and reception of HFNPDUs between the HFDL aircraft and ground station. The functions associated with this protocol should be as defined in Section [4.3] of [ICAO Manual on HFDL Technical Specifications]. c-4

The HFSNAcP controls the delivery and reception of packets to/from the user of the HFDL Subnetwork and should be in accordance with ISO 8208, with the user acting as a Data Terminal Equipment (DTE) and the aircraft and ground HFDL subsystem acting as a Data c-3 Communications Equipment (DCE). Specific ISO 8208 services, capabilities and facilities applicable to HFDL should be as defined in Section [4.4] of [ICAO Manual on HFDL Technical Specifications]. c-4

The IWF controls the interchange and flow of packets c-3 between the HFSNDP and the HFSNAcP. The IWF should be as defined in Section [4.5] of [ICAO Manual on HFDL Technical Specifications]. c-4

6.0 SERVICES AND PROTOCOLS OF LAYER 3 - THE NETWORK LAYER

6.2.4 Mapping Process Description

c-3 The rules for mapping ISO 8208 packets into HFNPDUs and HFNPDUs into ISO 8208 packets should be as
c-4 defined in Sections [4.3.15 and 4.3.16] of [ICAO Manual
c-3 on HFDL Technical Specifications].

The order of precedence of transmission of packet-mode data appearing at an HFDL port should be as shown in Attachment 3-1. A message is handled in the link layer by segmenting it, if necessary, into one or more Basic Data Units (BDUs). Transmission preemption, if necessary, should be effected by immediately changing the order of BDUs transmission such that the BDUs comprising the higher priority message are transmitted before lower priority BDUs in the first available transmission slot. Preemption of lower priority messages, if necessary, should be effected by any means necessary to preserve the higher priority message(s), e.g., the overwriting of buffers.

The target and selected values of priority of data on a connection in the ISO 8208 CALL REQUEST and CALL ACCEPTED packets should be mapped to the Link Interface Data Unit (LIDU) Q-number of the CONNECTION REQUEST and CONNECTION CONFIRM HFNPDUs as defined in Attachment 3-1.

The LIDU Q-number associated with the CONNECTION REQUEST and CONNECTION CONFIRM HFNPDUs should be mapped to the target and selected values of the priority data on a connection in the ISO 8208 INCOMING CALL and CALL CONNECTED packets as defined in Attachment 3-1.

c-1 Any attempt to establish a Virtual Circuit at a priority lower than the minimum priority should be rejected. Existing Virtual Circuits at priorities lower than the minimum priority will be maintained, but data will not be transmitted.

6.2.5 Timing

In all cases where the HFDL is logged on, the HFDL operations should not take longer than 0.4 seconds for regular traffic. This interval is defined as follows:

a. The time that a DATA packet with a user data field of 128 bytes is presented to the HFDL SubNetwork Layer (HFSNL) for downlink transfer and the time that the corresponding Link Interface Data Unit (LIDU) is passed to the Link Layer for transmission.

b. The time that a LIDU which contains a DATA HFNPDU with a user data field of 128 bytes, is passed to the HFDL SubNetwork Layer and the corresponding packet; i.e., a DATA packet of 128 bytes is available for delivery to the Higher Layer Entity (HLE).

In all cases where the HFDL is logged on, the HFDL operations should not take longer than 0.2 seconds for expedited traffic. This interval is defined as follows:

a. The time that an INTERRUPT packet with a user data field of 32 bytes, is presented to the HFDL SubNetwork Layer for downlink transfer, and the time that the corresponding Link Interface Data Unit (LIDU) is passed to the Link Layer for transmission.

b. The time that a LIDU which contains an INTERRUPT DATA HFNPDU with a user data field of 32 bytes, is passed to the HFDL SubNetwork Layer and the time that the corresponding packet; i.e., an INTERRUPT packet of 32 bytes, is available for delivery to the HLE.

6.2.6 Buffer Sizes

Depending on the HFDL implementation, buffers to operate a virtual channel may be assigned separately for each process within the High Frequency subnetwork access layer, the interworking function and the High Frequency specific subnetwork or may exist in a common area. The following buffer sizes apply to the entire Layer 3 High Frequency subnetwork.

The HFDL should have enough buffer space available to operate simultaneously a minimum of 32 Switched Virtual Circuits.

As an example, the HFDL could provide sufficient buffer space to hold either 12 DATA HFNPDUs of total length of 131 octets each (user data plus control information) or 3 DATA HFNPDUs of total length of 424 octets or any equivalent configuration, in the downlink and uplink direction per Switched Virtual Circuit.

In addition, the HFDL should provide enough buffer space to hold 1 INTERRUPT HFNPDU having a length of 34 octets (user data plus control information) in the downlink and in the uplink direction per Switched Virtual Circuit.

6.2.6.1 Overall Buffer Size

The size of the "Data Buffer" which is required to maintain synchronism between the two peer HFSNL entities, if flow control is invoked should be as defined in Table 6-1 below.

Table 6-1 HFDL Buffer Size

Transmit Channel Rate (bps)	HFDL Buffer Size (Octets) (requirement is the minimum of the two values)	
	Per Virtual Circuit (VC)	Total
300	2k	20k
600	3k	25k
1200	4k	25k
1800	4k	25k

6.3 Enveloped Packet-Mode Data Services

This section specifies the procedures and protocol used by the HFDL system to implement Enveloped Packet-Mode Data Service. Enveloped Packet-Mode Data Service uses a null HF SubNetwork Layer whereby the HFDL Link Layer Service Data Unit header is composed of two octets, set to $FFFF_h$ or $FF00_h$, to send an enveloped message.

6.0 SERVICES AND PROTOCOLS OF LAYER 3 - THE NETWORK LAYER

6.3.1 Link Layer Functions

Messages are transmitted with the Reliable Link Service (RLS) quality of service. Messages are transmitted at the Q Precedence Level of 7, unless otherwise conveyed from an external entity. In order to provide forward compatibility with a standard subnetwork layer, packet communication takes place at the link service interface.

The link service user receives a two octet header to the transmitted message to form a Link Service Data Unit (LSDU), and extracts a received message from an LSDU by recognizing the two octet header. Packets for transmission are accepted into the LSDU Segmentation Unit of the LSDU Segmentation and Reassembly SubLayer as shown in Attachment 2-1. Received packets are collected from the LSDU Reassembly Unit.

6.3.2 Enveloped Message Structure

Reference ARINC Characteristic 741, Aviation Satellite Communication System, Part 2, "System Design and Equipment Functional Description" Section 4.6.2.

6.3.3 Internetworking Functions

The LSDU is carried transparently through the Ground Station (where the Ground Station strips off the 2 octet header of $FFFF_h$ or $FF00_h$) between the HFDLs and their corresponding DTEs.

Once an aircraft has logged on to a ground station, a data path exists between the HFDL and the ground station. Only one such path is provided for each HFDL, allowing bi-directional communications. Messages are limited in size to the contents of one LSDU, less the two octet identifying header (422 octets). Messages received from other onboard avionics to be sent to the ground, where communications have been established, are sent in their entirety without additional compression.

COMMENTARY

> At the ground, a Switched Virtual Circuit (SVC) is established between the ground station and a predefined SubNetwork Point of Attachment (SNPA) DTE. The terrestrial connection is established by the ground station when the first aircraft is logged on at the ground station, and is cleared when all aircraft are logged off at the ground station.

6.3.3.1 Enveloped Packet-Data Transmit

Reference ARINC Characteristic 741, Aviation Satellite Communication System, Part 2, "System Design and Equipment Functional Description" Section 4.6.3.1.

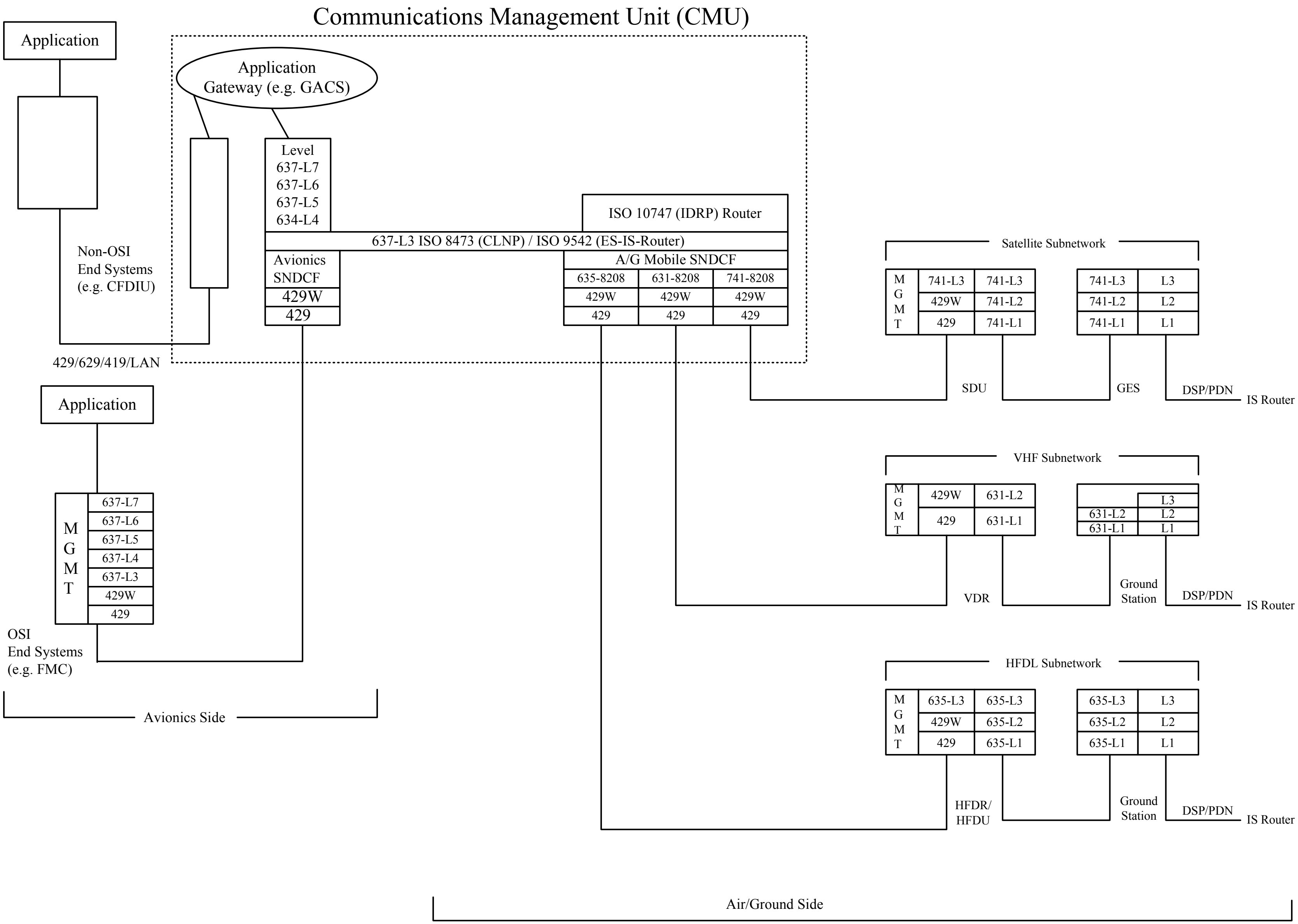
6.3.3.2 Enveloped Packet-Data Receive

Reference ARINC Characteristic 741, Aviation Satellite Communication System, Part 2, "System Design and Equipment Functional Description" Section 4.6.3.2.

6.3.3.3 Logged On Status

Reference ARINC Characteristic 741, Aviation Satellite Communication System, Part 2, "System Design and Equipment Functional Description" Section 4.6.3.3.

ATTACHMENT 1-1
AIRBORNE SUBSYSTEM BLOCK DIAGRAM

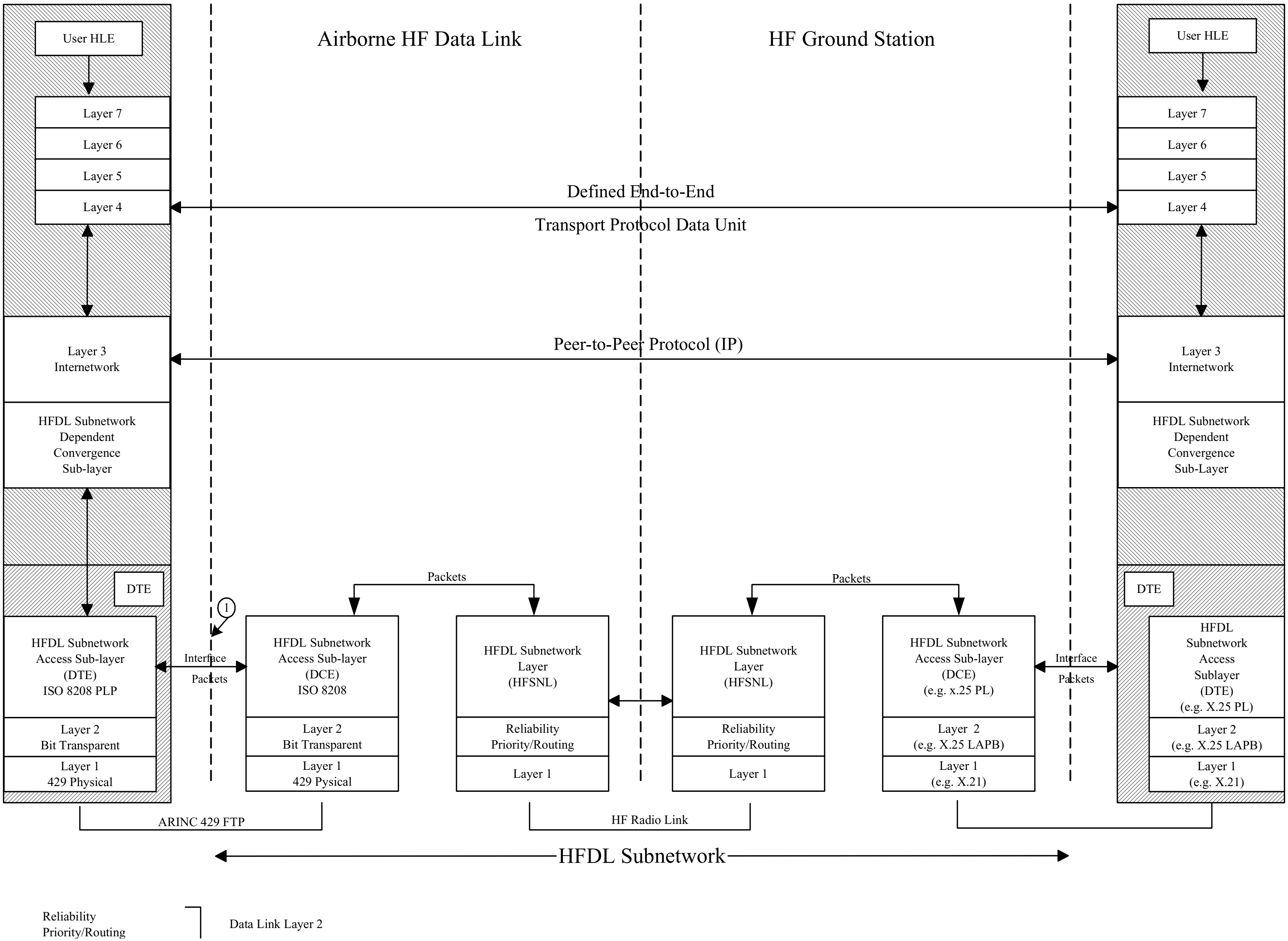


NOTES:

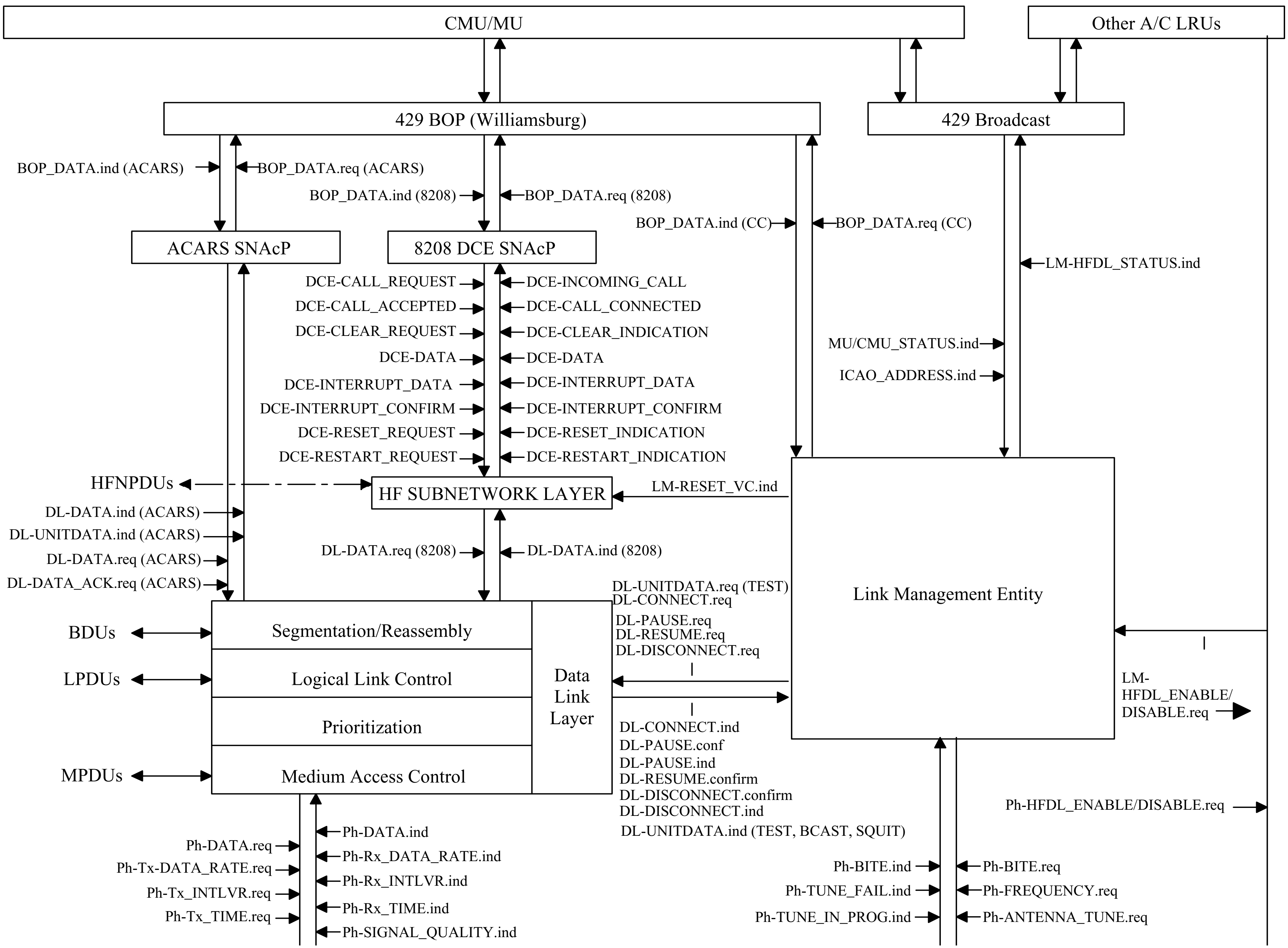
1. This figure appears in the following ARINC standards: 631, 635, 637, 750 and 753. Due to non-synchronous update of these standards, differences in this figure between standards may arise. In all cases, the figure with the most recent date (see lower left hand corner) should have precedence.

04 Sep 03

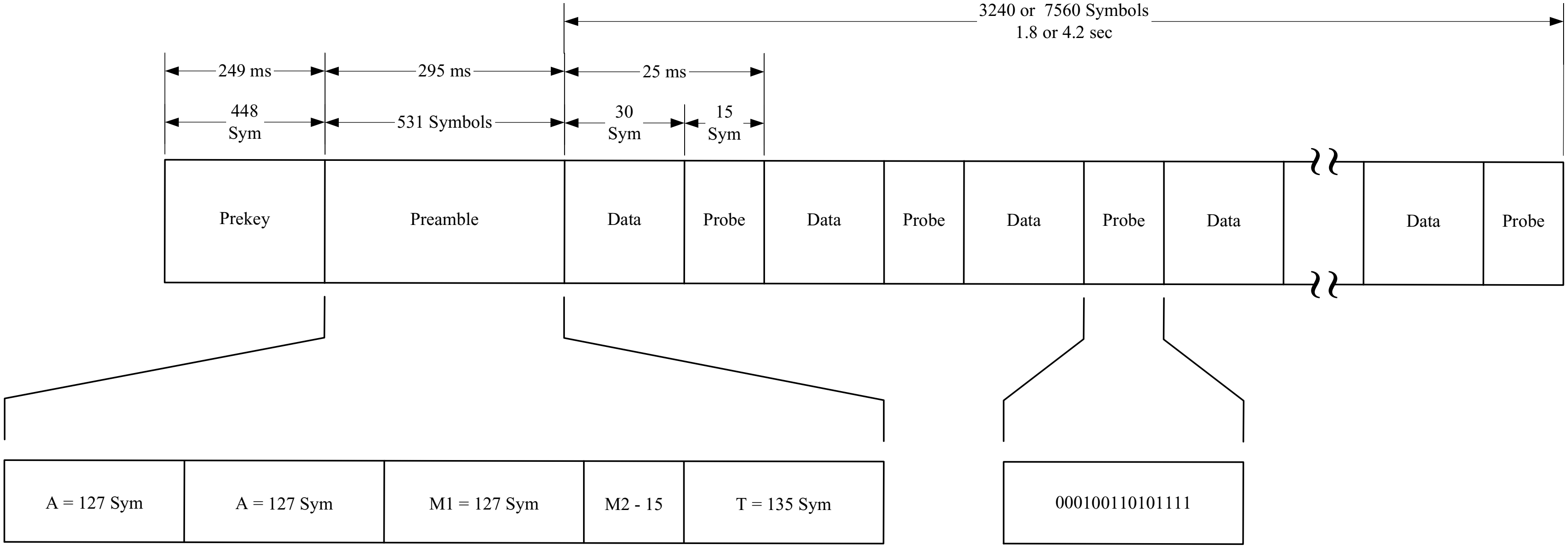
ATTACHMENT 1-2
HFDL REFERENCE MODEL



ATTACHMENT 2-1
AIRBORNE STATION PROTOCOL LAYER INTERFACES



ATTACHMENT 2-2
HF DATA LINK SIGNAL-IN-SPACE DEFINITION



A = 010 1101 1101 1110 0011 1010 0010 1011 1000 0001 1110 1100 1100 0100 1001 1100
1111 1001 0000 0100 0110 1010 1001 1011 0100 1010 0001 0110 0001 1001 0111 1111

M1 = 1 of 8 shifts of following sequence: 011 1011 0111 1010 0010 1100 1011
1110 0010 0000 0110 0110 1100 0111 0011 1010 1110 0001 0011 0000 0101
0101 1010 0100 1010 0111 1001 0001 1010 1000 0111 1111

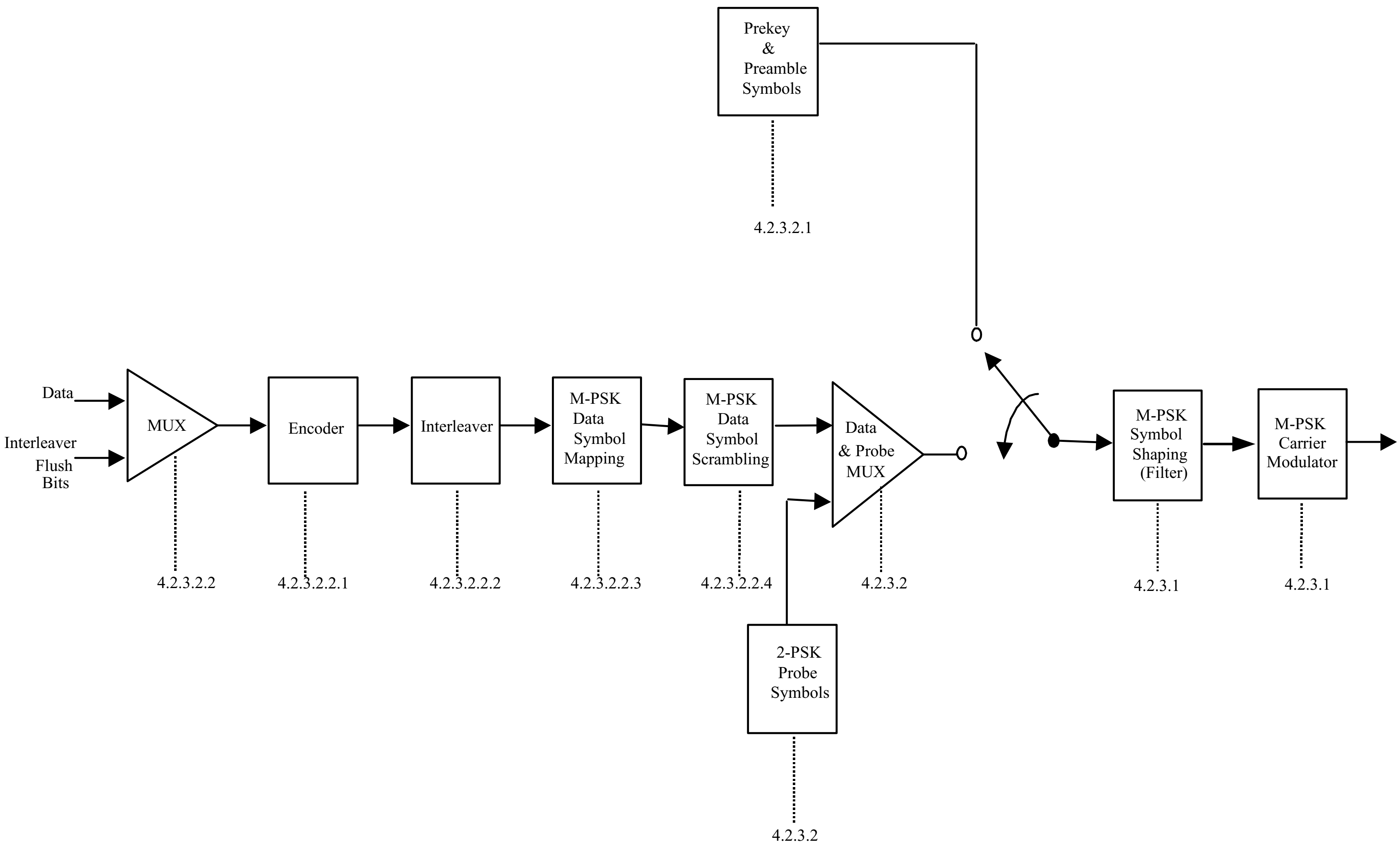
M2 = first 15 symbols of shifted M1 sequence

T = 000 100 110 101 111 repeated 9 times

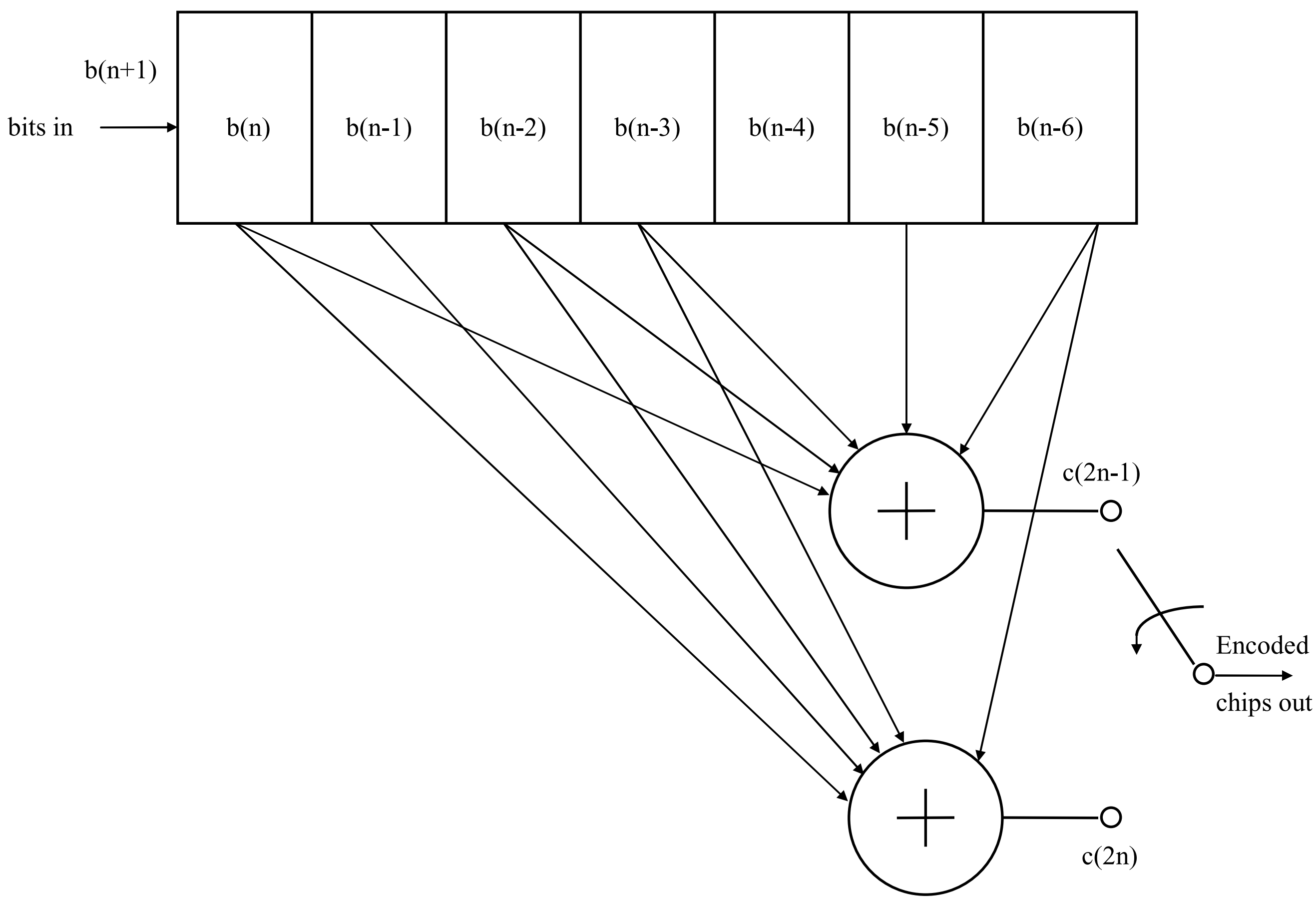
Note: Left most bit of each sequence is transmitted first

Date Rate	Interleaver	M1 Shift
300 bps	1.8 sec	72 Sym
600 bps	1.8 sec	82 Sym
1200 bps	1.8 sec	113 Sym
1800 bps	1.8 sec	123 Sym
300 bps	4.2 sec	61 Sym
600 bps	4.2 sec	103 Sym
1200 bps	4.2 sec	93 Sym
1800 bps	4.2 sec	9 Sym

ATTACHMENT 2-3
DATA MODULATOR ENCODING FUNCTIONS



ATTACHMENT 2-4
RATE ½ CONVOLUTIONAL ENCODER



ATTACHMENT 2-5
HF SIGNAL - IN - SPACE MINIMUM PACKET ERROR RATE PERFORMANCE WITH 1.8 SECOND INTERLEAVER

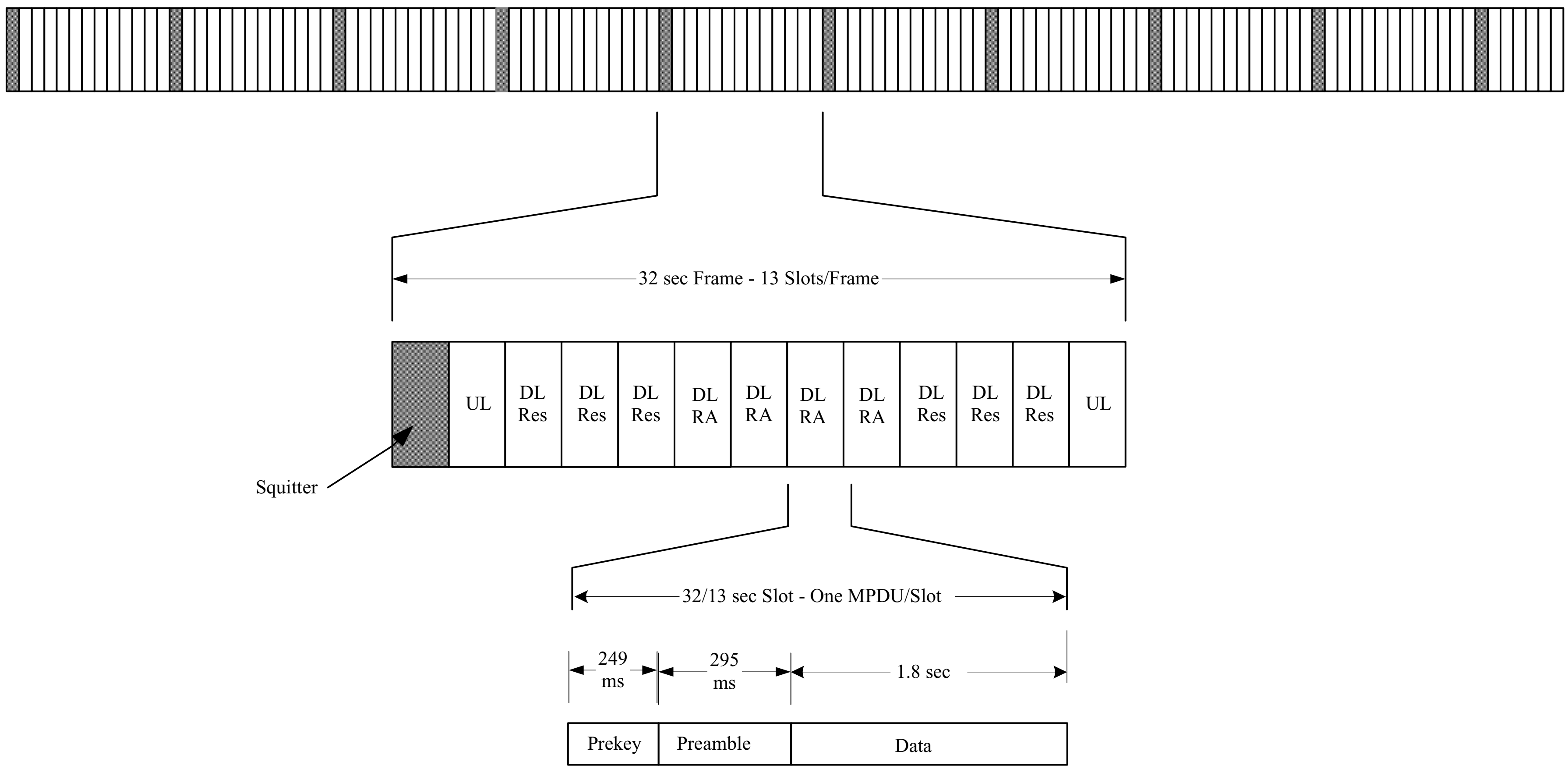
c-2

User mode (bps)	Number of Channel Paths	Multipath Spread (ms)	Fading BW (Hz) (Note 1)	Frequency Shift (Hz)	SNR (dB) (Note 2)	MPDU Packet Size (octets)	Packet Error Rate (%) (Note 3)
1200	1 Fixed	-	-	40	4.0	256	5%
1800	2 Fading	2	1	40	16.0	400	5%
1200	2 Fading	2	1	40	11.5	256	5%
600	2 Fading	2	1	40	8.0	128	5%
300	2 Fading	2	1	40	5.0	64	5%
1200	2 Fading	4	1	40	13.0	256	5%
1200	2 Fading	2	2	40	11.5	256	5%

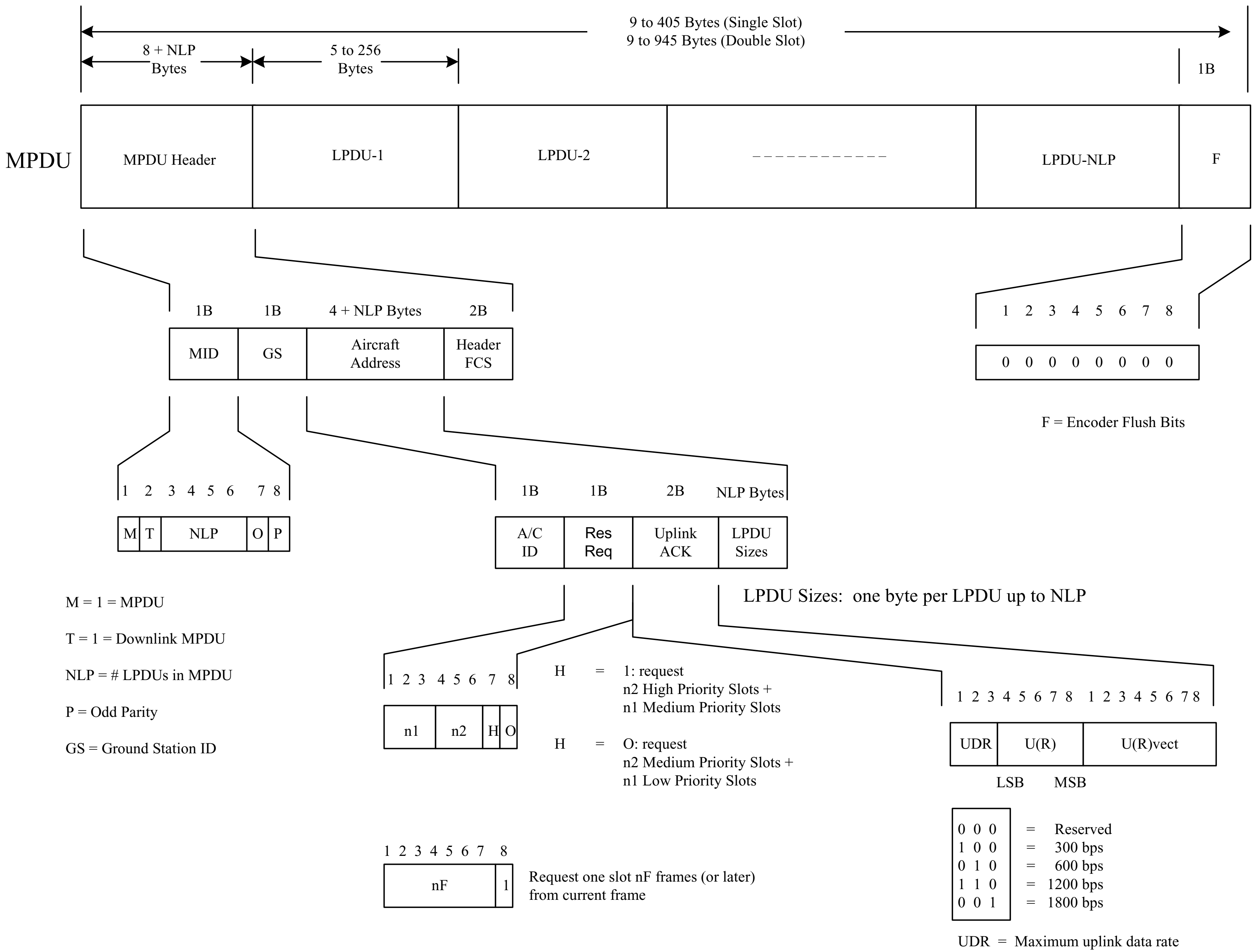
NOTES:

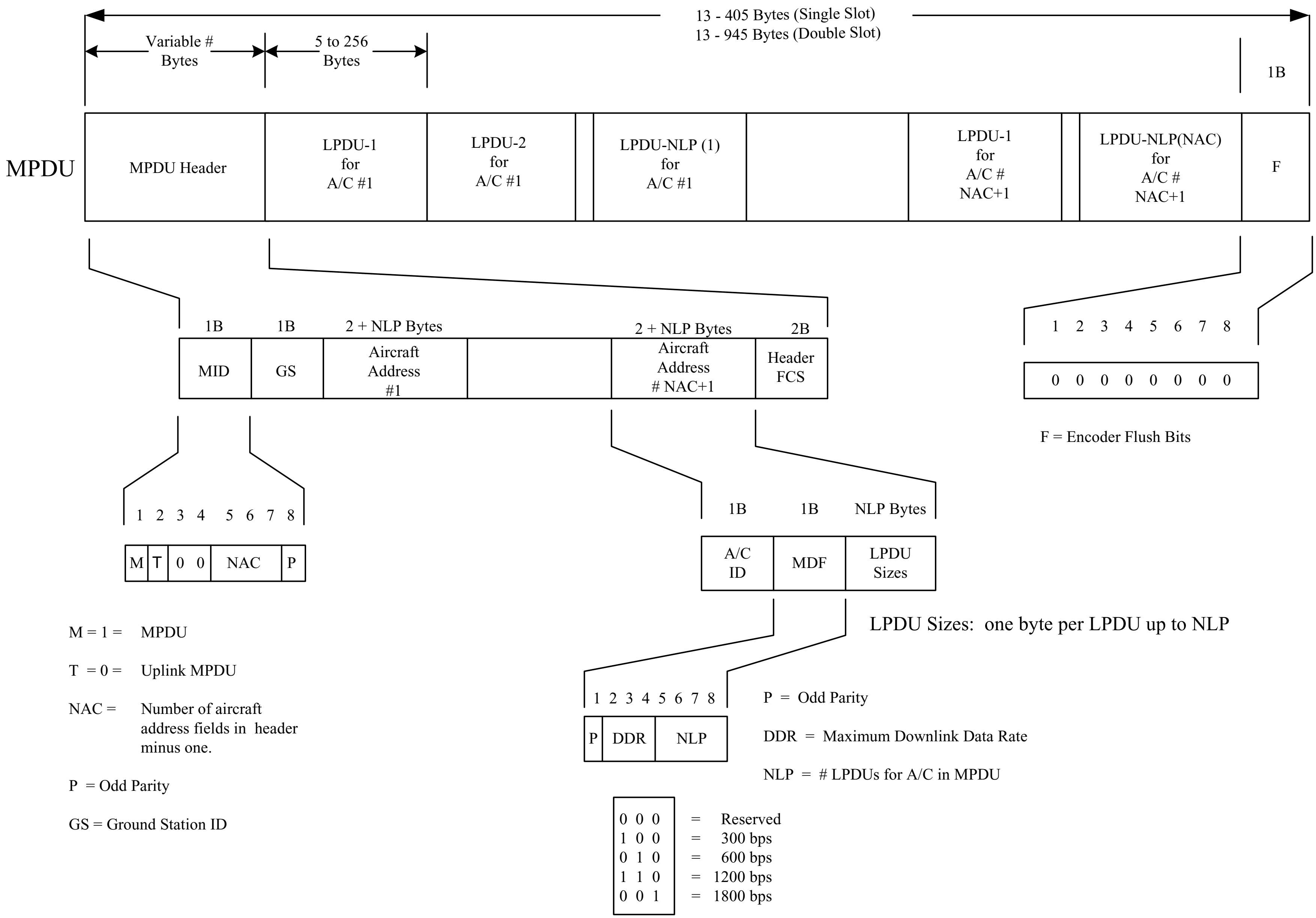
1. Per CCIR Report 549-2.
2. Both signal and noise powers are measured in a 3-kHz bandwidth.
3. Ratio of packets received with one or more bit errors to total number of packets sent. Errored packets include both missed preamble detection and packets received with user data bit errors.

ATTACHMENT 2-6
SLOTTED FRAME

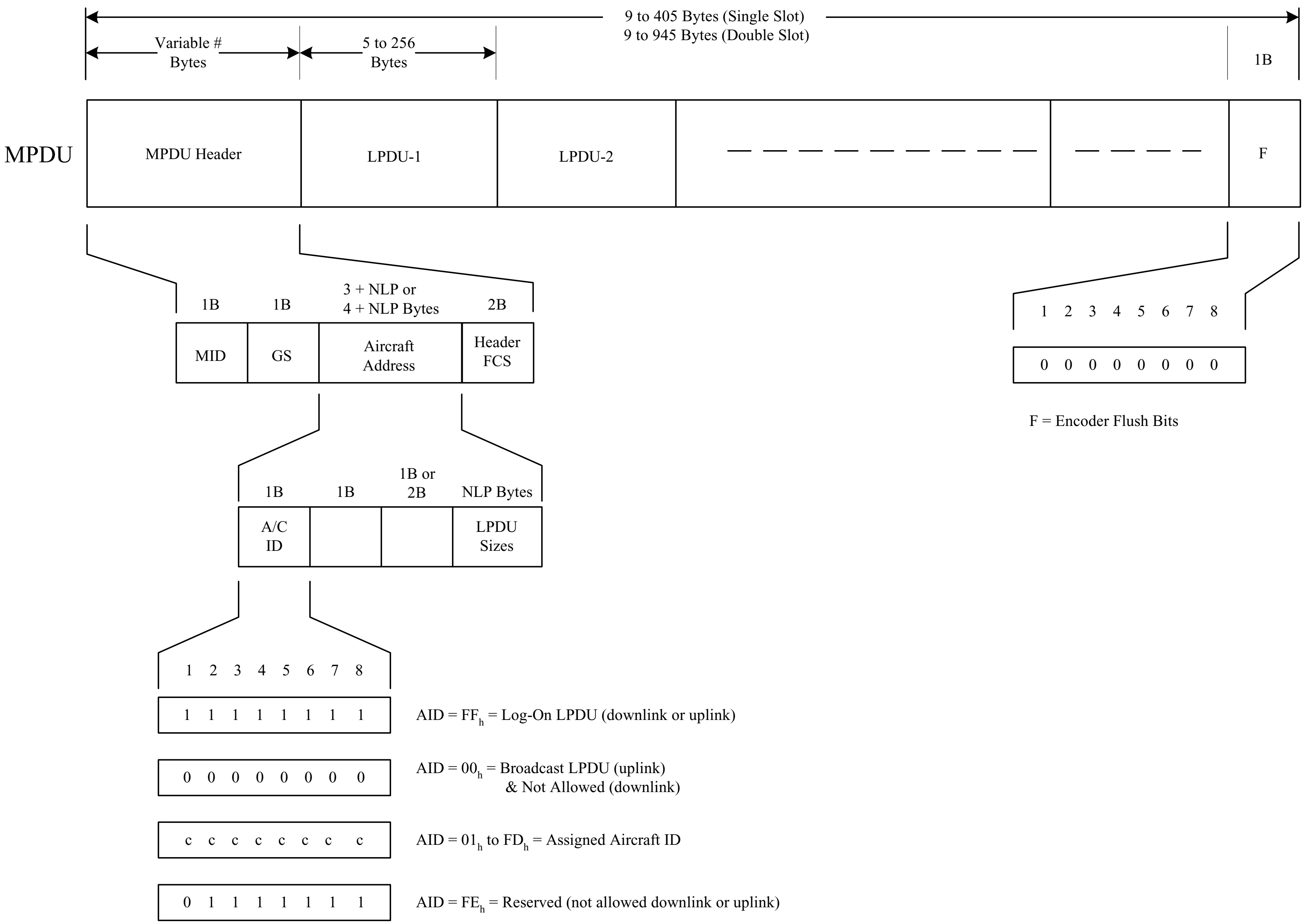


ATTACHMENT 2-7A
DOWNLINK MPDU FORMAT

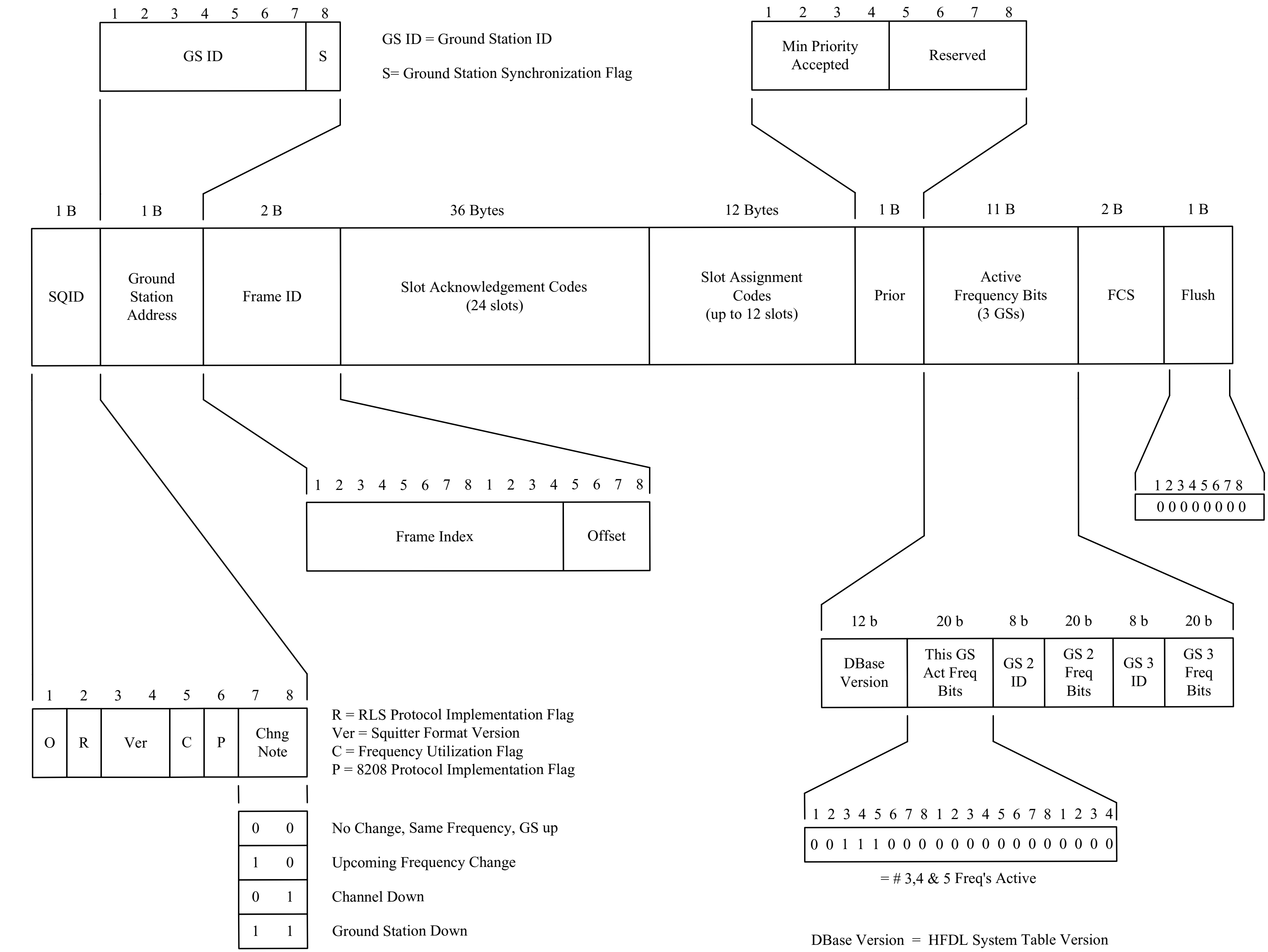



13 - 405 Bytes (Single Slot)
13 - 945 Bytes (Double Slot)
Variable # Bytes
5 to 256 Bytes
1B
MPDU
MPDU Header
LPDU-1 for A/C #1
LPDU-2 for A/C #1
LPDU-NLP (1) for A/C #1
LPDU-1 for A/C # NAC+1
LPDU-NLP(NAC) for A/C # NAC+1
F
1B
1B
2 + NLP Bytes
2 + NLP Bytes
2B
MID
GS
Aircraft Address #1
Aircraft Address # NAC+1
Header FCS
1 2 3 4 5 6 7 8
0 0 0 0 0 0 0 0
F = Encoder Flush Bits
1 2 3 4 5 6 7 8
M
T
0 0
NAC
P
1B
1B
NLP Bytes
A/C ID
MDF
LPDU Sizes
LPDU Sizes: one byte per LPDU up to NLP
M = 1 = MPDU
T = 0 = Uplink MPDU
NAC = Number of aircraft address fields in header minus one.
P = Odd Parity
GS = Ground Station ID
1 2 3 4 5 6 7 8
P
DDR
NLP
P = Odd Parity
DDR = Maximum Downlink Data Rate
NLP = # LPDUs for A/C in MPDU
0 0 0 = Reserved
1 0 0 = 300 bps
0 1 0 = 600 bps
1 1 0 = 1200 bps
0 0 1 = 1800 bps

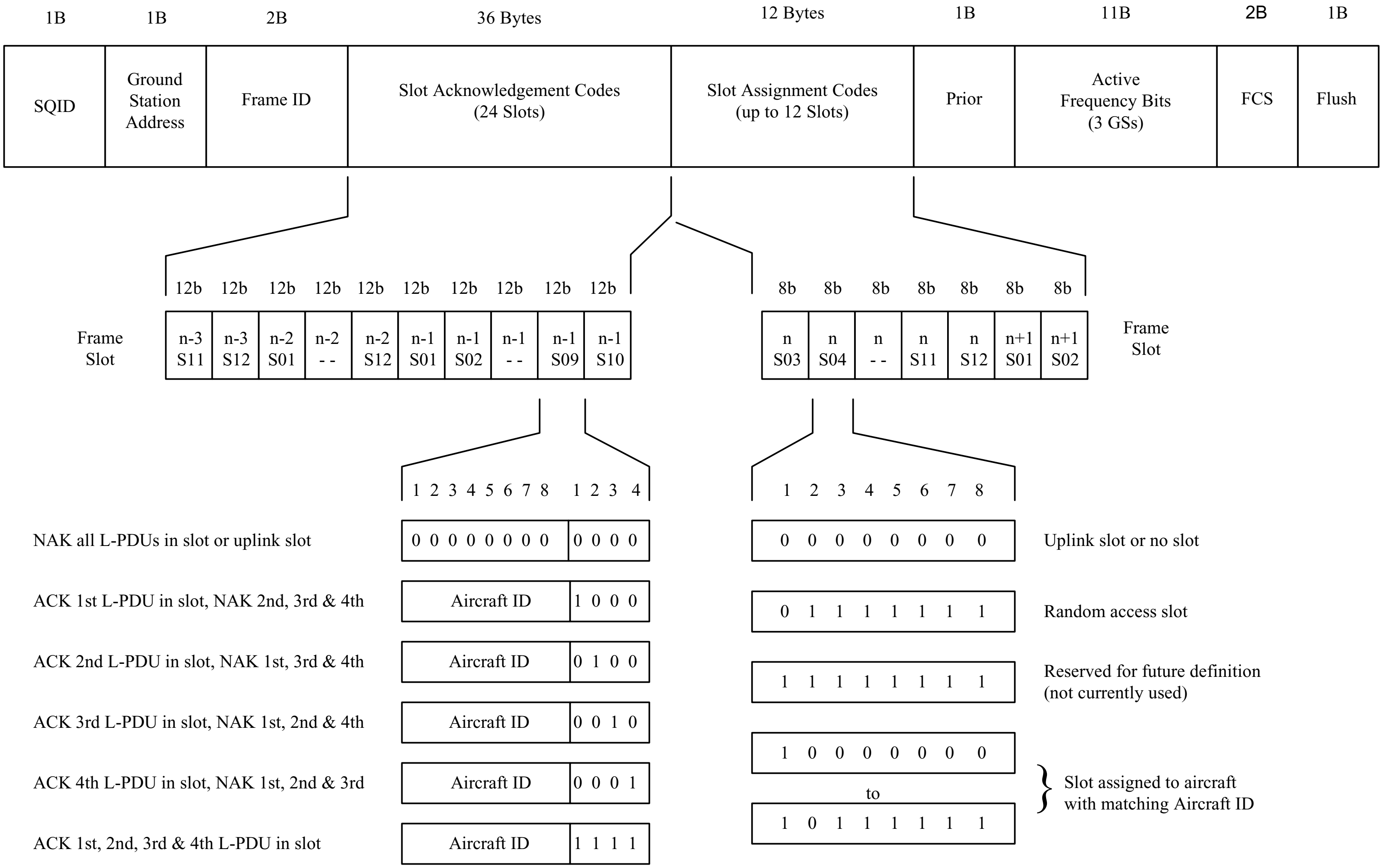
ATTACHMENT 2-7C
AIRCRAFT ID DEFINITION



ATTACHMENT 2-8A
SQUITTER SPDU FORMAT



ATTACHMENT 2-8B
SLOT ASSIGNMENTS AND ACKNOWLEDGMENTS IN SQUITTER



ATTACHMENT 2-8C
HFDL BIT MAP REPRESENTATIONS

The following HFDL bit map representations have been adopted for the transmission of SPDUs and MPDUs. The most significant bit of each byte is left justified and numbered bit 8. Bytes are numbered from top to bottom starting with 1, the first byte to be transferred. Integer representation is "little endian" order, i.e. the least significant bits of each integer are in the lowest number byte. Filling and transmission of each byte is from LSB to MSB. For integers represented by less than eight bits, the LSB is filled and transmitted first and the MSB is filled and transmitted last. c-3

These examples illustrate the loading of specific information into the data fields of selected signal units. The signal units depicted here are provided for illustration only and may not represent actual conditions. Note: The data is assumed for the purposes of illustration.

HFDL Signal Unit — References for Details and Comments

HFDL	GShex	8	7	6	5	4	3	2	1	Byte	References for Details and Comments
←	24	0	0	1	0	0	1	0	0	1	Bit 1=0=Squitter. Bits 2=0=Not RLS Capable. Bits 3-4=Version 1_d. Bit 5=0=Not loaded, Bit 6=ISO-8208 Supported. Bits 7-8=No Upcoming Freq. Change. Ref. 5.2.1.7 (a). c-2
	A2	1	0	1	0	0	0	1	0	2	Bits 1-7=34_d, =Station ID Bit8=1_b=GS Sync. Ref. 5.2.1.7 (b), and 5.2.1.7.2
	96	1	0	0	1	0	1	1	0	3	Bits 1-8=96_h=Lower Frame Index (096)=012007.4 UTC. Ref. 5.2.1.7 (c).
	30	0	0	1	1	0	0	0	0	4	Bits 1-4=0_h=High nibble of Frame Index. Bits 5-8=3_d=Offset 3 slots. Ref. 5.2.1.7 (c).
	12	0	0	0	1	0	0	1	0	5	Slot ACK Codes Field. See Ref. 5.2.1.7 (d) and Att. 2-8B for details. Bits 1-8> slot 11, frame n-3 ACK ID for Aircraft Access ID (AID)=12_h
	32	0	0	1	1	0	0	1	0	6	Bits 1-4=> ACK LPDU 2 and NAK LPDUs 1, 3, & 4 in slot 11 frame n-3. Bits 5-8=3_h, lower nibble of slot 11, frame n-3 ACK ID for AID=13_h
	61	0	1	1	0	0	0	0	1	7	Bits 1-4=1_h, upper nibble of slot 11, frame n-3 ACK ID for AID=13_h. Bits 5-8=> ACK LPDUs 2 & 3 and NAK LPDUs 1 & 4 from slot 12, frame n-3.
	27	0	0	1	0	0	1	1	1	8	Bits 1-8> slot 1, frame n-2 ACK ID for AID=27_h.
	07	0	0	0	0	0	1	1	1	9	Bits 1-4=> ACK LPDUs 1, 2, & 3, and NAK LPDU 4 slot 1, frame n-2. Bits 5-8=0_h, lower nibble of slot 2, frame n-2 ACK ID for AID=00_h.
	00	0	0	0	0	0	0	0	0	10	Bits 1-4=0, upper nibble of slot 2, frame n-2 ACK ID for AID=00_h Bits 5-8=> NAK all LPDUs in slot 2, frame n-2.
	00	0	0	0	0	0	0	0	0	11	Bits 1-8> slot 3, frame n-2 ACK ID for AID=00_h
	00	0	0	0	0	0	0	0	0	12	Bits 1-4=> NAK all LPDUs in slot 3 frame n-2 Bits 5-8=0_h, lower nibble of slot 4, frame n-2 ACK ID for AID 00_h
	00	0	0	0	0	0	0	0	0	13	Bits 1-4=0, upper nibble of slot 4, frame n-2 ACK ID for AID 00_h Bits 5-8=> NAK all LPDUs in slot 4, frame n-2
	00	0	0	0	0	0	0	0	0	14	Bits 1-8> slot 5, frame n-2 ACK ID for AID=00_h
	00	0	0	0	0	0	0	0	0	15	Bits 1-4=> NAK all LPDUs in slot 5 frame n2. Bits 5-8=0_h, lower nibble of slot 6, frame n-2 ACK ID for AID=00_h
	00	0	0	0	0	0	0	0	0	16	Bits 1-4=0, upper nibble of slot 6, frame n-2 ACK ID for AID=00_h Bits 5-8=> NAK all LPDUs in slot 6, frame n-2
	00	0	0	0	0	0	0	0	0	17	Bits 1-8> slot 7, frame n-2 ACK ID for AID=00_h.
	00	0	0	0	0	0	0	0	0	18	Bits 1-4=> NAK all LPDUs in slot 7 frame n-2. Bits 5-8=0_h, lower nibble of slot 8, frame n-2 ACK ID for AID=00_h
	00	0	0	0	0	0	0	0	0	19	Bits 1-4=0, upper nibble of slot 8, frame n-2 ACK ID for AID=00_h Bits 5-8=> NAK all LPDUs in slot 8, frame n-2.
	00	0	0	0	0	0	0	0	0	20	Bits 1-8> slot 9, frame n-2 ACK ID for AID=00_h
	00	0	0	0	0	0	0	0	0	21	Bits 1-4=> NAK all LPDUs in slot 9 frame n-2. Bits 5-8=0_h, lower nibble of slot 10, frame n-2 ACK ID for AID=00_h
	00	0	0	0	0	0	0	0	0	22	Bits 1-4=0, upper nibble of slot 10, frame n-2 ACK ID for AID=00_h Bits 5-8=> NAK all LPDUs in slot 10, frame n-2.
	00	0	0	0	0	0	0	0	0	23	Bits 1-8> slot 11, frame n-2 ACK ID for AID=00_h
	00	0	0	0	0	0	0	0	0	24	Bits 1-4=> NAK all LPDUs in slot 11 frame n-2. Bits 5-8=0_h, lower nibble of slot 12, frame n-2 ACK ID for AID=00_h.

Figure 1 – Squitter SPDU Uplink

ATTACHMENT 2-8C
HFDL BIT MAP REPRESENTATIONS

	HFDL	GShex	8	7	6	5	4	3	2	1		References for Details and Comments
	←	00	0	0	0	0	0	0	0	0	25	Bits 1-4=0, upper nibble of slot 12, frame n-2 ACK ID for AID 00_h Bits 5-8=> NAK all LPDUs in slot 12, frame n-2.
		00	0	0	0	0	0	0	0	0	26	Bits 1-8> slot 1, frame n-1 ACK ID for AID=00_h
		00	0	0	0	0	0	0	0	0	27	Bits 1-4=> NAK all LPDUs in slot 1 frame n-1. Bits 5-8=0_h, lower nibble of slot 2, frame n-1 ACK ID for AID=00_h
		00	0	0	0	0	0	0	0	0	28	Bits 1-4=0, upper nibble of slot 2, frame n-1 ACK ID for AID=00_h Bits 5-8=> NAK all LPDUs in slot 2, frame n-1.
		00	0	0	0	0	0	0	0	0	29	Bits 1-8> slot 3, frame n-1 ACK ID for AID=00_h
		00	0	0	0	0	0	0	0	0	30	Bits 1-4=> NAK all LPDUs in slot 3 frame n-1. Bits 5-8=0_h, lower nibble of slot 4, frame n-1 ACK ID for AID=00_h
		00	0	0	0	0	0	0	0	0	31	Bits 1-4=0, upper nibble of slot 4, frame n-1 ACK ID for AID=00_h Bits 5-8=> NAK all LPDUs in slot 4, frame n-1.
		00	0	0	0	0	0	0	0	0	32	Bits 1-8> slot 5, frame n-1 ACK ID for AID=00_h
		00	0	0	0	0	0	0	0	0	33	Bits 1-4=> NAK all LPDUs in slot 5 frame n-1. Bits 5-8=0_h, lower nibble of slot 6, frame n-1 ACK ID for AID=00_h
		00	0	0	0	0	0	0	0	0	34	Bits 1-4=0, upper nibble of slot 6, frame n-1 ACK ID for AID=00_h Bits 5-8=> NAK all LPDUs in slot 6, frame n-1.
		00	0	0	0	0	0	0	0	0	35	Bits 1-8> slot 7, frame n-1 ACK ID for AID=00_h
		00	0	0	0	0	0	0	0	0	36	Bits 1-4=> NAK all LPDUs in slot 7 frame n-1. Bits 5-8=0_h, lower nibble of slot 8, frame n-1 ACK ID for AID=00_h
		00	0	0	0	0	0	0	0	0	37	Bits 1-4=0, upper nibble of slot 8, frame n-1 ACK ID for AID=00_h Bits 5-8=> NAK all LPDUs in slot 8, frame n-1.
		00	0	0	0	0	0	0	0	0	38	Bits1-8> slot 9, frame n-1 ACK ID for AID=00_h
		00	0	0	0	0	0	0	0	0	39	Bits 1-4=> NAK all LPDUs in slot 9 frame n-1. Bits 5-8=0_h, lower nibble of slot 10, frame n-1 ACK ID for AID=00_h
		00	0	0	0	0	0	0	0	0	40	Bits 1-4=0, upper nibble of slot 10, frame n-1 ACK ID for AID=00_h Bits 5-8=> NAK all LPDUs in slot 10, frame n-1.
		15	0	0	0	1	0	1	0	1	41	Bits 1-8=00_h Current Frame, slot 3 assigned to Aircraft ID 15_h. Ref. 5.2.1.7 (e), and Attachment 2-8B.
		12	0	0	0	1	0	0	1	0	42	Bits 1-8=12_h Current Frame, slot 4 assigned to Aircraft ID 12_h.
		12	0	0	0	1	0	0	1	0	43	Bits 1-8=12_h Current Frame, slot 5 assigned to Aircraft ID 12_h.
		FE	1	1	1	1	1	1	1	0	44	Bits 1-8=FE_h Current Frame, slot 6 assigned for Random Access. Ref. 5.2.1.7 (e) and Attachment 2-8B.
		13	0	0	0	1	0	0	1	1	45	Bits 1-8=13_h Current Frame, slot 7 assigned to Aircraft ID 13_h.
		FE	1	1	1	1	1	1	1	0	46	Bits 1-8=FE_h Current Frame, slot 8 assigned for Random Access.
c-2		FE	1	1	1	1	1	1	1	0	47	Bits 1-8=FE_h Current Frame, slot 9 assigned for Random Access.
		FE	1	1	1	1	1	1	1	0	48	Bits 1-8=FE_h Current Frame, slot 10 assigned for Random Access.
		FE	1	1	1	1	1	1	1	0	49	Bits 1-8=FE_h Current Frame, slot 11 assigned for Random Access.
		FE	1	1	1	1	1	1	1	0	50	Bits 1-8=FE_h Current Frame, slot 12 assigned for Random Access.
		00	0	0	0	0	0	0	0	0	51	Bits 1-8=00_h Current Frame + 1, slot 1 reserved for uplink.
		FE	1	1	1	1	1	1	1	0	52	Bits 1-8=FE_h Current Frame + 1, slot 2 assigned for Random Access.
c-2		0B	0	0	0	0	1	0	1	1	53	Bits 1-4=B_h=11_d lowest packet priority accepted by Ground Station. Bits 5-8=0_h=Reserved. Ref. 5.2.1.7 (f)
		BA	1	0	1	1	1	0	1	0	54	Data base version number=$1BA_h$. Bits 1-8=BA_h. Ref. 5.2.1.7 (g).

Figure 1 – Squitter SPDU Uplink (cont'd)

ATTACHMENT 2-8C
HFDL BIT MAP REPRESENTATIONS

HFDL Signal Unit — References for Details and Comments

HFDL ← GS

hex	8	7	6	5	4	3	2	1	Octet	References for Details and Comments	
41	0	1	0	0	0	0	0	1	55	Bits 1-4=1_h. Bits 5-8=4_h=Active frequency is 3rd highest freqencies assigned. Ref. 5.2.1.7 (g)	
21	0	0	1	0	0	0	0	1	56	Bits 1-8=21_h=Active frequencies are 5th, & 10th highest frequencies assigned.	
0A	0	0	0	0	1	0	1	0	57	Bits 1-8=$0A_h$=Active frequencies are 14th, & 16th highest frequencies assigned.	
23	0	0	1	0	0	0	1	1	58	Bits 1-8=23_h 2nd GS ID. Bit 8 indicates GS is not synchronized to UTC.	
0C	0	0	0	0	1	1	0	0	59	Bits 1-8=$0C_h$ Active frequencies are 3rd & 4th highest frequencies assigned.	
22	0	0	1	0	0	0	1	0	60	Bits 1-8=22_h Active frequencies are 10th & 14th highest frequencies assigned.	
32	0	0	1	1	0	0	1	0	61	Bits 1-4=2_h Active frequency is the 18th highest assigned. Bits 5-8=3_h=Lower nibble of 3rd GS ID.	
4A	0	1	0	0	1	0	1	0	62	Bits 1-4=A_h=Higher nibble of 3rd GS ID. Bit 4 indicates GS is sync. to UTC. Bits 5-8= Active frequency is 3rd highest frequency assigned.	
51	0	1	0	1	0	0	0	1	63	Bits 1-8=51_h= Active frequencies are 5th, 9th & 11th highest frequencies assigned.	
00	0	0	0	0	0	0	0	0	64	Bits 1-8=00_h= No frequencies, 13-20, are active at this GS.	
76	0	1	1	1	0	1	1	0	65	Ref. 5.2.1.7 (h) and CCITT Blue Book, Recommendation X. 25, 1988, 2.2.7, page 163. (Over octets 1 through 64)	c-2
	FCS										
F6	1	1	1	1	0	1	1	0	66	FCS Remainder = $6E6F_h$.	
00	0	0	0	0	0	0	0	0	67	Bits 1-8=00_h Flush bits. Ref 5.2.1.7 (I).	

NOTE: Except for FCS all SUs are transmitted least significant bit and lowest numbered byte first. Unles otherwise noted, multi-octet fields are filled most significant byte first. c-3

Figure 1 Squitter SPDU Uplink (cont'd)

HFDL Signal Unit — References for Details and Comments

HFDL → GS

hex	8	7	6	5	4	3	2	1	Octet	References for Details and Comments	
07	0	0	0	0	0	1	1	1	1	Bit 1=1_b=MPDU. Bit 2=1_b=Downlink. Bit 3-6=NLP=1. Bits 7= RESERVED=0. 8=0_b=Odd Parity. Ref. 5.2.2 (a).	c-2
A2	1	0	1	0	0	0	1	0	2	Bits 1-7=34_d=Station ID. Bit 8=1_b=GS Sync. Ref. 5.2.1.7 (b).	
FF	1	1	1	1	1	1	1	1	3	Bits 1-8=$2FF_h$=Log-on Identification. Ref. 5.2.2 (c1), and Attachment 2-7C, and Attachment 2-10D.	
00	0	0	0	0	0	0	0	0	4	Bits 1-8=00_h=Reservation Request. Ref. 5.2.2 (c2).	
04	0	0	0	0	0	1	0	0	5	Uplink ACK Field. Bits 1-3=100_b=UDR=1800 bps. Bits 4-8=U(R)=00000_b. Ref. 5.2.2 (c4) and Attachment 2-7A.	c-2
00	0	0	0	0	0	0	0	0	6	Bit 1-8=0_b=U(R) vect. Ref. 5.2.2 (c4) and 5.2.4.2.3.	
05	0	0	0	0	0	1	0	1	7	Bit 1-8=5_h=LPDU Size. Ref. 5.2.2 (c5).	
6A	0	1	1	0	1	0	1	0	8	Ref. 5.2.2 (d), page 21 and CCITT Blue Book, Recommendation X. 25, 1988, 2.2.7, page 163. (Over octets 1 through 7.)	
	FCS										
02	0	0	0	0	0	0	1	0	9	FCS Remainder = 5640_h	
8F	1	0	0	0	1	1	1	1	10	LPDU Type=8Fh=Log-On Request (RLS Version). Ref. Attachments 2-9A & 2-10D.	
95	1	0	0	1	0	1	0	1	11	ICAO 24-bit Aircraft Address. Assumed to be (A1) 10101001 01010010 01110111 (A24) (LSB) (Represents Aircraft N70CR, Octal 52251167.)	c-2
4A	0	1	0	0	1	0	1	0	12		

Figure 2 – Log-On Request

ATTACHMENT 2-8C
HFDL BIT MAP REPRESENTATIONS

HFDL Signal Unit — References for Details and Comments

	HFDL	GShex	8	7	6	5	4	3	2	1		
	→	EE	1	1	1	0	1	1	1	0	13	
c-2		EB	1	1	1	0	1	0	1	1	14	Ref. 5.2.2 (d), page 21 and CCITT Blue Book, Recommendation X. 25, 1988, 2.2.7, page 163. (Over octets 10 through 13.)
			FCS									
		66	0	1	1	0	0	1	1	0	15	FCS Remainder = D766$_h$
		00	0	0	0	0	0	0	0	0	16	Bits 1-8=00$_h$ Flush bits. Ref. 5.2.1.7 (I).

Figure 2 Log-On Request (cont'd)

	HFDL	GShex	8	7	6	5	4	3	2	1		
	←	01	0	0	0	0	0	0	0	1	1	Bit 1=1$_b$=MPDU. Bit 2=0$_b$=Up Link. Bits 3-4=0=Reserved. Bit 5-7=NAC=000$_b$=0+1 AA Fields. Bit 8=0=Odd parity. Ref. 5.2.2 (a) and Attachment 2-7B.
c-2		A2	1	0	1	0	0	0	1	0	2	Bits 1-7=34$_d$= Station ID. Bit 8=1$_b$=GS Sync. Ref. 5.2.1.7 (b), and 5.2.1.7.2
c-2		FF	1	1	1	1	1	1	1	1	3	Bits 1-8=FF$_h$=Log-on Identification. Ref. 5.2.2 (c1), and Attachment 2-7C, and Attachment 2-10D.
		19	0	0	0	1	1	0	0	1	4	MDF Field. Bit 1=1$_b$=Odd Parity bit. Bits 2-4=100$_b$=Max. downlink data rate = 1800 b/s. Bits 5-8=1$_d$=No. LPDUs for A/C. Ref Attachment 2-7B.
c-2		08	0	0	0	0	1	0	0	0	5	LPDU #1 Size-1=8$_d$ bytes. Ref. 5.2.2 (c5) and Attachment 2-10E.
c-2		4A	0	1	0	0	1	0	1	0	6	Ref. 5.2.2 (d), page 21 and CCITT Blue Book, Recommendation X. 25, 1988, 2.2.7, page 163. (Over octets 1 through 5.)
			FCS									
c-2		57	0	1	0	1	0	1	1	1	7	FCS Remainder = 52EA$_h$
c-2		9F	1	0	0	1	1	1	1	1	8	LPDU Type=9F$_h$=Log-On Confirm. Ref.5.2.2 (a).
		95	1	0	0	1	0	1	0	1	9	ICAO 24-bit Aircraft Address. Assumed to be (A1) 10101001 01010010 01110111 (A24) (LSB). (Represents Aircraft N70CR, Octal 52251167.)
		4A	0	1	0	0	1	0	1	0	10	
		EE	1	1	1	0	1	1	1	0	11	
		A2	1	0	1	0	0	0	1	0	12	Assigned Aircraft ID=A2$_h$. Ref. Sections 5.2.2.3 & 5.2.5.1.1.
c-2		03	0	0	0	0	0	0	1	1	13	Bits 1-4=3$_d$=Transmit Window k=3+1=4. Bits 5-8=0=RESERVED always 0$_h$. Ref. 5.2.2.3, and Attachment 2-10E.
c-2		22	0	0	1	0	0	0	1	0	14	Ref. 5.2.2 (d), and CCITT Blue Book, Recomendation X. 25, 1988, 2.2.7, page 163. (Over octets 8 through 13.)
			FCS									
c-2		E8	1	1	1	0	1	0	0	0	15	FCS Remainder= 4417$_h$.
		00	0	0	0	0	0	0	0	0	16	Bits 1-8=00$_h$ Flush bits. Ref. 5.2.1.7 (I).

c-3 NOTE: Except for FCS alls Sus are transmitted least *significant* bit and lowest numbered byte first. Unless otherwise noted, multi-octet fields are filled most significant byte first.

Figure 3 – Log-On Confirm

ATTACHMENT 2-8C
HFDL BIT MAP REPRESENTATIONS

HFDL	GShex	8	7	6	5	4	3	2	1		References for Details and Comments	
←	21	0	0	0	0	0	0	0	1	1	Bit 1=1_b=MPDU. Bit 2=0_b=Uplink. Bit 3-4=RESERVED, always=0. Bits 5-7=000_b=1 AA in MPDU. Bit 8=1=Odd parity. Ref. 5.2.2 (a), Attachment 2-7B, 2-10C.	
	A2	1	0	1	0	0	0	1	0	2	Bits 1-7=34_d=Station ID. Bit 8=1_b=GS Sync. Ref. 5.2.1.7 (b), and 5.2. 1.7.2.	c-2
	00	0	0	0	0	0	0	0	0	3	Bits 1-8=00_h=Broadcast Identification. Ref. 5.2.2.5.1 (c) and Attachment 2-10C.	
	16	0	0	0	1	0	1	1	0	4	MDF Field. Bit 1=0_b=Odd parity. Bits 2-4=110_b=Max. downlink data rate= 1200 b/s. Bits 5-8=1_d=No. LPDUs for A/C. Ref. 5.2.2.5.1 (c1).	
	51	0	1	0	1	0	0	0	1	5	LPDU #1 Size-1=51_h $(82-1=81)_d$ bytes. Ref. 5.2.2.1.5 (c2) and Attachment 2-10G.	c-2
	A4	1	0	1	0	0	1	0	0	6	Ref. 5.2.2 (d), page 21 and CCITT Blue Book, Recomendation X. 25, 1988, 2.2.7, page 163. (Over octets 1 through 5)	c-2
	BD	FCS 1	0	1	1	1	1	0	1	7	FCS Remainder = $25BD_h$.	c-2
	0D	0	0	0	0	1	1	0	1	8	LPDU Type=$0D_h$=Unnumbered Data. Ref. 5.2.2.5.1 (d).	
	FF	1	1	1	1	1	1	1	1	9	Bits 1-8=FF_h=First byte of HFNPDU Type=$FFD0_h$ Ref. 5.2.2.5.1 (e) and Attachment 2-10C	
	D0	1	1	0	1	0	0	0	0	10	Bits 1-8=$D0_h$=Second byte of HFNPDU Type=$FFD0_h$. Ref. 5.2.2.5.1 (e) Attachment 2-10C.	c-2
	11	0	0	0	1	0	0	0	1	11	Bits 1-4=Seq. #=1_d Bits 5-8=No. of Packets = 1_d. Ref. 5.2.2.5.1 (f), and Attached 2-10C	c-2
	A0	1	0	1	0	0	0	0	0	12	Bits 1-4=0_h=Pad. Bits 5-8=A_h=Low order hex digit of Dbase version. REF. 5.2.2.5.1 (g) and Attachment 2-10G (Assumed to be Ver. $15A_h$.)	
	15	0	0	0	1	0	1	0	1	13	Bits 1-8=15_h=High Order hex digits of Dbase Version Number.	
	81	1	0	0	0	0	0	0	1	14	Bits 1-7=1_d=Station ID. Bit 8=1_b=GS Sync. Ref. 5.2.1.7 (b), and 5.2.1.7.2, page 18/20.	c-2
	3A	0	0	1	1	1	0	1	0	15	Bits 1-8=$3A_h$=Lower 8 bits of Latitude (assumed to be N42º 1.91´=$1DE3A_h$). 19 bit resolution.	
	DE	1	1	0	1	1	1	1	0	16	Bits 1-8=DE_h=Mid 8 bits of Latitude.	
	C1	1	1	0	0	0	0	0	1	17	Bits 1-4=1_h=Upper nibble of Latitude (bit 4=0=North). Bits 5-8=C_h=Lower nibble of Longitude (assumed to be W91º 38.60´= $BED4C_h$). 19 bit resolution.	c-2
	D4	1	1	0	1	0	1	0	0	18	Bits 1-8=$D4_h$=Mid 8 bits of Longitude.	
	BE	1	0	1	1	1	1	1	0	19	Bits 1-4=BE_h=Upper 8 bits of Longitude. Bit 8=1=West. Ref. 5.2.2.5.1 (h2) and Attachment 2-10G.	
	41	0	1	0	0	0	0	0	1	20	Bits 1-3=001_b=Squitter. Ver. Bits 4-8=8_d=Number of Frequencies at station 20_d. Ref. 5.2.2.5.1 (h3).	c-2
	50	0	1	0	1	0	0	0	0	21	Bits 1-4=0_h=Freq. #1 100s Hz. F1=21.765 MHz. Ref. 5.2.2.5.1 (c4) Bits 5-8=5_h=Freq. #1 kHz.	
	76	0	1	1	1	0	1	1	0	22	Bits 1-4=6_h=Freq. #1 10s kHz. Bits 5-8=7_h=Freq. #1 100s kHz.	
	21	0	0	1	0	0	0	0	1	23	Bits 1-4=1_h=Freq. #1 MHz. Bits 5-6=10_b=Freq. #1 10s MHz. Bits 7-8=00_b.	
	00	0	0	0	0	0	0	0	0	24	Bits 1-4=0_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref.=5.2.2.5.1 (h4)	
	00	0	0	0	0	0	0	0	0	25	Bits 1-4=0_h=Freq. #2 100s Hz. F2=19.510 MHz. Bits 5-8=0_h=Freq. #2 kHz.	
	51	0	1	0	1	0	0	0	1	26	Bits 1-4=1_h=Freq. #2 10s kHz. Bits 5-8=5_h=Freq. #2 100s kHz.	
	19	0	0	0	1	1	0	0	1	27	Bits 1-4=9_h=Freq. #2 MHz Bits 5-6=01_b=Freq. #2 10s MHz. Bits 7-8=00_b.	
	02	0	0	0	0	0	0	0	1	28	Bits 1-4=2_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref.=5.2.2.5.1 (h4)	
	00	0	0	0	0	0	0	0	0	29	Bits 1-4=0_h=Freq. #3 100s Hz. F3=14.890 MHz. Bits 5-8=0_h=Freq. #3 kHz.	

Figure 4 – Broadcast HFDL System Table (5.2.2.5.1)

ATTACHMENT 2-8C
HFDL BIT MAP REPRESENTATIONS

HFDL Signal Unit — References for Details and Comments

HFDL	GShex	8	7	6	5	4	3	2	1		References for Details and Comments
←	89	1	0	0	0	1	0	0	1	30	Bits 1-4=9_h=Freq. #3 10s kHz. Bits 5-8=8_h=Freq. #3 100s kHz.
	14	0	0	0	1	0	1	0	0	31	Bits 1-4=4_h=Freq. #3 MHz. Bits 5-6=01_b=Freq. #3 10s MHz. Bits 7-8=00_b
	04	0	0	0	0	0	1	0	0	32	Bits 1-4=4_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4)
	30	0	0	1	1	0	0	0	0	33	Bits 1-4=0_h=Freq. #4 100s Hz. F4=12.133 MHz. Bits 5-8=3_h=Freq. #4 kHz.
	13	0	0	0	1	0	0	1	1	34	Bits 1-4=3_h=Freq. #4 10s kHz Bits 5-8=1_h=Freq. #4 100s kHz.
	12	0	0	0	1	0	0	1	0	35	Bits 1-4=2_h=Freq. #4 MHz. Bits 5-6=01_b=Freq. #4 10s MHz. Bits 7-8=00_b
	06	0	0	0	0	0	1	1	0	36	Bits 1-4=6_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4)
	10	0	0	0	1	0	0	0	0	37	Bits 1-4=0_h=Freq. #5 100s Hz. F5=10.291 MHz. Bits 5-8=1_h=Freq. #5 kHz.
	29	0	0	1	0	1	0	0	1	38	Bits 1-4=9_h=Freq. #5 10s kHz. Bits 5-8=2_h=Freq. #5 100s kHz.
	10	0	0	0	1	0	0	0	0	39	Bits 1-4=0_h=Freq. #5 MHz. Bits 5-6=01_b=Freq. #5 10s MHz. Bits 7-8=00_b.
	08	0	0	0	0	1	0	0	0	40	Bits 1-4=8_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4)
	00	0	0	0	0	0	0	0	0	41	Bits 1-4=0_h=Freq. #6 100s Hz. F6=8.170 MHz. Bits 5-8=0_h=Freq. #6 kHz.
	17	0	0	0	1	0	1	1	1	42	Bits 1-4=7_h=Freq. #6 10s kHz. Bits 5-8=1_h=Freq. #6 100s kHz.
	08	0	0	0	0	1	0	0	0	43	Bits 1-4=8_h=Freq. #6 MHz. Bits 5-6=00_b=Freq. #6 10s MHz. Bits 7-8=00_b.
	0A	0	0	0	0	1	0	1	0	44	Bits 1-4=A_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4)
	00	0	0	0	0	0	0	0	0	45	Bits 1-4=0_h=Freq. #7 100s Hz. F7=5.610 MHz. Bits 5-8=0_h=Freq. #7 kHz.
	61	0	1	1	0	0	0	0	1	46	Bits 1-4=1_h=Freq. #7 10s kHz. Bits 5-8=6_h=Freq. #7 100s kHz.
	05	0	0	0	0	0	1	0	1	47	Bits 1-4=5_h=Freq. #7 MHz. Bits 5-6=00_b=Freq. #7 10s MHz. Bits 7-8=00_b.
	0C	0	0	0	0	1	1	0	0	48	Bits 1-4=C_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4)
	20	0	0	1	0	0	0	0	0	49	Bits 1-4=0_h=Freq. #8 100s Hz. F8=3.482 MHz. Bits 5-8=2_h=Freq. #8 kHz.
	48	0	1	0	0	1	0	0	0	50	Bits 1-4=8_h==Freq. #8 10s kHz. Bits 5-8=4_h=Freq. #8 100s kHz.
	03	0	0	0	0	0	0	1	1	51	Bits 1-4=3_h=Freq. #8 MHz. Bits 5-6=00_b=Freq. #8 10s MHz. Bits 7-8=0_h.
	01	0	0	0	0	0	0	0	1	52	Bits 1-4=1_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4).
c-2	82	1	0	0	0	0	0	1	0	53	Bits 1-7=2_d=Station ID. Bit 8=1_b=GS Sync. Ref. 5.2.1.7 (b), and 5.2.1.7.2, page 18/20.
	67	0	1	1	0	0	1	1	1	54	Bits 1-8=67_h=Lower 8 bits of Latitude (assumed to be N59º 21.70´=$2A367_h$). 19 bit resolution.
	A3	1	0	1	0	0	0	1	1	55	Bits 1-8=$A3_h$=Mid 8 bits of Latitude.
	22	0	0	1	0	0	0	1	0	56	Bits 1-4=2_h=Upper nibble of Latitude (bit 4=0=North). Bits 5-8=2_h=Lower nibble of Longitude (assumed to be E17º 12.65´=$0C3D2_h$).
	3D	0	0	1	1	1	1	0	1	57	Bits 1-8=$3D_h$=Mid 8 bits of Longitude.
	0C	0	0	0	1	1	0	1	0	58	Bits 1-4=$0C_h$=Upper 8 bits of Longitude. Bit 8=0=East. Ref. Attachment 2-10G.

Figure 4 – Broadcast HFDL System Table (cont'd)

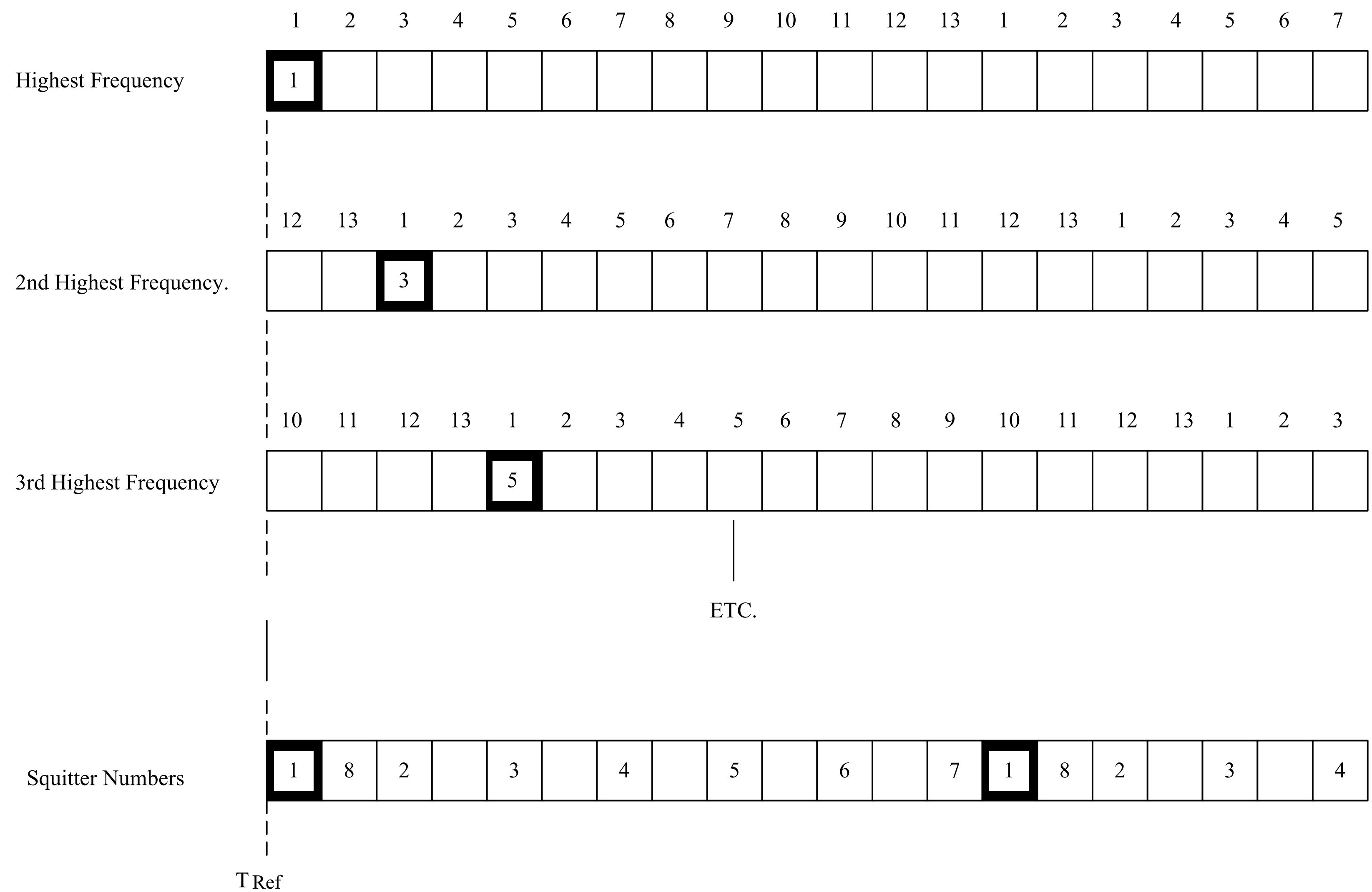
ATTACHMENT 2-8C
HFDL BIT MAP REPRESENTATIONS

HFDL	GShex	8	7	6	5	4	3	2	1		References for Details and Comments
←	41	0	1	0	0	0	0	0	1	59	Bits 1-3=001_b=Squitter. Ver. Bits 1-8=8_d=Number of Frequencies at station 20_d. Ref. 5.2.2.5.1 (h3)..
	00	0	0	0	0	0	0	0	0	60	Bits 1-4=0_h=Freq. #1 100s Hz. F1=23.210 MHz. Ref. 5.2.2.5.1 (h4) Bits 5-8=0_h=Freq. #1 kHz.
	21	0	0	1	0	0	0	0	1	61	Bits 1-4=1_h=Freq. #1 10s kHz. Bits 5-8=2_h=Freq. #1 100s kHz.
	23	0	0	1	0	0	0	1	1	62	Bits 1-4=3_h=Freq. #1 MHz. Bits 5-6=10_b=Freq. #1 10s MHz. Bits 7-8=00_b.
	00	0	0	0	0	0	0	0	0	63	Bits 1-4=0_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4)
	70	0	1	1	1	0	0	0	0	64	Bits 1-4=0_h=Freq. #2 100s Hz. F2=21.997 MHz. Bits 5-8=7_h=Freq. #2 kHz.
	99	1	0	0	1	1	0	0	1	65	Bits 1-4=9_h=Freq. #2 10s kHz. Bits 5-8=9_h=Freq. #2 100s kHz.
	21	0	0	1	0	0	0	0	1	66	Bits 1-4=1_h=Freq. #2 MHz. Bits 5-6=10_b=Freq. #2 10s MHz. Bits 7-8=00_b.
	00	0	0	0	0	0	0	0	0	67	Bits 1-4=0_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4).
	60	0	1	1	0	0	0	0	0	68	Bits 1-4=0_h=Freq. #3 100s Hz. F3=17.916 MHz. Bits 5-8=6_h=Freq. #3 kHz.
	91	1	0	0	1	0	0	0	1	69	Bits 1-4=1_h=Freq. #3 10s kHz. Bits 5-8=9_h=Freq. #3 100s kHz.
	17	0	0	0	1	0	1	1	1	70	Bits 1-4=7_h=Freq. #3 MHz. Bits 5-6=01_b=Freq. #3 10s MHz. Bits 7-8=00_b.
	00	0	0	0	0	0	0	0	0	71	Bits 1-4=0_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4).
	20	0	0	1	0	0	0	0	0	72	Bits 1-4=0_h=Freq. #4 100s Hz. F4=13.342 MHz. Bits 5-8=2_h=Freq. #4 kHz.
	34	0	0	1	1	0	1	0	0	73	Bits 1-4=4_h=Freq. #4 10s kHz. Bits 5-8=3_h=Freq. #4 100s kHz.
	13	0	0	0	1	0	0	1	1	74	Bits 1-4=3_h=Freq. #4 MHz. Bits 5-6=01_b=Freq. #4 10s MHz. Bits 7-8=00_b.
	00	0	0	0	0	0	0	0	0	75	Bits 1-4=0_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4).
	50	0	1	0	1	0	0	0	0	76	Bits 1-4=0_h=Freq. #5 100s Hz. F5=11.345 MHz. Bits 5-8=5_h=Freq. #5 kHz.
	34	0	0	1	1	0	1	0	0	77	Bits 1-4=4_h=Freq. #5 10s kHz. Bits 5-8=3_h=Freq. #5 100s kHz.
	11	0	0	0	1	0	0	0	1	78	Bits 1-4=1_h=Freq. #5 MHz. Bits 5-6=01_b=Freq. #5 10s MHz. Bits 7-8=00_b.
	00	0	0	0	0	0	0	0	0	79	Bits 1-4=0_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4).
	00	0	0	0	0	0	0	0	0	80	Bits 1-4=0_h=Freq. #6 100s Hz. F6=8.930 MHz. Bits 5-8=0_h=Freq. #6 kHz.
	93	1	0	0	1	0	0	1	1	81	Bits 1-4=3_h=Freq. #6 10s kHz. Bits 5-8=9_h=Freq. #6 100s kHz.
	08	0	0	0	0	1	0	0	0	82	Bits 1-4=8_h=Freq. #6 MHz. Bits 5-6=00_b=Freq. #6 10s MHz. Bits 7-8=00_b.
	00	0	0	0	0	0	0	0	0	83	Bits 1-4=0_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4).
	10	0	0	0	1	0	0	0	0	84	Bits 1-4=0_h=Freq. #7 100s Hz. F7=5.541 MHz. Bits 5-8=1_h=Freq. #7 kHz.
	54	0	1	0	1	0	1	0	0	85	Bits 1-4=4_h=Freq. #7 10s kHz. Bits 5-8=5_h=Freq. #7 100s kHz.
	05	0	0	0	0	0	1	0	1	86	Bits 1-4=5_h=Freq. #7 MHz. Bits 5-6=00_b=Freq. #7 10s MHz. Bits 7-8=00_b.
	00	0	0	0	0	0	0	0	0	87	Bits 1-4=0_h=Master Frame Slot. Bits 5-8=0_h=Pad. Ref. = 5.2.2.5.1 (h4).
	46	0	1	0	0	0	1	1	0	88	Ref. 5.2.2 (d), page 21 and CCITT Blue Book, Recommendation X. 25, 1988, 2.2.7, page 163. (Over octets 8 through 87) c-2
	2B	0	0	1	0	1	0	1	1	89	FCS Remainder = $62D4_h$.
	00	0	0	0	0	0	0	0	0	90	Bits 1-8=00_h Flush bits. Ref. 5.2.1.7 (I)

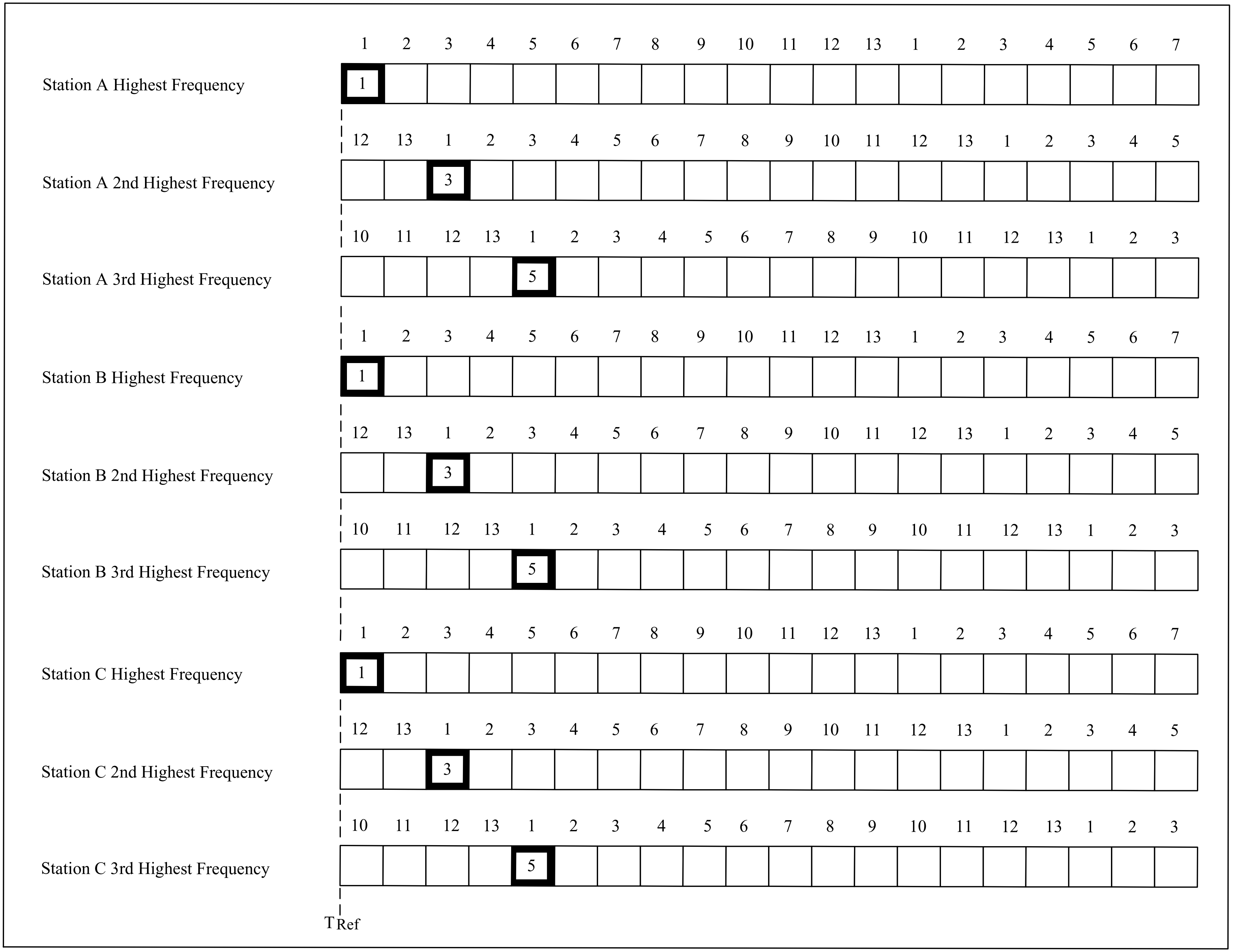
NOTE: Except for FCS all SUs are transmitted least significant bit and lowest numbered byte first. Unless otherwise noted, multi-octet fields are filled most significant byte first. c-3

Figure 4 – Broadcast HFDL System Table (cont'd)

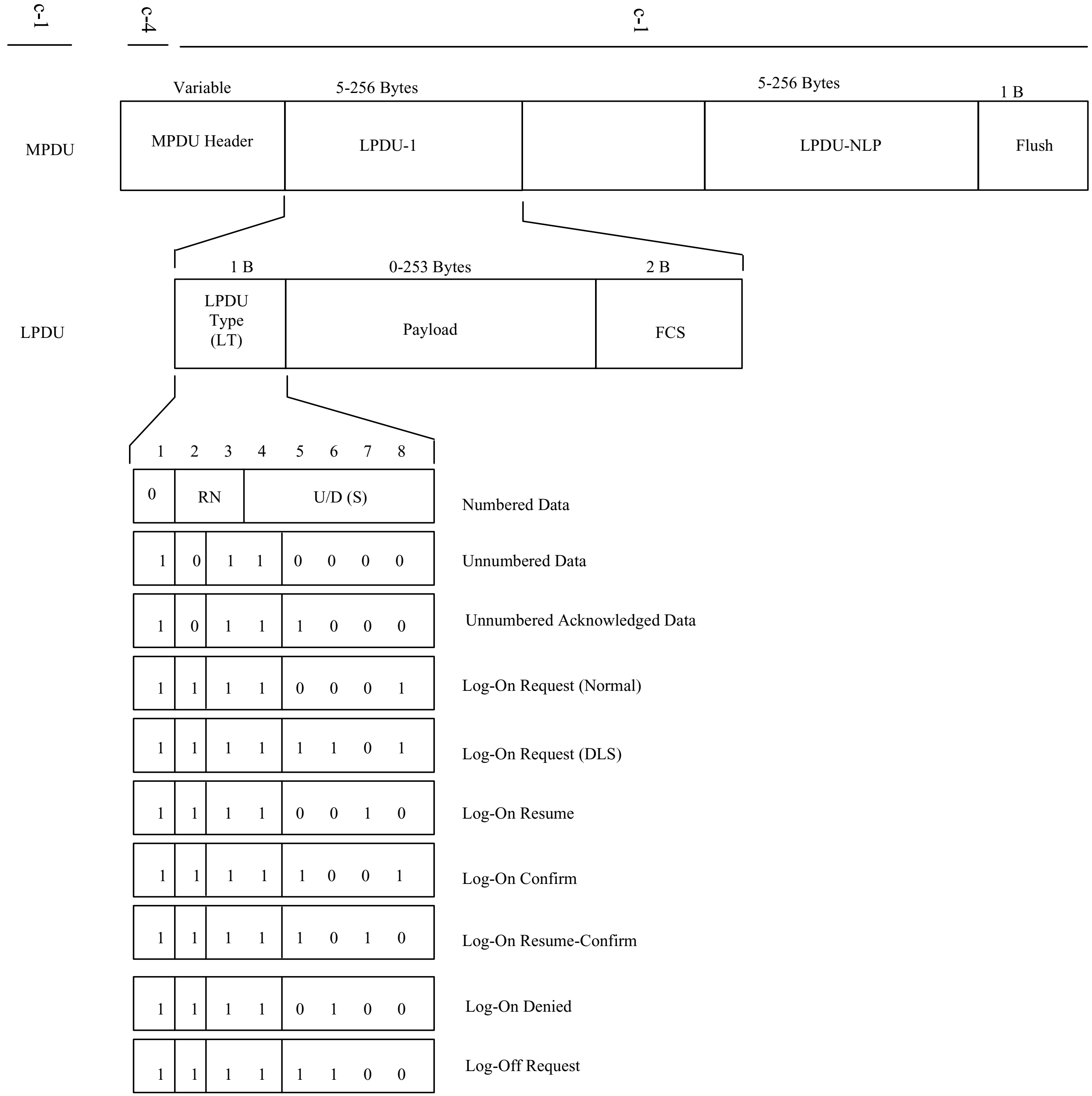
ATTACHMENT 2-8D
INTRA-STATION SYNCHRONIZATION



ATTACHMENT 2-8E
INTER-STATION SYNCHRONIZATION

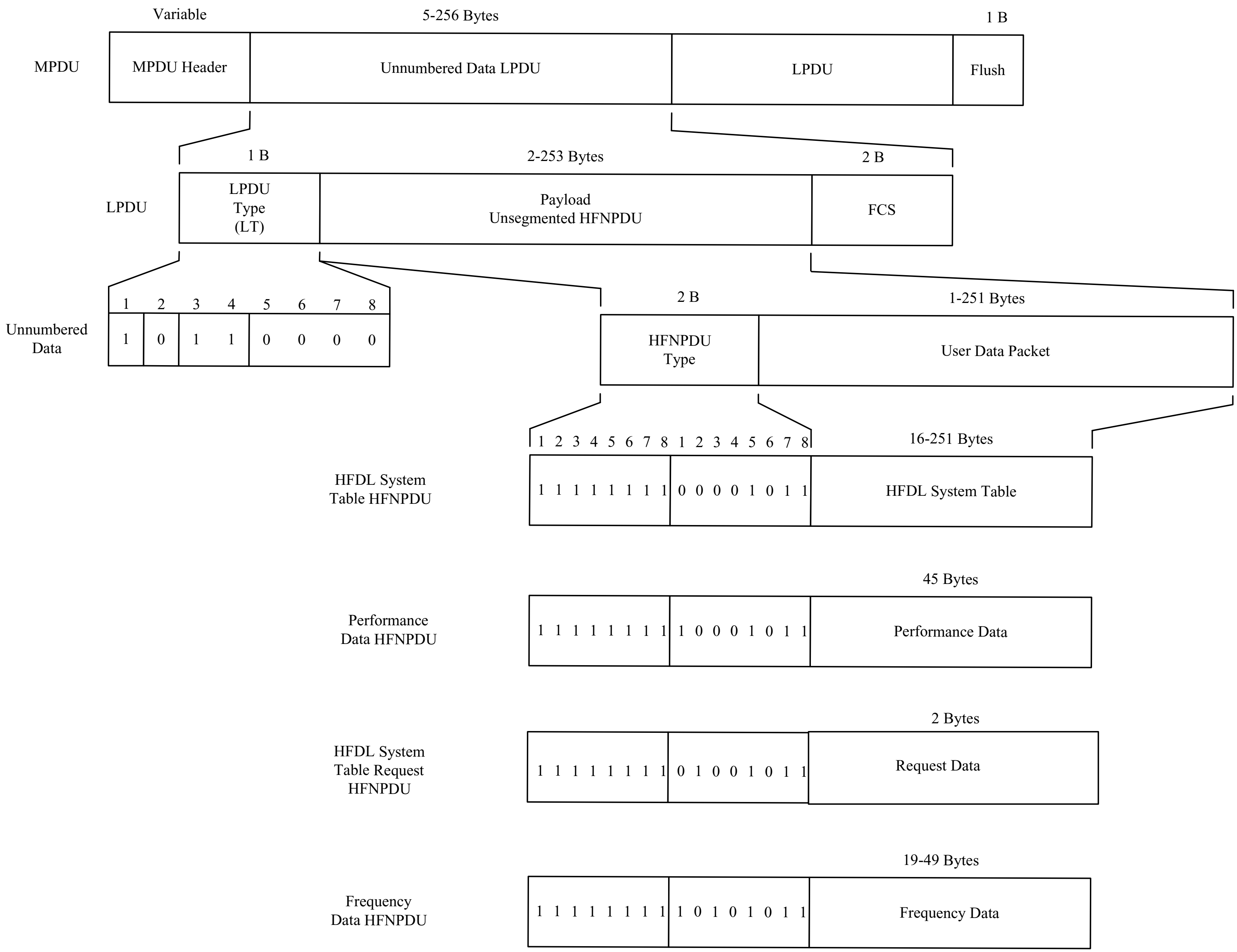


ATTACHMENT 2-9A
LPDU TYPES AND FORMAT DEFINITION

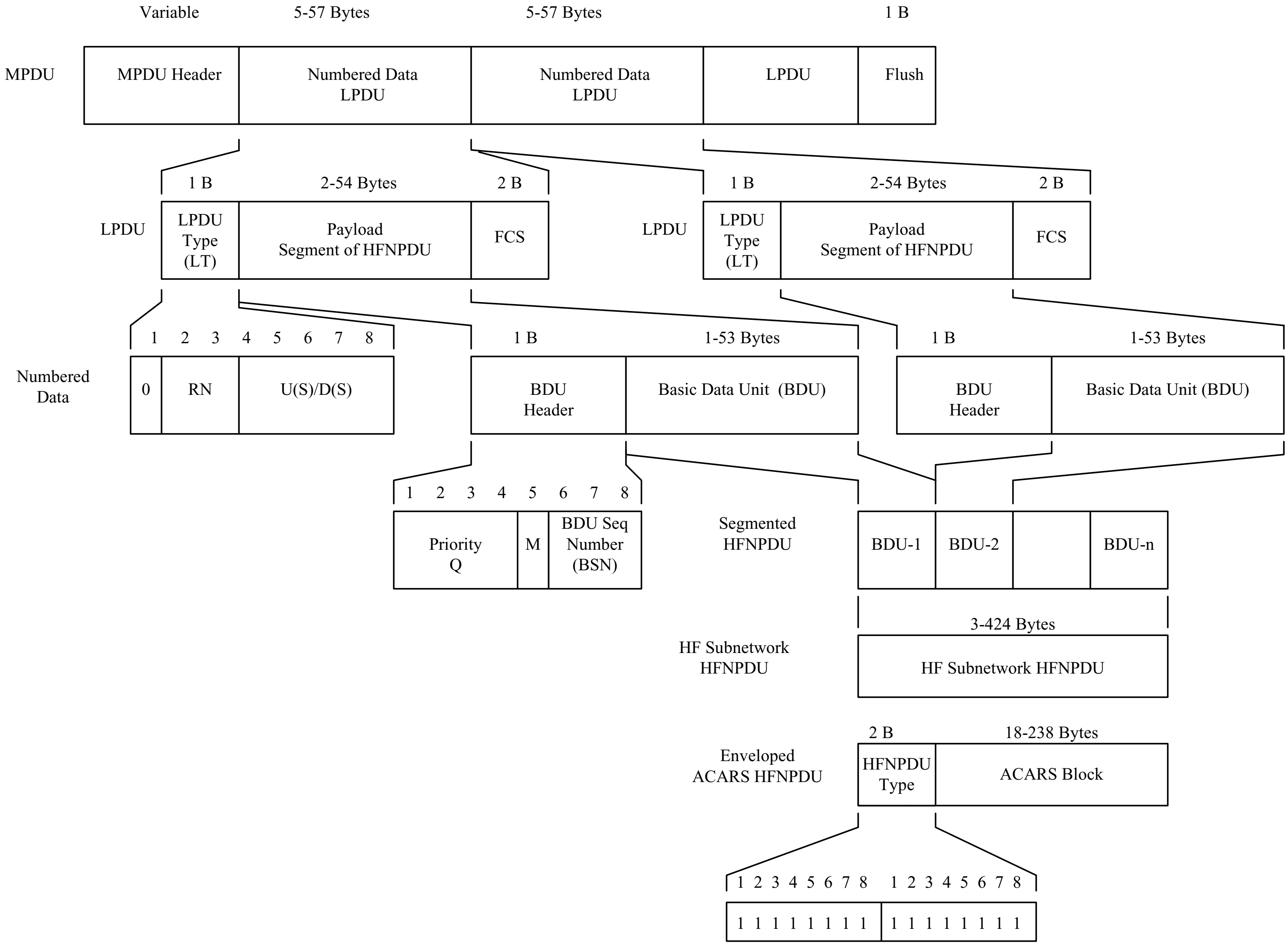


ATTACHMENT 2-10A

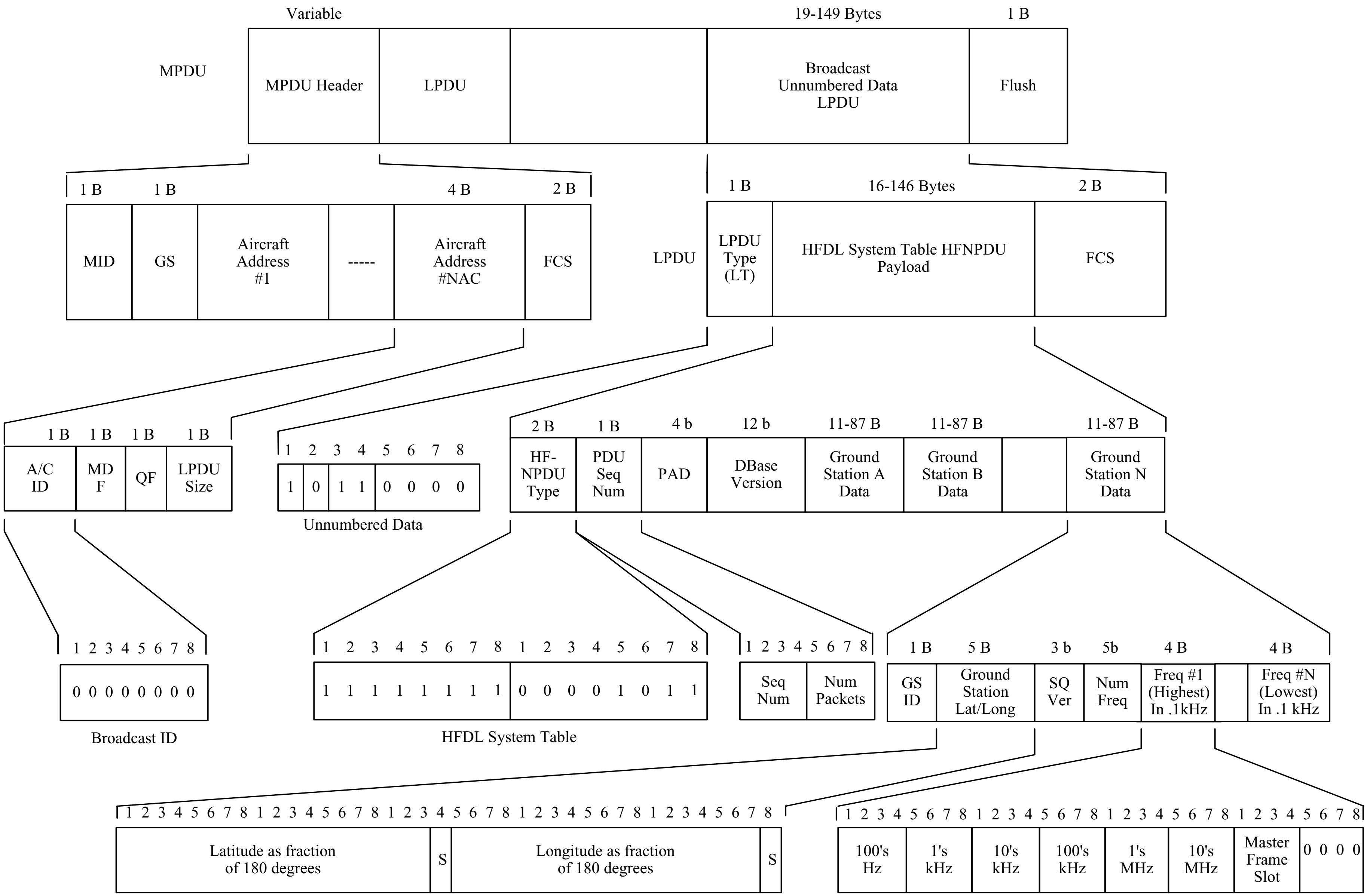
UNNUMBERED DATA LPDU FORMAT DEFINITION



ATTACHMENT 2-10B
NUMBERED DATA LPDU FORMAT DEFINITION

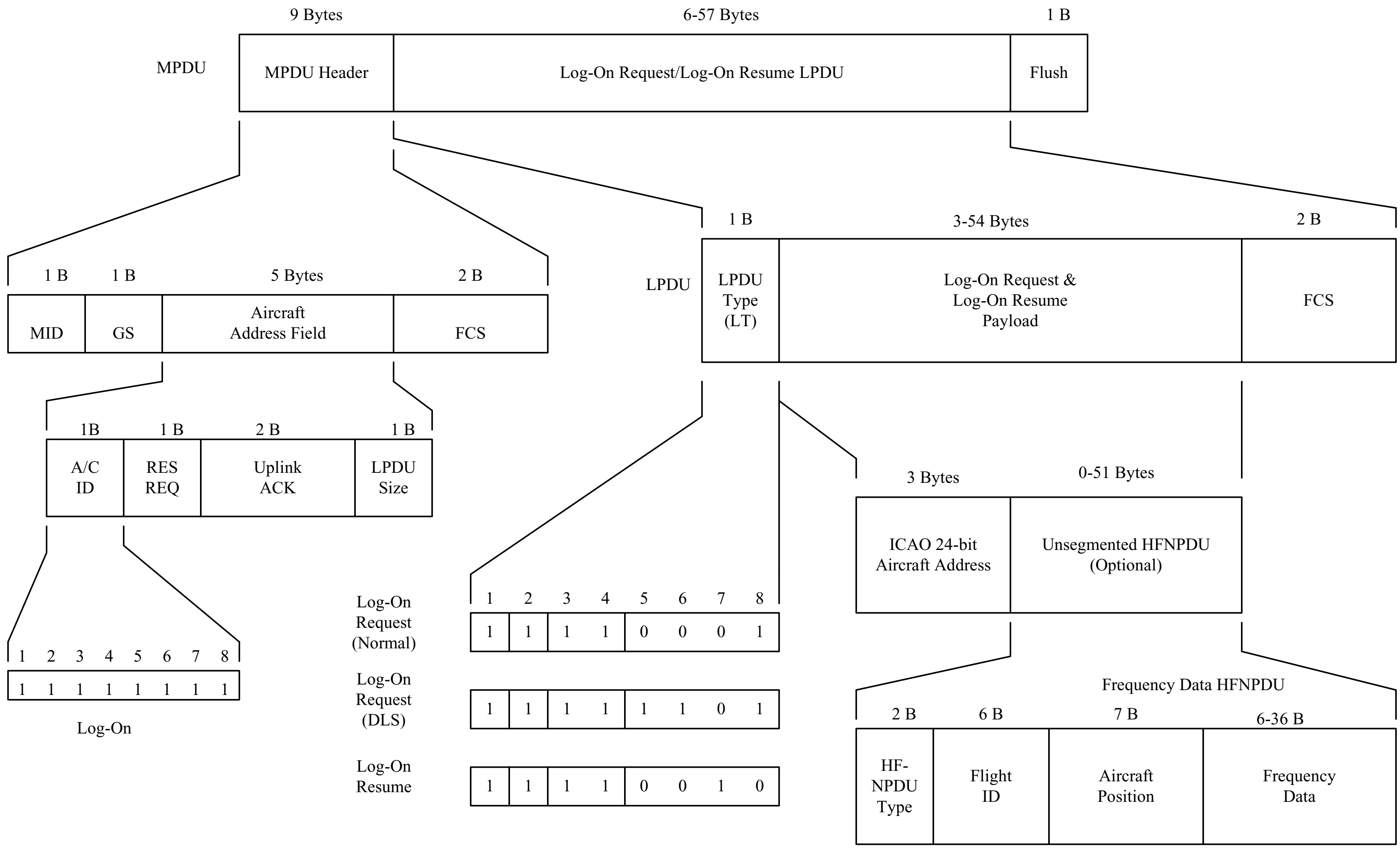


ATTACHMENT 2-10C
UNNUMBERED DATA LPDU WITH BROADCAST HFDL SYSTEM TABLE

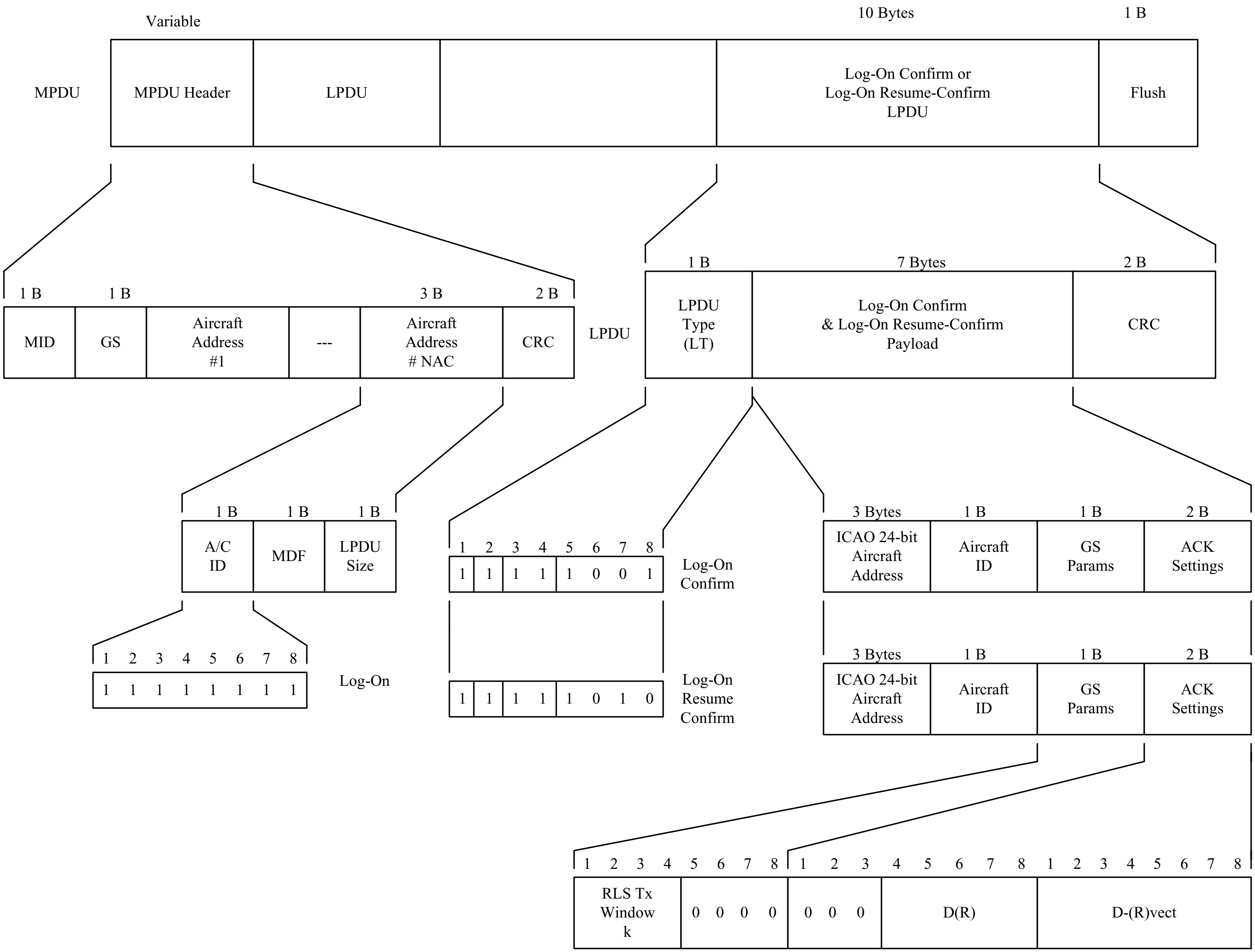


c-1 c-3 c-1

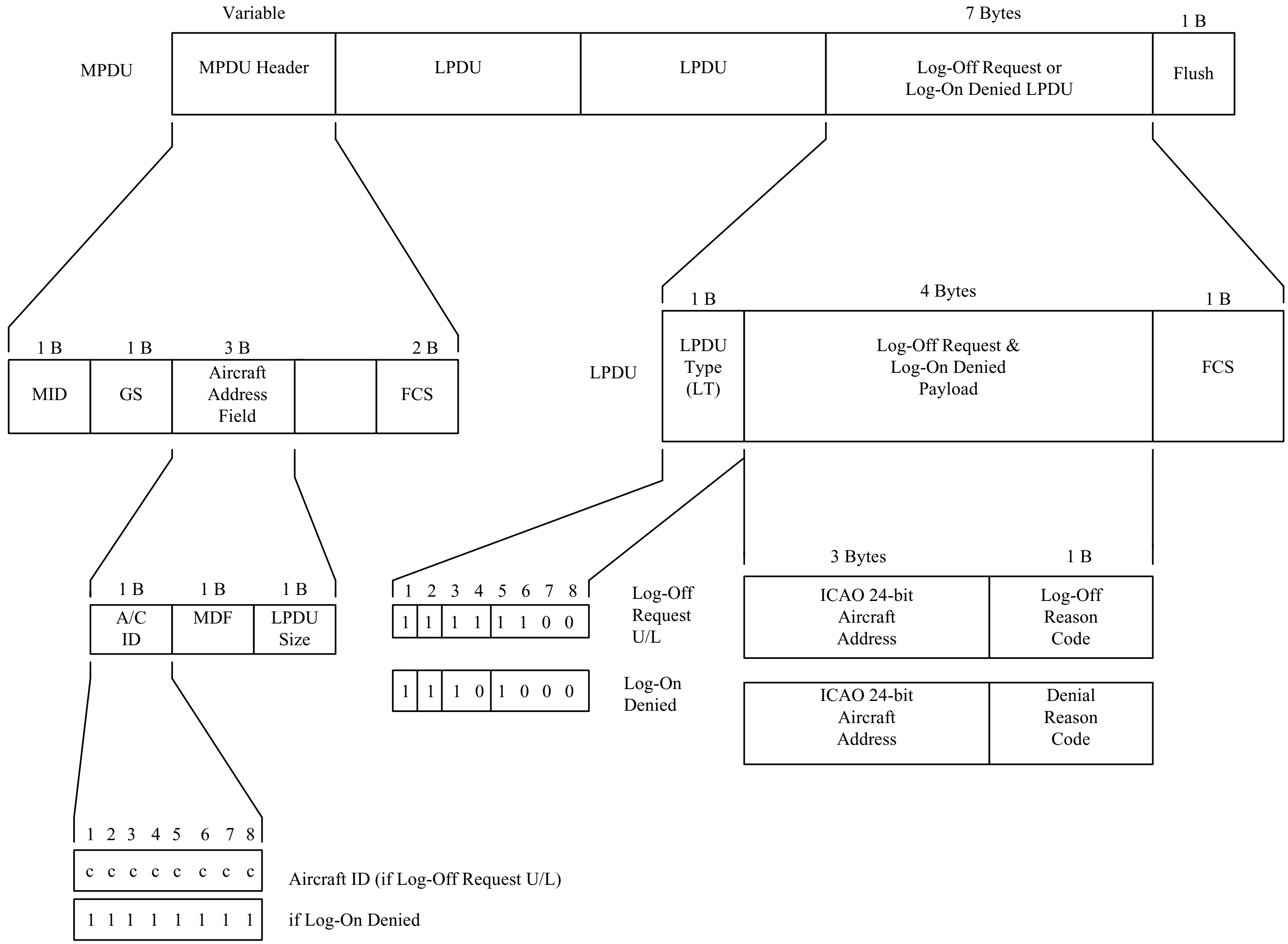
ATTACHMENT 2-10D
LOG-ON REQUEST AND LOG-ON RESUME LPDU FORMAT DEFINITIONS



ATTACHMENT 2-10E
LOG-ON CONFIRM AND LOG-ON RESUME-CONFIRM LPDU FORMAT DEFINITION

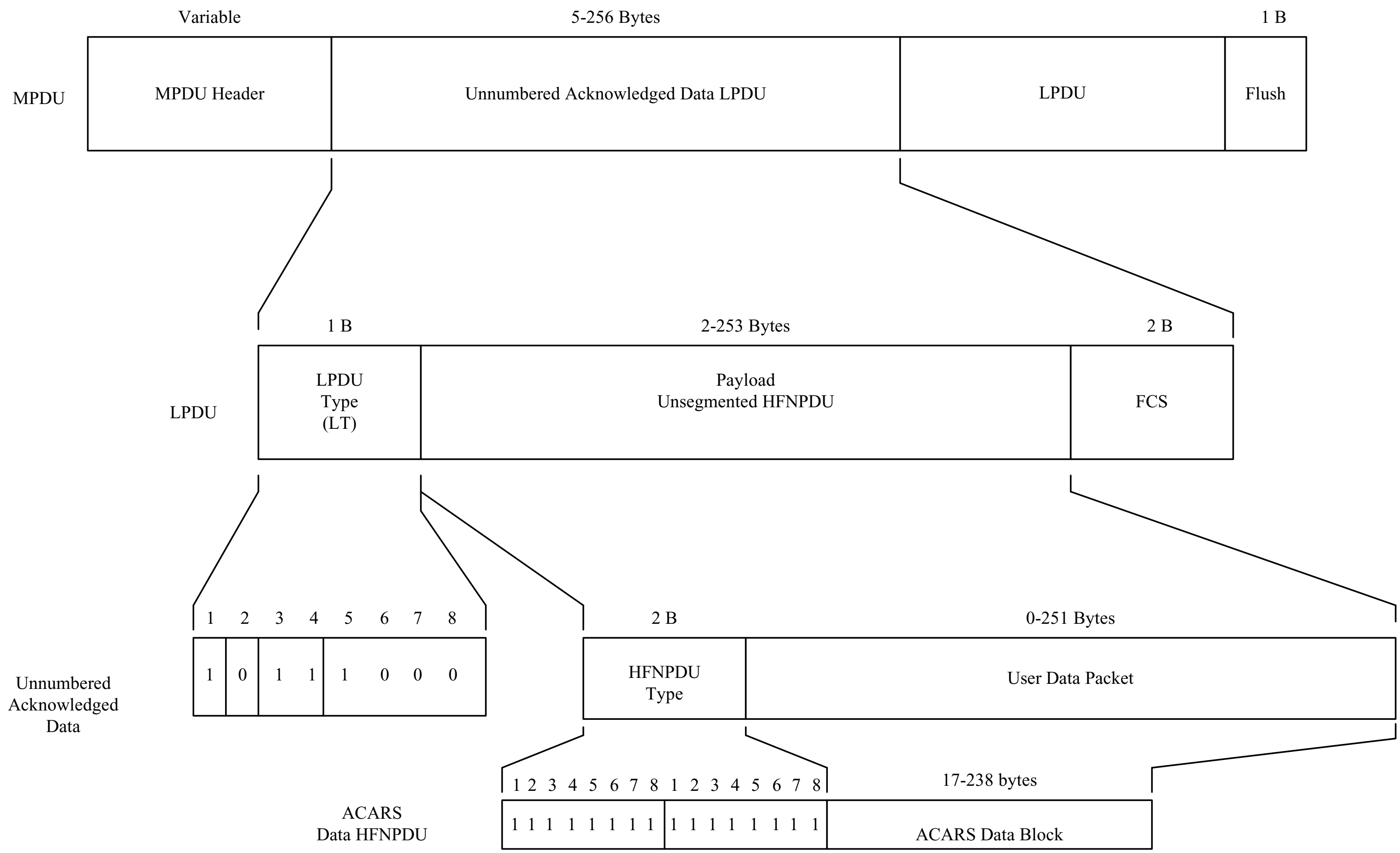


c-1

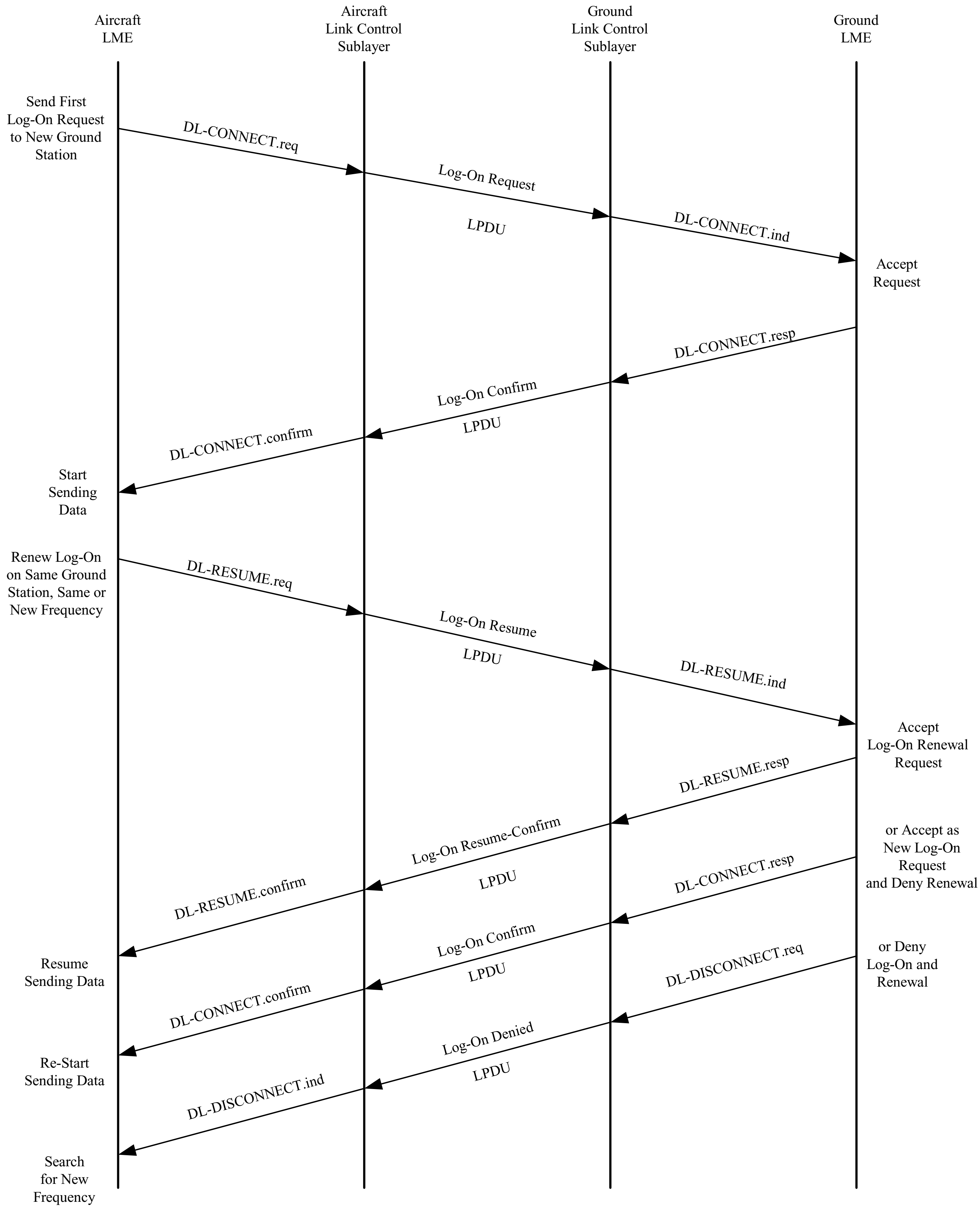


ATTACHMENT 2-10F
LOG-OFF REQUEST AND LOG-ON DENIED LPDU FORMAT DEFINITION

ATTACHMENT 2-10G
UNNUMBERED ACKNOWLEDGED DATA LPDU FORMAT DEFINITION



ATTACHMENT 2-11
HFDL LOG-ON PROCEDURES



ATTACHMENT 2-12
DATA LINK LAYER

Table 1 Main State Transition Table - Aircraft

Events	STATES					
	Disconnected 0	Connection Pending 1	Connection Paused 5	Resume Connection Pending 6	Connected 7	
DL-CONNECT.req	LOG-ON REQUEST RC200 = 0 Start T200 New State: 1		LOG-ON REQUEST RC200 = 0 Start T200 New State: 1			
DL-RESUME.req			LOG-ON RESUME RC200 = 0 Start T200 New State: 6			
LPDU LOG-ON CONFIRM		DL-CONNECT.conf Stop T200 New State: 7		DL-CONNECT.conf Stop T200 New State: 7		
LPDU LOG-ON RESUME CONFIRM				DL-RESUME.conf Stop T200 New State: 7		
LPDU LOG-ON DENIED		DL-DISCONNECT.ind Stop T200 New State: 0		DL-PAUSE.ind Stop T200 New State: 5		
LPDU LOG-OFF REQUEST		DL-DISCONNECT.ind Stop T200 New State: 0	DL-DISCONNECT.ind New State: 0	DL-DISCONNECT.ind Stop T200 New State: 0	DL-DISCONNECT.ind New State: 0	
T200 expired & RC200 < N200		LOG-ON REQUEST RC200++ Start T200		LOG-ON RESUME RC200++ Start T200		
RC200 = N200		DL-DISCONNECT.ind Stop T200 New State: 0		DL-DISCONNECT.ind Stop T200 New State: 0		
DL-PAUSE.req		DL-DISCONNECT.conf Stop T200 New State: 0	DL-PAUSE.conf	DL-PAUSE.conf Stop T200 New State: 5	DL-PAUSE.conf New State: 5	
DL-DISCONNECT.req	DL-DISCONNECT.conf	DL-DISCONNECT.conf Stop T200 New State: 0	DL-DISCONNECT.conf New State: 0	DL-DISCONNECT.conf Stop T200 New State: 0	DL-DISCONNECT.conf LOG-OFF REQUEST New State: 0	c-1
LPDU Numbered Data (New NS)					RLS-BDU.ind MAC-ACK.req Update VR & VectR	
LPDU Numbered Data (Old NS)					MAC-ACK.req Discard duplicate LPDU	
LPDU Numbered Data (Bad NS)					DL-DISCONNECT.ind New State: 0	
LPDU Unnumbered Data					DL-UNITDATA.ind	
ACK/NAK (Bad NR/VectNR)					DL-DISCONNECT.ind New State: 0	
DL-UNITDATA.req			Store request	Store request	Unnumbered Data LPDU	
DL-DATA-ACK.req			Store request	Store request	See Unnumbered Acknowledged Data Transfer Table 3B	c-1
RLS-BDU.req			Store request	Store request	See Numbered Data Transfer Transition Table 3A	c-1
RC204 = N204					DL-PAUSE.ind New State: 5	

Note: When processing events, LPDUs should be given priority over requests and timers, and requests should be given priority over timers. c-1

ATTACHMENT 2-12
DATA LINK LAYER

Table 2 Main State Transition Table - Ground Station

Events	STATES				
	Disconnect 0	Connection Pending 1	Connection Paused 5	Resume Connection Pending 6	Connected 7
LPDU LOG-ON REQUEST	DL-CONNECT.ind New State: 1		DL-CONNECT.ind Stop T202 New State: 1		DL-CONNECT.ind Stop T202 New State: 1
LPDU LOG-ON RESUME	DL-CONNECT.ind New State: 1		DL-RESUME.ind Stop T202 New State: 6		DL-RESUME.ind Stop T202 New State: 6
DL-CONNECT.resp		LOG-ON CONFIRM Start T202 New State: 7		LOG-ON CONFIRM Start T202 New State: 7	
DL-RESUME.resp				LOG-ON RESUME CONFIRM Start T202 New State: 7	
DL-DISCONNECT.req		LOG-ON DENIED New State: 0	LOG-OFF REQUEST Stop T202 New State: 0	LOG-ON DENIED New State: 0	LOG-OFF REQUEST Stop T202 New State: 0
T202 expired			DL-DISCONNECT.ind New State: 0		DL-DISCONNECT.ind New State: 0
LPDU NUMBERED DATA (New NS)			RLS-BDU.ind Update VR & VectR Restart T202 New State: 7		RLS-BDU.ind Update VR & VectR Restart T202
LPDU NUMBERED DATA (Old NS)			ACK Restart T202 New State: 7		Restart T202 Discard duplicate LPDU
LPDU NUMBERED DATA (Bad NS)			LOG-OFF REQUEST Stop T202 New State: 0		LOG-OFF REQUEST Stop T202 New State: 0
LPDU UNNUMBERED DATA			DL-UNITDATA.ind Restart T202 New State: 7		DL-UNITDATA.ind Restart T202
LPDU UNNUMBERED ACKNOWLEDGED DATA			DL-UNITDATA.ind Restart T202 New State: 7		DL-UNITDATA.ind Restart T202
DL-UNITDATA.req			Store request	Store request	Send: UNNUMBERED DATA LPDU
RLS-BDU.req			Store request	Store request	See Numbered Data Transfer Transition Table 3A
ACK/NAK (Bad NR/VectNR)			LOG-OFF REQUEST Stop T202 New State: 0		LOG-OFF REQUEST Stop T202 New State: 0
RC204 = N204					New State: 5

c-1 Note: When processing events, LPDUs should be given priority over requests and timers, and requests should be given priority over timers.

ATTACHMENT 2-12
DATA LINK LAYER

c-1

Table 3A Numbered Data Transfer State Transition Table

Events	STATES			
	Idle 7.0	WaitTxInd 7.1	WaitAck 7.3	Retry WaitTxInd 8.1
RLS-BDU.req	Send: NUMBERED DATA LPDU RC204 = 0 VS++ New State: 7.1			
MAC-TX.ind		Start T204 New State: 7.3		Start T204 New State: 7.3
ACK			Stop T204 Update VA & VectA New State: 7.0	Stop T204 Update VA & VectA New State: 7.0
NAK & RC204 < N204			Send: NUMBERED DATA LPDU RC204++ Stop T204 New State: 8.1	
T204 expired & RC204 < N204			Send: NUMBERED DATA LPDU RC204++ New State: 8.1	

c-1

Table 3B Unnumbered Acknowledged Data Transfer State Transition Table

Events	STATES			
	Idle 7.0	WaitTxInd 7.1	WaitAck 7.3	Retry WaitTxInd 8.1
DL-DATA_ACK.req	Send: UNNUMBERED ACKNOWLEDGED DATA LPDU RC204 = 0 New State: 7.1			
MAC-TX.ind		Start T204 New State: 7.3		Start T204 New State: 7.3
ACK			Stop T204 New State: 7.0	Stop T204 New State: 7.0
NAK & RC204 < N204			Send: UNNUMBERED ACKNOWLEDGED DATA LPDU RC204++ Stop T204 New State: 8.1	
T204 expired & RC204 < N204			Send: UNNUMBERED ACKNOWLEDGED DATA LPDU RC204++ New State: 8.1	

c-1

ATTACHMENT 2-12
DATA LINK LAYER

Table 4 Timers, Counters and Other Parameters

	Name	Type	Comment
	T200	Timer/Event on aircraft side	Connection retry timer
	RC200	Variable on aircraft side	Connection retransmission counter
c-1	N200	Variable on aircraft side	Max number of LOG-ON REQUEST or LOG-ON RESUME LPDU retransmissions reached
	T202	Timer/Event on ground side	Idle connection timer
	T204	Timer/Event	Data transfer retry timer
	RC204	Variable	Data transfer retransmission counter
c-1	N204	Variable	Max number of NUMBERED DATA LPDU retransmissions reached
	NS	LPDU field	NUMBERED DATA LPDU sequence number. A correct sequence number in reception must be in the range [VR... VR+K] where K is the window size.
	NR - VectNR	MPDU field	Sequence number and the vector value of the ACK field. A correct NR in reception must be in the [VA... VS].
	VS	Variable	Next NUMBERED DATA LPDU sequence number to be sent for the first time.
	VR	Variable	Lowest NUMBERED DATA LPDU sequence number expected to be received.
	VectR	Variable	NUMBERED DATA LPDU sequence numbers already received in the receive window
	VA	Variable	Lowest NUMBERED DATA LPDU sequence number transmitted and not yet acknowledged
	VectA	Variable	NUMBERED DATA LPDU sequence numbers transmitted and already acknowledged in the transmit window
c-1	MAC_ACK.req	Primitive	Interface primitive used by LLC sublayer to pas to MAC sublayer updated Acknowledgment field.
	MAC_TX.ind	Primitive	Interface primitive between MAC and LLC used to notify transmission of specific LPDU. Useful to use timer T204 efficiently in data transfer mode.
	ACK NAK	Events	Generic term describing the acknowledgement of a NUMBERED DATA LPDU event. Its occurrence is implementation dependent. On the aircraft side, it can occur when analyzing the ACK field of a received squitter. On the ground side, it can occur when analyzing the ACK field of a received MPDU downlink.
c-1	RLS_BDU.req	Primitive	Interface primitive used by Segmentation/Reassembly sublayer to request transmission of a BDU by LLC sublayer using the RLS protocol.
	RLS_BDU.ind	Primitive	Interface primitive used by LLC sublayer to deliver received BDU to Segmentation/Reassembly sublayer for reassembly into a complete HFNPDU.

Table 1 Link Management Layer State Transition Table - Aircraft

Events	Disconnected 0	Connection Pending 1	Disonnection Pending 2	Pause Connection Pending 4	Connection Paused 5	Resume Connection Pending 6	Connection 7	
Good Frequency Found Same Ground Station Note 1	DL-CONNECT. req New State: 1				DL-RESUME. req New State: 6			
Good Frequency Found New Ground Station Note 1	DL-CONNECT. req New State: 1				DL-CONNECT. req New State: 1			
DL-CONNECT.conf		HFDL Status: Available New State: 7				HFDL Status: Available New State: 7		
DL-RESUME.conf						HFDL Status: Available New State: 7		
Pause Desired Note 2		DL-DISCONNECT. req New State: 2				DL-PAUSE. req New State: 4	DL-PAUSE. req New State: 4	c-1
DL-PAUSE.conf				HFDL Status: Unavailable New State: 5				
DL-PAUSE.Ind.				HFDL Status: Unavailable New State: 5		Set HFDL Status: Unavailable New State: 5	HFDL Status: Unavailable New State: 5	c-1
Disconnection Desired Note 3		DL-DISCONNECT. req New State: 2		DL- DISCONNECT. req New State: 2	DL-DISCONNECT. req New State: 2	DL-DISCONNECT. req New State: 2	DL- DISCONNECT. req New State: 2	
DL-DISCONNECT.conf			HFDL Status: Unavailable New State: 0			HFDL Status: Unavailable New State: 0	HFDL Status: Unavailable New State: 0	
DL-DISCONNECT.ind		New State: 0	HFDL Status: Unavailable New State: 0	HFDL Status: Unavailable New State: 0	HFDL Status: Unavailable New State: 0	HFDL Status: Unavailable New State: 0	HFDL Status: Unavailable New State: 0	

Note 1: The "Good Frequency Found" event occurs when a good squitter is received during a frequency search initiated when the HF-ENABLE discrete changes state from not set to set.

Note 2: The "Pause Desired" event can occur for example when the HF-ENABLE discrete changes state from set to not set or when the LME decides to initiate a frequency change.

Note 3: The "Disconnection Desired" event can occur for example when the HF-ENABLE discrete has not been set for a period of time longer than the log-off timer. c-1

Note 4: Pause Desired and Disconnection desired events should be given priority over the confirmation and indication events.

c-2

ATTACHMENT 2-14
HF DATA LINK CONTENTION SLOT SELECTION
BACKOFF ALGORITHM STATE MACHINE [1]

c-1

State Label / State Name: B0	contention slot selection backoff inactive	
Entry Actions:	-	
Transition Events	**Transition Actions**	**Next States**
contention slot clash detected [2]	initialize slot retry count, n=1	B1
State Label / State Name: B1	process present squitter slot assignment codes	
Entry Actions:	select uniform random variable, m; where 0 <= m <= (3n-1)	
Transition Events	**Transition Actions**	**Next States**
reserved slot assigned this aircraft	schedule reserved slot time	B0
(no reserved slot for this a/c) & (m>0)	m=m-1	B2
(no slots available) & (m=0)	-	B2
(contention slot only avail.) & (m=0)	preselect random contention slot from those available	B3
State Label / State Name: B2	await next squitter	
Entry Actions:	-	
Transition Events	**Transition Actions**	**Next States**
consecutive squitters not received	indicate frequency search required	B0
reserved slot assigned this aircraft	schedule reserved slot time	B0
(no reserved slot for this a/c) & (m>0)	m=m-1	B2
(no slots available) & (m=0)	-	B2
(contention slot only avail.) & (m=0)	preselect random contention slot from those available	B3
State Label / State Name: B3	await active slot	
Entry Actions:	schedule preselected contention slot time	
Transition Events	**Transition Actions**	**Next States**
slot time active	-	B4
State Label / State Name: B4	transmit MPDU	
Entry Actions:	request MPDU transmission	
Transition Events	**Transition Actions**	**Next States**
MPDU transmit indication received	-	B5
State Label / State Name: B5	await acknowledgement codes	
Entry Actions:	check acknowledgement codes in appropriate squitter(s)	
Transition Events	**Transition Actions**	**Next States**
consecutive squitters not received	indicate frequency search required	B0
all LPDUs ACK	-	B0
partial LPDUs ACK	indicate retransmission required [3]	B0
(no LPDUs ACK) & (n=2)	indicate frequency search required	B0
(no LPDUs ACK) & (n<2)	n=n+1	B1

Notes:

[1] The contention slot selection backoff algorithm is a function within the HFDL MAC protocol. This state chart is not intended to represent all MAC functionality.

[2] Entry condition for the backoff algorithm is:
(prior MPDU transmission was in a contention slot) &
(no LPDUs were ACKed for that transmission) &
(a data transmission request is pending)

[3] Retransmission is directed by the HFDL LLC protocol and depends upon the LPDU type.

ATTACHMENT 2-15
ATTACHMENTS-TO-SECTIONS CROSS REFERENCE

c-1

Attachment	Title	Section of Text Applicable	
1-1	Airborne Subsystem Block Diagram	3.2	
1-2	HFDL Reference Model	3.2 and 6.2.2	
2-1	Airborne Station Protocol Layers	4.2.4, 5.3 and 6.2.1	
2-2	HF Data Link Signal-in Space Definition	4.2.3.2 and subsections	
2-3	Data Modulator Encoding Sections	4.2.3.2.2 and subsections	
2-4	Rate 1/2 Convolutional Code Encode	4.2.3.2.2.1	
2-5	Serial (single-Tone) Mode Minimum Performance	4.2.2.4	
2-6	Slotted Frame	5.2.1	
2-7A	Downlink MPDU Format	5.2.2	
2-7B	Uplink MPDU Format	5.2.2	
2-7C	Aircraft ID Definition	5.2.2 paragraph c1	
2-8A	Squitter SPDU Format	5.2.1 and 5.2.1.7	
2-8B	Squitter SPDU Format	5.2.1 and 5.2.1.7 paragraphs d and e	c-3
2-8C	HFDL Bit Map Representations	5.2.1.7, 5.2.2.2, 5.2.2.3, and 5.2.2.5.1	
2-8D	Intra-Station Synchronization	5.2.1.7.1	
2-8E	Inter-Station Synchronization	5.2.1.7.2	
2-9A	LPDU Frame Types and Format Definition	5.2.2.1	
2-10A	Unnumbered Data LPDU Format Definition	5.2.2.5	
2-10B	Numbered Data LPDU Format Definition	5.2.2.6 and 5.2.4.2.1	
2-10C	Unnumbered Data LPDU with Broadcast HFDL System Table	5.2.2.5 and 5.2.5.4	c-3
2-10D	Log-On Request and Log-On Resume LPDU Format Definition	5.2.2.2	
2-10E	Log-On Confirm and Log-On Resume-Confirm LPDU Format Definition	5.2.2.3	
2-10F	Log-Off Request and Log-On Denied LPDU Format Definition	5.2.2.4	
2-10G	Unnumbered Acknowledged Data LPDU Format Definition	5.2.2.7	c-3
2-11	HFDL Log-On Procedures	5.2.5.1.1 and 5.2.5.1.2	
2-12	Data Link Layer Protocol State Transition Tables	5.2.4 and subsections	
2-13	Link Management Entity State Transition Table	5.2.5.1.1, 5.2.5.1.2 and 5.2.5.3	
2-14	HF Data Link Contention Slot Selection Backoff Algorithm State Machine	5.2.1.3.1	c-1
3-1	Packet Mode Priorities	3.5.2 and 6.2.4	c-3

ATTACHMENT 3-1
PACKET-MODE PRIORITIES

Table 1 HF Data Link Subsystem Packet-Mode-Priority Structure

	Category of Messages	SNC Priority in CALL_REQUEST/ CALL_ACCEPTED Packet at Data Port	Q-Number (Link Layer) [1]	SNC Priority in Incoming Call/CALL_ CONNECTED Packet
c-1	Unspecified (ISO 8208 explicit)	255	0	None
	Reserved	254-15	Invalid/reject	Not Applicable
	Distress Communications, Urgent Communications, Network/Systems Management. [2]	14	14	14
c-2	HF Data Link Management	Not Applicable	13	Not Applicable
	Reserved	12	Invalid/reject	Not Applicable
	Flight Safety Messages, Communications Relating to Direction Finding	11	11	11
	Reserved	10	Invalid/reject	Not Applicable
	Reserved	9	Invalid/reject	Not Applicable
	Meteorological Communications	8	8	8
	Flight Regularity Communications	7	7	7
	Aeronautical Information Service Messages (NOTAMs, ATIS, etc.)	6	6	6
	Aeronautical Administrative Messages [3] Network/Systems Administration [2]	5	5	5
	Reserved	4	Invalid/reject	Not Applicable
	Urgent Priority Administrative and UN Charter Communications (AAC/APC)	3	3	3
	High Priority Administrative and State/ Government Communications (AAC/APC)	2	2	2
	Normal Priority Administrative (AAC/APC)	1	1	1
	Low Priority Administrative (AAC/APC)	0	0	None
	Unspecified	None	0	None

Notes:

[1] Q-Number refers to the precedence contained in a BDU to transmitted.

[2] Network/System Management and Administration are not categories of messages, but are used by ATN or other network management/administration

[3] Aeronautical Administrative Messages and above can be either ATS or AOC Communications.

[4] Priorities 0 through 3 are not applicable to HF Data Link as of November 14, 1994.

[5] The SNC Priority is in the facility field of the CALL_REQUEST and CALL_ACCEPTED Packets.

APPENDIX A
ACRONYM LIST

AA	Aircraft Address
AAC	Aeronautical Administrative Communications
ACARS	Aircraft Communications Addressing and Reporting System
ACK	Acknowledge
ADS	Automatic Dependent Surveillance
AEEC	Airlines Electronic Engineering Committee
AGC	Automatic Gain Control
AID	Aircraft ID
ALO	Aloha word
ALR	Aloha Response
AOC	Aeronautical Operational Control
APC	Aeronautical Passenger (or Public) Communications
ARINC	Aeronautical Radio, Inc.
ATC	Air Traffic Control
ATN	Aeronautical Telecommunications Network
ATS	Air Traffic Service
BCD	Binary Coded Decimal
BCS	Block Check Sequence
BDU	Basic Data Unit
BITE	Built In Test Equipment
BM	Broadcast Message
BNR	Binary
BOP	Bit Oriented File Transfer Protocol
BSN	BDU Sequence Number
CCITT	International Telegraph and Telephone Consultative Committee
CDU	Control/Display Unit
CMU	Communications Management Unit
CRC	Cyclical Redundancy Code
CTS	Clear To Send
dc	direct current
DCE	Data Communication-terminating Equipment
DEL	Delete
DLPDU	Data Link Protocol Data Unit
DLS	Data Link Service
DLS	Direct Link Service
DTE	Data Terminal Equipment
FAX	Facsimile
FCS	Frame Check Sequence
FD	Frequency Data
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FMC	Flight Management Computer
GFI	General Format Identifier
GS	Ground Station
GSID	Ground Station Identifier
HDLC	High-Level Data Link Control
HF	High Frequency
HFDL	HF Data Link
HFDR	HF Data Radio
HFNPDU	HF Network Protocol Data Unit
HFPAC	HF Packet Communications
HFSND	HF SubNetwork Dependent
HFSNL	HF SubNetwork Layer
HLE	Higher Layer Entity
ICAO	International Civil Aviation Organization
ID	Identifier
IFR	Instrument Flight Rules
ISO	International Organization for Standardization
ITU	International Telecommunication Union

APPENDIX A
ACRONYM LIST

LCN	Logical Channel Number
LIDU	Link Interface Data Unit
LME	Link Management Entity
LPDU	Link Protocol Data Unit
LRU	Line Replaceable Unit
LSB	Least Significant Bit/Byte
LSDU	Link Service Data Unit
LT	LPDU Type
MAC	Media Access Control
MBS	M-Bit Sequence
MPDU	Media Access Control Protocol Data Unit
MSB	Most Significant Bit
MTCN	Minimum Throughput Class Negotiation
MU	Management Unit
NAK	Not Acknowledge
NC	Network Connection
NLP	Number of Link PDUs
NSAP	Network Service Access Point
OSI	Open Systems Interconnection
PC	Power Compensation
PD	Performance Data
PDD	Performance Data Disable
PDE	Performance Data Enable
PDU	Protocol Data Unit
PEP	Peak Envelope Power
PLP	Packet Layer Protocol
PPDU	Physical Layer Protocol Data Unit
PSK	Phase Shift Keying
PSN	Packet Sequence Number
QM	Quality Measure
QOS	Quality of Service
RF	Radio Frequency
RLS	Reliable Link Service
RN	Reference Number
RR	Reservation Request
SAL	System Address Label
SAP	Service Access Points
SNAc	SubNetwork Access
SNAcP	SubNetwork Access Protocol
SNC	SubNetwork Connection
SNPA	SubNetwork Point of Attachment
SNPDU	SubNetwork Protocol Data Unit
SNS	SubNetwork Service
SOH	Start of Header
SPDU	Squitter Protocol Data Unit
SQM	Signal Quality Measure
SSB	Single Side Band
SSM	Sign Status Matrix
SVC	Switched Virtual Circuit
SYN	Synchronization
TCN	Throughput Class Negotiation
TDMA	Time Division Multiple Access
TDSAI	Transit Delay Selection and Indication
UTC	Universal Coordinated Time
VHF	Very High Frequency

APPENDIX B
REFERENCES

ARINC Characteristic	Title
597	Aircraft Communications Addressing and Reporting System (ACARS)
597A	Enhanced ACARS Avionics
724	Mark 2 Aircraft Communications Addressing and Reporting System (ACARS)
724B	Aircraft Communications Addressing and Reporting System (ACARS)
753	HF Data Link System
758	Communications Management Unit (CMU) Mark 2

ARINC Specification	Title	
429	Mark 33 Digital Information Transfer System (DITS)	
618	Air-Ground Character-Oriented Protocol Specification	
637P1	Aeronautical Telecommunications Network (ATN) Implementation Provisions, Part 1, Protocols and Services	c-3
638	OSI Upper Layer Specifications (End System Communication Specifications)	

ARINC Report	Title
634	HF Data Link System Design Guidance Material

ISO	Title
7498	OSI Basic Reference Model, Version 1
TR 8509	OSI Service Conventions, Version 1
8208	X.25 Packet Level Protocol for Data Terminal equipment

APPENDIX C
DELAYED ECHO APPLICATION

1. Overview

It is recommended that each aircraft HF Data Link implement a Delayed Echo Application (DEA). This application serves as an additional link service user to allow testing of the HF Data Link Layer.

The DEA Protocol is based on the principal of parameterized echo. Each DEA Protocol Data Unit (DEAPDU) is carried as user data in the HFNPDUs of the HF Data Link Layer. All testing should be initiated by a tester on the ground station side.

The DEA Protocol should be capable of testing the internal protocol logic of the HF Data Link Layer, the interactions with the ground station, and the interactions between the HFDL and it's HLEs (Higher Layer Entities).

The interface between the DEA and the HFDL should be exactly the same as that existing between other HLEs (i.e., the Network Layer) and the HFDL. The items exchanged across this interface are called Link Interface Data Units (LIDUs). When the aircraft DEA receives a LIDU from the HFDL, it either ignores the packet, or produces one of the following types of downlink LIDUs in response:

a. An echo of the received LIDU.
b. An internally created LIDU containing default data.
c. A report on the last LIDU received by the DEA.

After the DEA produces the appropriate LIDU in response, the LIDU is either immediately scheduled for transmission, or stored for later transmission. The DEA downlinks the stored packets after applying an indicated delay.

c-2

2. Uses and Benefits of DEA

a. During laboratory software and system testing of requirements.
b. During initial over the air testing of the HF Data Radio system.
c. During periodic operational evaluations

The DEA is very useful for requirements testing since it allows testing the internal protocol logic of the HFDL, the interactions with the ground station, and the interactions between the HFDL and it's HLEs. Almost any situation can be established by causing the ground station to set the squitter values, and producing data for the aircraft to transmit, and then causing the ground station to react to this transmission.

DEA allows the ground station to fill the reaction queue of an HFDR / HFDU with reaction packets, and then cause them to be introduced at predicable times with reference to slot and frame timing. The DEA application allows for the development of repeatable tests. These tests can be used for such protocol test cases as:

a. Tests involving usage of particular slots.
b. Testing of priority preemption.
c. Tests that address loading issues.
d. Tests that address minimum priority usage.
e. Tests that address actions taken by the aircraft at the time of a frequency discontinuation.
f. Testing of repeat transmissions.
g. Tests that address the selection of single and double slots.
h. Tests that address negative and positive acknowledgments provided to the HLE.

The DEA is a suitable platform for testing almost every aspect of the HF Data Link Layer Protocol.

The DEA is useful for over the air testing. The ground station should be able to use DEA to:

a. Generate dummy uplink and downlink transmissions.
b. Test loading issues.
c. Test connectivity issues.
d. Test availability.
e. Test integrity.
f. Test delays.

APPENDIX C
DELAYED ECHO APPLICATION

3. Link Interface Data Units

LIDUs (Link Interface Data Units) are exchanged between the Data Link Layer (layer 2) and its Link Service User or HLE (layer 3). Examples of HLEs would include ACARS, the Network Layer, and DEA. The contents of each LIDU are represented in the following table:

LIDU Name	Parameters
Data request (Link Service user to Link Layer)	Ground Station ID Priority Link service user data
Data indication (Link Layer to Link Service User)	Ground Station ID Priority Link service user data Receive quality (received with error / received without error)
Transmission status indication (Fail or Success)	Ground Station ID Priority First 2 octets of Link service user data Transmit quality (Ack or Nack)

4. Data Storage Needed by DEA

4.1 Received LIDU Buffer

The DEA should be capable of storing the last LIDU received from the HF Data Link Layer. Thus, when the nth LIDU is a Report Request, the DEA can respond with a Report DEAPDU describing the previous LIDU received. If the HFDL indicates it is not logged on, or has a logon resume pending, then the Received LIDU Buffer should be purged.

Only LIDUs describing DEAPDUs should be placed into this buffer. When the HF Data Link Layer provides either LIDUs containing ACARS packets, or LIDUs containing HF Data Network Layer packets, these should not be provided to DEA. c-2

4.2 Reaction Queue

The reaction queue should hold 6 downlink Reaction Queue elements with a maximum size of 424 octets of data each. If the HFDL indicates it is not logged on, or has a logon resume pending, then the reaction queue should be purged.

Associated with each element of the reaction queue, the following information should be held:

a. Frame and Slot Delay received in the Uplink DEAPDU.
b. Scheduled Transmit Slot (set when the execute queue DEAPDU Uplink is received).
c. Priority to be used when sending downlink.
d. Octet data length.
e. Octet data to be transmitted.

5. Actions Taken by DEA

5.1 Actions Taken Upon Receiving an Uplink DEA Packet When DEA Not Implemented

If a vendor chooses not to implement the DEA testing service, then the HFDL should discard any uplink HFNPDU received having the first two octets set to $FFDE_h$.

5.2 Actions Taken by DEA Upon Receiving an Uplink DEA Packet

The following steps describe the actions taken by DEA upon receiving an Uplink DEA Packet:

a. Produce the appropriate downlink reaction packet (if any).
b. If the delay parameters are zero, then schedule the Reaction DEAPDU LIDU for transmission in the appropriate slot (see Section 8). No Execute Queue is required in this case.
c. If the delay parameters are not zero, then insert the downlink reaction packet (if any) into the reaction queue for later transmission. The reaction packet should be discarded when the reaction queue is full.
d. Store the original LIDU in the Received LIDU Buffer.

APPENDIX C
DELAYED ECHO APPLICATION

5.3 Actions Taken by DEA at Each Slot Boundary

The following steps describe the actions taken by DEA upon notification of the next slot. The following steps apply to each element of the reaction queue for which the transmit slot has been scheduled.

a. Determine if each Reaction Element LIDU should be introduced to the data link for transmission by looking at the scheduled transmit slot field of the Reaction Element LIDU.

b. If a Reaction Element LIDU should be introduced for transmission, then remove it from the Reaction Queue and provide it to the HF Data Link Layer for transmission.

Reaction packet LIDUs which are scheduled for transmission in the same slot should be provided to the Data Link Layer in the order they were created. The Data Link Layer is responsible for transmitting the LIDUs in priority order.

6. Definition of DEA Protocol

6.1 DEA Protocol Implicit Reactions

The DEA should treat the following LIDUs as indicating No Action:

a. LIDU indicating an uplink received with an error.
b. LIDU indicating a downlink transmission status of failure.
c. LIDU indicating a downlink transmission status of success.
d. LIDU containing an invalid DEAPDU.
e. LIDU containing a vendor ID of another vendor, or an undefined vendor ID (vendor ID of zero is allowed).
f. LIDU containing a non-industry standard Reaction field.

c-2 6.2 DEA Protocol Explicit Reactions

The ground station tester indicates to the aircraft DEA how to react to each DEAPDU received. Each DEAPDU contains a reaction code. The Reaction field is used to indicate how the DEA should react when a DEAPDU is received.

6.2.1 Explicit Reactions for the Do Nothing DEAPDU

When an uplink DEAPDU is received with a reaction type set to Do Nothing DEAPDU, 00_h, no reaction packet is constructed.

6.2.2 Explicit Reactions for the Purge Queue DEAPDU

When an uplink DEAPDU is received with a reaction type set to Purge Queue DEAPDU, 01_h, the internal reaction queue should be cleared.

6.2.3 Explicit Reactions for the Execute Queue DEAPDU

When an uplink DEAPDU is received with a reaction type set to Execute Queue DEAPDU, 02_h, each reaction packet currently held in the Reaction Queue should be scheduled for transmission based on the frame / slot delay values indicated in the Reaction DEAPDU LIDU, and the current frame / slot number (see Section 8). It is the responsibility of DEA to introduce the elements of the reaction queue with the appropriate amount of lead slots so that the resulting HFNPDU can be transmitted in the indicated slot.

6.2.4 Explicit Reactions for the Echo Downlink DEAPDU

When an uplink DEAPDU is received with a reaction type set to Echo Downlink DEAPDU, 03_h, an echo Reaction Packet should be constructed (see Section 9.4) and the new Reaction Packet inserted into the reaction queue. If the delay values are both zero then the reaction packet should immediately be scheduled for transmission. If the delay values are not both zero then the reaction packet should be scheduled for transmission when the Execute Queue Uplink DEAPDU is received.

APPENDIX C
DELAYED ECHO APPLICATION

6.2.5 Explicit Reactions for the Default Downlink DEAPDU

When an uplink DEAPDU is received with a reaction type set to Default Downlink DEAPDU, 04_h, a new Reaction DEAPDU should be constructed (see Section 9.7) and the new Reaction Packet inserted into the reaction queue. If the delay values are both zero then the reaction packet should immediately be scheduled for transmission. If the delay values are not both zero then the reaction packet should be scheduled for transmission when the Execute Queue Uplink DEAPDU is received.

6.2.6 Explicit Reactions for the Report Downlink DEAPDU

When an uplink DEAPDU is received with a reaction type set to Report Downlink DEAPDU, 05_h, a new Reaction DEAPDU should be constructed (see Section 9.10) and the new Reaction Packet inserted into the reaction queue. If the delay values are both zero then the reaction packet should immediately be scheduled for transmission. If the delay values are not both zero then the reaction packet should be scheduled for transmission when the Execute Queue Uplink DEAPDU is received.

6.2.7 Explicit Reactions for Uplink DEAPDU with Vendor Specific Reaction Fields

When an uplink DEAPDU is received with a vendor specific Reaction Field then that vendor is responsible for the format, and resulting actions that take place. The format and the resulting actions may need to be negotiated with ground service providers.

7. DEA Packets Transmit Order

The format of each DEAPDU packet type follows in subsequent sections. Each DEAPDU is composed of an integral number of octets. All fields of DEAPDU packets are held in one octet (other than data array fields whose length is specified by a length field). The octets of a DEAPDU should be transmitted by the HF Data Link Layer beginning with octet 1 and continuing through the DEAPDU octets in order. Each octet of the resultant HFNPDU should be specified so that when the octets are transmitted, the least significant bit of each octet is transmitted first continuing to the most significant bit of each octet. c-2

8. Frame/Slot Transmit Scheduling For Reaction Packets

The following table is provided to indicate the frame and slot in which the reaction packets generated by DEA should be transmitted. Each uplink DEAPDU has a frame and slot delay. These delays, together with the slot in which the uplink DEAPDU or Execute Queue DEAPDU was received, indicate a frame and slot in which the downlink reaction DEAPDU should be transmitted. DEA should provide the reaction LIDU to the HF Data Link Layer for transmission with an appropriate amount of lead time so that the resulting HFNPDU is transmitted in the scheduled slot.

The HF Data Link Layer may or may not have been provided a downlink slot at the scheduled transmit slot for the reaction DEAPDU. If the slot assignments provided to the data link have a downlink designated to the aircraft for that slot (or a contention slot is chosen) then the transmission occurs in the indicated slot. If not, the transmission occurs as soon thereafter as a downlink slot is provided (or a contention slot is chosen). It is up to the tester at the ground station to set the slot assignments appropriately for the test in progress.

Case	Frame Delay Specified in Uplink DEAPDU	Slot Delay Specified in Uplink DEAPDU	Slot Execute Queue Received	Slot to Transmit Reaction Packet
1	Frame Delay = 0	Slot Delay = 0	No Execute Queue DEAPDU is required. Schedule for transmit.	3 slots after slot in which Uplink DEAPDU was received.
2	Frame Delay = 0	Slot Delay > 0	0 to 12	S slots after slot in which Execute Queue was received, where S = 3 + Slot Delay
3	Frame Delay > 0	Slot Delay ≥ 0	0 to 9	Frame = current frame number + Frame Delay Slot = Slot Delay
4	Frame Delay > 0	Slot Delay ≥ 0	10 to 12	Frame = current frame number + Frame Delay + 1 Slot = Slot Delay

APPENDIX C
DELAYED ECHO APPLICATION

8. Frame/Slot Transmit Scheduling For Reaction Packets (cont'd)

For frame delays of 0, the scheduled transmit slot is advanced by 3 slots. This is due to the processing time to receive and respond to an Uplink DEAPDU. Each vendor should be capable of receiving an Uplink DEAPDU in slot n and transmitting the resulting reaction DEAPDU in slot n + 3.

Case 1: When the ground station uplinks a DEAPDU with a frame delay of 0, and a slot delay of 0 in slot n, then the resulting reaction packet should be scheduled for transmission by the AC during slot n+3. During slot n+1 the AC processes the received DEAPDU, and provides the resulting reaction LIDU to the HF Data Link Layer for transmission. During slot n+2 a Downlink MPDU is created which contains the reaction LIDU. During slot n+3 the reaction packet is transmitted. This assumes that slot n is an uplink slot and slot n+3 is a downlink slot.

Case 2: When the ground station transmits a DEAPDU to the aircraft with a frame delay of 0, and a slot delay > 0, then the resulting reaction packet is stored in the reaction queue, but is not scheduled for transmission until an Uplink DEAPDU Execute Queue is received. When the Uplink DEAPDU Execute Queue is received by the aircraft during slot n, that element of the reaction queue is scheduled for transmission during slot n + 3 + the slot delay of the reaction element LIDU.

Case 3: When the ground station transmits a DEAPDU to the aircraft with a frame delay > 0 then the resulting reaction packet is stored in the reaction queue, but is not scheduled for transmission until an Uplink DEAPDU Execute Queue is received. When the Uplink DEAPDU Execute Queue is received by the aircraft, during slots 0 to 9, of frame F, that element of the reaction queue is scheduled for transmission during frame F + frame delay held in the reaction element, and slot = slot delay held in the reaction element. Notice that no processing delay is added to the transmit slot. This has been allowed for since the transmit slot is into the next frame, which is at least 3 slots in the future.

c-2 Case 4: When the ground station transmits a DEAPDU to the aircraft with a frame delay > 0 then the resulting reaction packet is stored in the reaction queue, but is not scheduled for transmission until an Uplink DEAPDU Execute Queue is received. When the Uplink DEAPDU Execute Queue is received by the aircraft, during slots 10 to 12, of frame F, that element of the reaction queue is scheduled for transmission during frame F + 1 + frame delay held in the reaction element, and slot = slot delay held in the reaction element. When the Execute Queue DEAPDU is received in slots 10 through 12, and a reaction queue element has a frame delay > 0, the scheduled transmit slot is advanced by one frame. This is due to the processing time to receive and respond to an Uplink DEAPDU.

The following table is intended to provide several examples of scheduling Reaction Packets for transmission. For purposes of this table the current frame number is 1.

Frame Delay Specified in Uplink DEAPDU	Slot Delay Specified in Uplink DEAPDU	Slot Execute Queue Received	Slot to Transmit Reaction Packet
0	0	Current slot = 2. No Execute Queue DEAPDU is required. Schedule for transmit.	Slot 5 = (2 + 3).MOD 13. Frame 1 which is the current frame.
0	0	Current slot = 11. No Execute Queue DEAPDU is required. Schedule for transmit.	Slot 1 = (11 + 3).MOD 13. Frame 2 which is the next frame.
0	2	5	Slot 10 = 5 + 3 + 2 Frame 1 which is the current frame.
0	2	11	Slot 3 = (11 + 3 + 2) MOD 13 Frame 2 which is the next frame.
1	2	8	Frame 2 = 1 + 1 Slot = 2
1	2	11	Frame 3 = 1 + 1 + 1 Slot = 2

APPENDIX C
DELAYED ECHO APPLICATION

9. DEA Packets

There are four packet types used by DEA. The packet formats and field definitions are described below for the following DEA packet types:

a. DEA Uplink Packet.
b. DEA Echo Downlink Packet.
c. DEA Default Downlink Packet.
d. DEA Report Downlink Packet.

9.1 DEAPDU Octets Common To All Packets

The first 5 octets of each DEAPDU share a common format. These five octets are described in the following paragraphs.

9.1.1 DEAPDU Octet Number One, Two, and Three

The first three octets of each DEAPDU are 'FF DE A0_h'.

9.1.2 DEAPDU Octet Number Four

The fourth octet of each DEAPDU indicates the Vendor ID. The following table describes meanings of the vendor identifiers. c-2

Vendor ID Value	Vendor Specified
0	Vendor not specified
1	AlliedSignal
2	ARINC
3	Rockwell Collins
4-255	Invalid

All HF Data Radios should respond to the vendor ID of 0.

9.1.3 DEAPDU Octet Number Five

Octet number five of each DEAPDU is used to denote the type of packet. In an uplink DEAPDU this field is called a Reaction field. In a downlink DEAPDU this field is called a Downlink Type. The following tables denotes the values to be used for this field. The HFDR supplied by each vendor should accept DEAPDU Uplink packets with a vendor ID 0, and the vendor ID for the given vendor. Other vendor ID values mean the DEAPDU may be discarded.

Vendor ID	Reaction Types (0-$7F_h$)	Downlink Types (80_h -FF_h)
0 => Vendor not specified	0 => Do Nothing 1 => Purge Queue 2 => Execute Queue 3 => Echo Downlink Packet Request 4 => Default Downlink Packet Request 5 => Report Downlink Packet Request 6 - $7F_h$ => Reserved	80_h => Echo Downlink 81_h => Default Downlink 82_h => Report Downlink 83_h - FF_h => Invalid
1 => Allied Signal 2 => ARINC 3 => Rockwell Collins	0 => Do Nothing 1 => Purge Queue 2 => Execute Queue 3 => Echo Downlink Packet Request 4 => Default Downlink Packet Request 5 => Report Downlink Packet Request 6 - $3F_h$ => Reserved 40_h - $7F_h$ => These can be defined by each vendor.	80_h => Echo Downlink 81_h => Default Downlink 82_h => Report Downlink 83_h - BF_h => Invalid $C0_h$ - FF_h => These can be defined by each vendor.

APPENDIX C
DELAYED ECHO APPLICATION

9.2 DEA Uplink Packet Format

Octet Number	Field Title	Octets Required
Octet 1	Header Octet 1 = FF_h	1
Octet 2	Header Octet 2 = DE_h	1
Octet 3	Header Octet 3 = $A0_h$	1
Octet 4	Vendor ID	1
Octet 5	Reaction Type	1
Octet 6	Frame Delay	1
Octet 7	Slot Delay	1
Octet 8	Priority	1
Octet 9	Reaction Length Octet 1	1
Octet 10	Reaction Length Octet 2	1
Octet 11	Data Length Octet 1	1
Octet 12	Data Length Octet 2	1
Octet 13-length	Data Octets	n octets, where n = Data Length Octet 1 + Data Length Octet 2.

9.3 DEA Uplink Packet Field Definitions

9.3.1 Frame Delay

The Frame Delay is used to indicate the number of frames that the DEA should delay before supplying the reaction DEA packet to the HF Data Link Layer for transmission. Frame Delays ranging from 0 to 255 are allowed. When the reaction packet is placed into the reaction queue, the frame delay should be stored. This value is used to determine the scheduled transmit time.

c-2 #### 9.3.2 Slot Delay

The Slot Delay is used to indicate the number of slots that the DEA should delay before supplying the reaction DEA packet to the HFDL for transmission. Slot Delays ranging from 0 to 255 are allowed. When the reaction packet is placed into the reaction queue, the slot delay should be stored. This value is used to determine the scheduled transmit time.

9.3.3 Priority Field

The Priority field is used to indicate the priority at which the resulting reaction downlink packet should be sent. The valid values for this field are 0 to 15.

9.3.4 Reaction Length Field

The Reaction Length field is used to indicate the length of the downlink reaction packet. The resulting reaction packet produced by DEA should be the size indicated in this Reaction Length Field. If the length of the resulting reaction packet is less than this field value, then a pad of FF_h octets should be added to the end. If the resulting reaction packet is more than this field value, then only the first n octets of the reaction packet should be transmitted in the downlink, where n = value of the Reaction Length field. The maximum allowed value of this field should be 424 (when operating in DLS ACARS mode, the largest value should be 253). The minimum allowed value of this field should be 3. Any uplink packet received with a reaction length outside of this range should be treated as a Do Nothing DEAPDU. The length is determined by adding the value of octets one and two of this field. Therefore, the maximum specifiable value could be 255 + 255 = 510 (which exceeds the valid value range).

9.3.5 Data Length Field

The Data Length field is used to indicate the number of data octets that follow at the end of the uplink DEAPDU. The maximum allowed value of this field should be 424 - 12 (number of octets through the data length field) = 412. The length is determined by adding the value of octets one and two of this field. Any uplink packet received with a reaction length outside of this range should be treated as a Do Nothing DEAPDU. The length is determined by adding the value of octets one and two of this field. Therefore, the maximum specifiable value could be 255 + 255 = 510 (which exceeds the valid value range).

APPENDIX C
DELAYED ECHO APPLICATION

9.3.6 Data Octets field

The Data Octets field is composed of free form octet values. The length of this field is specified by the Data Length field.

9.4 DEA Echo Downlink Packet Format

Octet Number	Field Title	Octets Required
Octet 1	Header Octet 1 = FF_h	1
Octet 2	Header Octet 2 = DE_h	1
Octet 3	Header Octet 3 = $A0_h$	1
Octet 4	Vendor ID	1
Octet 5	Downlink Type	1
Octet 6	Echo Length octet 1	1
Octet 7	Echo Length octet 2	1
Octet 8-length	Echo	n-7 octets, where n = Reaction Length (424 max). 7 is the number of fields preceding this field.

9.5 DEA Echo Downlink Packet Field Definitions

9.5.1 Echo Length Field

The Echo Length field is used to indicate the number of data octets that follow the header of the downlink DEAPDU. The maximum allowed value of this field should be 424 - 7 = 417 (7 = number of octets through the Echo Length field). Any uplink packet received with a reaction length outside of this range should be treated as a Do Nothing DEAPDU. The length is determined by adding the value of octets one and two of this field. Therefore, the maximum specifiable value could be 255 + 255 = 510 (which exceeds the valid value range). c-2

9.5.2 Echo Field

The Echo field is simply an exact echo of the octets 8 to n of the DEAPDU Uplink received, where n = Reaction Length field specified in the uplink DEAPDU. Therefore, the first octet of this field should have the value of the priority field found in the uplink packet (see Section 9.2).

9.6 DEA Echo Downlink Packet Transmit Priority

The priority used for downlink transmission of the Echo Downlink Reaction Packet should be that indicated in the DEA uplink packet received.

9.7 DEA Default Downlink Packet Format

Octet Number	Field Title	Octets Required
Octet 1	Header Octet 1 = FF_h	1
Octet 2	Header Octet 2 = DE_h	1
Octet 3	Header Octet 3 = $A0_h$	1
Octet 4	Vendor ID	1
Octet 5	Downlink Type	1
Octet 6	Data Length octet 1	1
Octet 7	Data Length octet 2	1
Octet 8-length	Data	n-7 octets, where n = Reaction Length (424 max). 7 is the number of fields preceding this field.

APPENDIX C
DELAYED ECHO APPLICATION

9.8 DEA Default Downlink Packet Field Definitions

9.8.1 Data Length Field

The Data Length field is used to indicate the number of data octets that follow at the end of the downlink DEAPDU. The maximum allowed value of this field should be 424 - 7 = 417 (7 = number of octets through the data length field). The length of the Data Field is determined by adding the value of the Data Length Octet 1 and the Data Length Octet 2. Therefore, the maximum specifiable value could be 255 + 255 = 510 (which exceeds the valid value range).

9.8.2 Data Field

The Data field should have a length of n-7 where n = Reaction Length.

The nth octet of the packet, starting at octet 8 should be set to:

[(n-1) MOD 53] MOD 16 + (n-1+53) DIV 53] * 16].

Given this definition, a Default Downlink (Rockwell Collins) packet with a total length of 424 would be formatted as follows (hexadecimal values used):

The first 7 octets are defined as follows:

FF_h DE_h $A0_h$	DEAPDU Header
03_h	Vendor ID (Rockwell Collins)
81_h	Default Downlink
c-2 FF_h $A2_h$	Data Length Octets 1 and 2 (FF_h + $A2_h$ = 417 decimal)

octets 1 to 53:
FF DE A0 03 81 FF A2 18 19 1A 1B 1C 1D 1E 1F
10 11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F
10 11 12 13 14 15 16 17 18 19 1A 1B 1C 1D 1E 1F
10 11 12 13 14

octets 54 to 106:
20 21 22 23 24 25 26 27 28 29 2A 2B 2C 2D 2E 2F
20 21 22 23 24 25 26 27 28 29 2A 2B 2C 2D 2E 2F
20 21 22 23 24 25 26 27 28 29 2A 2B 2C 2D 2E 2F
20 21 22 23 24

octets 107 to 371: not shown

octets 372 to 424:
80 81 82 83 84 85 86 87 88 89 8A 8B 8C 8D 8E 8F
80 81 82 83 84 85 86 87 88 89 8A 8B 8C 8D 8E 8F
80 81 82 83 84 85 86 87 88 89 8A 8B 8C 8D 8E 8F
80 81 82 83 84

9.9 DEA Default Downlink Packet Transmit Priority

The priority used for downlink transmission of the Default Downlink Reaction Packet should be that indicated in the DEA uplink packet received.

9.10 DEA Report Downlink Packet Format

Octet Number	Field Title	Octets Required
Octet 1	Header Octet 1 = FF_h	1
Octet 2	Header Octet 2 = DE_h	1
Octet 3	Header Octet 3 = $A0_h$	1
Octet 4	Vendor ID	1
Octet 5	Downlink Type	1
Octet 6	Received LIDU	1
Octet 7	Priority	1
Octet 8	Error Detected	1
Octet 9	Received Data Length Octet 1	1
Octet 10	Received Data Length Octet 2	1
Octet 11-length	Received Data	n octets, where n = Received Data Length

APPENDIX C
DELAYED ECHO APPLICATION

9.11 DEA Report Downlink Packet Field Definitions

9.11.1 Received LIDU Field

The Received LIDU field is used to indicate the type of LIDU being described. There are the three possibilities:

9.11.1.1 No LIDU Has Been Received Since Last Clear

The Received LIDU field is set to 0 when No LIDU has been received since last clear.

9.11.1.2 Last LIDU Received Was a Transmission Status LIDU

The Received LIDU field is set to 1 when the last LIDU received was a Transmission Status LIDU. This LIDU is used by the HF Data Link Layer to describe the transmission status of a previous downlink LIDU received from the HLE.

9.11.1.3 Last LIDU Received Was a Received Uplink LIDU

The Received LIDU field is set to 2 when the last LIDU received was a Received Uplink LIDU. This LIDU is used by the HF Data Link Layer to provide an uplink received from the ground station to the HLE.

9.11.2 Priority Field

The Priority field is used to indicate the priority of the transmission or receipt of a packet. The valid values for this field are 0 to 15.

9.11.2.1 No LIDU Has Been Received Since Last Clear

This field is not relevant and is set to 0.

9.11.2.2 Last LIDU Received Was a Transmission Status LIDU

This field indicates the priority of last completed DEAPDU downlink transmission. c-2

9.11.2.3 Last LIDU Received Was a Received Uplink LIDU

This field indicates the priority of the last DEAPDU received.

9.11.3 Error Detected Field

The Error Detected field is used to indicate if an error was encountered in either the transmission or receipt of a packet. When errors were encountered this field is set to $0E_h$. When no errors were encountered this field is set to $A0_h$.

9.11.3.1 No LIDU Has Been Received Since Last Clear

This field is not relevant and is set to 0.

9.11.3.2 Last LIDU Received Was a Transmission Status LIDU

This field indicates whether or not the DEAPDU downlink transmission was completed successfully or not.

9.11.3.3 Last LIDU Received Was a Received Uplink LIDU

This field indicates whether or not the DEAPDU last received was received with errors or not.

9.11.4 Received Data Length Field

The Received Data Length field is used to indicate the number of octets used for the Received Data field. The value of this field is equal to Reaction Length Octet 1 (Uplink DEAPDU)+ Reaction Length Octet 2 (Uplink DEAPDU) - Downlink DEAPDU Report header length (10). The maximum allowed value of this field should be 414 = 424 - 10 (number of octets through the data length field).

APPENDIX C
DELAYED ECHO APPLICATION

9.11.4 Received Data Length Field (cont'd)

The length of the Received Data Field is determined by adding the value of the field Received Data Length Octet 1 and the field Received Data Length Octet 2. Therefore, the maximum specifiable value could be 255 + 255 = 510 (which exceeds the valid value range).

9.11.5 Received Data Field

The Received Data field is used to echo the data from the LIDU for which the report packet is being prepared.

9.11.5.1 No LIDU Has Been Received Since Last Clear

No octets from a LIDU should be included in this packet.

c-2 9.11.5.2 Last LIDU Received Was a Transmission Status LIDU

This field should include the first two octets of the packet transmitted.

9.11.5.3 Last LIDU Received Was a Received Uplink LIDU

This field should contain a copy of the octets of data received in the uplink DEAPDU for which this report is being prepared.

9.12 DEA Report Downlink Packet Transmit Priority

The priority used for downlink transmission of the Report Downlink Reaction Packet should be that indicated in the DEA uplink packet received.

AERONAUTICAL RADIO, INC
2551 Riva Road
Annapolis, Maryland 21401

SUPPLEMENT 1
TO
ARINC SPECIFICATION 635
HF DATA LINK PROTOCOLS

Published: December 12, 1996

Prepared by the Airlines Electronic Engineering Committee

Adopted by the Airlines Electronic Engineering Committee: October 22, 1996

A. PURPOSE OF THIS SUPPLEMENT

This Supplement includes updates primarily to the Link Layer Protocols. Updates were made to the Channel Access Protocol, Data Link Layer Packet Encapsulation, LPDU Prioritization and Preemption, Link Control Protocols, and Airborne Link Management Functions. These updates enhance utilization of slots at 1800 bps and support implementing HF Data Link using the DLS Mode protocol. The DLS Mode protocol implementation may be used to support ACARS message traffic including FANS 1 messages. For a complete tabulation of changes see Section C below.

B. ORGANIZATION OF THIS SUPPLEMENT

This Supplement introduces a rework of ARINC Specification 635 to reflect an evolving HF Data Link System. The normal practice of publishing a separate Supplement to update the existing document has not been followed. The changes introduced by Supplement 1 resulted in the impracticality of producing a separate set of replacement pages. Supplement 1 is therefore available only as an integral part of ARINC Specification 635-1. The modified and added material on each page is identified by a "c-1" in the margins.

C. CHANGES TO ARINC SPECIFICATION 635 INTRODUCED BY THIS SUPPLEMENT

This section presents a complete tabulation of the changes and additions to the Specification introduced by this Supplement. Each change or addition is defined by the section number and the title employed in the Specification. In each case a brief description of the change or addition is included.

1.3.1 ARINC Characteristic 758

Text rewritten.

4.2.2.3 Forward Error Correction

Deleted the rate 1/8 convolutional code.

4.2.3.1 Analog Waveform Definition

Corrected the P(t) definition by adding absolute bars around "f".

4.2.3.2.2.1 Forward Error Correction Encoding

Deleted the 150 bps references, (rate 1/8 encoding, repeating each output chip 4 times, and 8 output chips transmitted), from the second paragraph below Table 4-4. Deleted the code rate 1/8 row from Tables 4-5a and 4-5b and changed the table title.

4.2.4 Service Primitives

Deleted service primitive l "Ph-FREQUENCY.indication" and re-lettered the remaining service primitives. Changed "Ph-HFDL_ENABLE.request" to "Ph-HFDL_ENABLE-DISABLE.request" and changed the definition.

4.2.4.8 Physical Layer Receive Interleaver Setting Indication

Corrected the "Ph-Rx_DATA_RATE.indication" to be "Ph-Rx_INTERLEAVER.indication".

4.2.4.14 Physical Layer HFDL Enable-Disable Request

Changed the name of the service primitive and the parameters.

5.2.1.2.1 Transmission of MPDUs in Assigned Uplink Slots

Deleted the commentary after sub-section a.

5.2.1.3 Selection of Downlink Slot by Aircraft

Changed the fourth paragraph to send an MPDU with an LPDU containing a performance data HFNPDU. Added "and Unnumbered Acknowledged Data LPDUs" in sub-section a. Deleted the commentary after sub-section a.

5.2.1.3.1 Contention/Random Access Slot Selection

Added text and commentary describing the Exponential Backoff mode algorithm for selecting contention slots.

5.2.1.5 Maximum MPDU Size Adjustment

Added a sentence on the HFDR default to the maximum downlink rate of 300 bps to the end of the second paragraph.

5.2.1.7 Squitter SPDU Format

Added new text and commentary in sub-section a. **SPDU ID** after bit 5 concerning heavily loaded frequencies. Added new text at the end of sub-section a. concerning randomizing the selection of a random access downlink slot used for a Log-on Request after a frequency change notice has been received in a squitter.

Added acknowledgment of received LPDUs is provided for all LPDU types at the end of the second paragraph in sub-section d. **Slot Acknowledgment Codes**. Changed "four" to "eight" in the last commentary in sub-section d.

Changed the title of sub-section f. from "**Priority**" to "**Minimum Priority Accepted**". Added sentence to first paragraph. Edited second sentence of commentary and deleted the remainder of the commentary.

Deleted the first paragraph of the commentary in sub-section g. **Ground Station Active Frequency Bits**. Added two new paragraphs after the commentary concerning updating the active frequency bits during the Frequency Change process.

5.2.1.7.1 Intra-Ground Station Synchronization

Added new paragraph after the first commentary concerning use of actual aircraft position, if known, to determine the distance to each ground station in the

HFDL System Table. Added a sentence in the paragraph that follows Table 5-3 indicating there is a single HFDL System Table supporting the operation of the HFDL subnetwork. Replaced second sentence of the second commentary with new text on frequency searching.

5.2.1.7.3 Ground Station Synchronization Status

Added new paragraph to indicate when the ground station is not synchronized to UTC and that a failure in the external time source has occurred.

5.2.2 Data Link Layer Packet Encapsulation

Changed "8" to "15" in second paragraph and added "Each uplink MPDU can contain only one Aircraft Address which is addressed to any one aircraft". Changed "4" to "8" and "8" to "15" in second paragraph of sub-section a. **MID**. Added "Each uplink MPDU can contain only one Aircraft Address which is addressed to any one aircraft" to the end of the second paragraph in sub-section c. **Aircraft Address Field**. Appended the last paragraph to the first paragraph in sub-section c1. **AID** and added a sentence. Rewrote the fourth paragraph of sub-section c1. **AID**. Rewrote most of sub-section c2. **Reservation Request**. Edited the first sentence of sub-section c3. **MDF** and added new text on uplink MPDUs used to broadcast uplinks LPDUs. Changed "1 to 15 LPDUs" to "0 to 15 LPDUs". Changed "four" to "eight" and "8" to "15" in sub-section e. **Data Field**.

5.2.2.1 LPDU Encapsulation

Changed "252" to "253" in first paragraph. Revised section to support Unnumbered Acknowledged Data LPDUs.

5.2.2.3 Log-On Confirm and Log-On Resume-Confirm LPDUs

Changed the title from "Log-On Confirm, Log-On Resume-Confirm and Log-On Denied LPDUs" to "Log-On Confirm and Log-On Resume-Confirm LPDUs". Added the k window size calculation algorithm. Deleted the fourth, fifth and last sentences.

5.2.2.4 Log-On Denied and Log-Off Request LPDUs

Changed the title from "Log-Off Request LPDU" to "Log-On Denied and Log-Off Request LPDUs". Added text concerning the Log-On Denied LPDU and reject codes 01_h and 02_h. Replaced second sentence, under the Log-Off Request LPDU, with text showing the Log-Off Request LPDU is used by the ground station to terminate an abnormal air/ground link connection. Added reason codes 01_h through 05_h.

5.2.2.5.1 HFDL System Table

Revised the first paragraph and added a new second paragraph to allow the ground stations to broadcast a new HFDL System Table to all aircraft on the channel, prior to updating the HFDL System Table version in the squitter. The objective is to reduce the number of aircraft HFDL functions which would have to contend for available random access downlink slots to request the HFDL System Table.

Revised last sentence in third paragraph to indicate that the HFDL System Broadcast Table should be broadcast at 300 bps and sized to fit within a double slot. Made an editorial change in the commentary. Added text concerning the HFDL System Table at end of paragraph following commentary. Sub-sections f. and g. were swapped. Added new text to new sub-section g. **PAD and Dbase Version** describing incrementing the Dbase Version number. Added sentence on HFDL System Table HFNPDU to end of sub-section g.

5.2.2.5.2 HFDL System Table Request

Replaced section and added commentary. The new text added a two byte field to the HFDL System Table Request payload to enable the selective retransmission of HFDL System Table HFNPDUs rather than rebroadcasting the entire HFDL System Table.

5.2.2.5.3 Performance Data

Replaced first paragraph and commentary with two new paragraphs and commentary outlining the use of the optional Performance Data HFNPDU. Added new text in sub-section g. **Flight Number ID** concerning setting of the six octets in this field. Replaced the text for sub-sections i. **Performance Data**, and i1. **PD Version**. Removed the 'b' subscript from '1' and '20' in sub-section i4. **Frequency ID**. Replaced the commentary under sub-section i9. **Downlink MPDU Data**. Added a sentence at the beginning of sub-section i10. **Frequency Change Code**, indicating that this is a one octet field.

5.2.2.5.4 Frequency Data

Section renumbered. This was formerly Section 5.2.2.5.5. The former Section 5.2.2.5.4, PD Enable and PD Disable, was deleted. Added reference to Section 5.2.2.5.2 in sub-section g. **Flight Number ID**. Changed "...1 to 8 fields with 4 octets each. Each 4 octet field..." to "...1 to 6 fields with 6 octets each. Each 6 octet field..." in sub-section i. **Frequency Data**. Added text to sub-section i2. **Propagating Frequencies** concerning the second 20 bits encoding.

5.2.2.6 Numbered Data LPDU

Rewrote section and provided references to other areas of the document.

5.2.2.7 Unnumbered Acknowledged Data LPDU

Added new section.

5.2.3 LPDU Prioritization and Preemption

Removed the word "frame" from the first paragraph, third sentence. Changed text, following Table 5-4 LPDU Priorities, to indicate that priorities should apply to HFNPDUs transmitted in unnumbered or numbered LPDUs.

5.2.4.1 Direct Link Service Mode Protocol

Added new text to support implementing HF Data Link using only the DLS Mode protocol. This type of implementation may be used to support ACARS message traffic including FANS 1 messages.

5.2.4.2 Reliable Link Service Mode Protocol

Updated a reference. Added a new row to Table 5-5 to describe the D(N)vect and U(N)vect.

5.2.4.2.1 Segmentation of HFNPDUs Into BDUs and Flow Control

Added new paragraph between first paragraph and first commentary concerning discarding ACARS packets already in process. Added two new paragraphs under sub-section c. **BDU Sequence Number**. The first new paragraph shows the relationships between MPDUs, LPDUs, and BDUs. The second new paragraph outlines considerations when choosing sequence numbers.

5.2.4.2.2 Reassembly of BDUs into HFNPDUs, Flow Control and Routing

Added a third paragraph on receiving BDUs and reassembling them into HFNPDUs.

5.2.4.2.3 Uplink Transmission of LPDUs and Flow Control

Added sentence indicating that all U(S) sequence number operations should be done using modulo 32 arithmetic. Changed "U(A)+8" to "U(A)+k" and added "where k is the transmit window size in the U(A)vect definition. Added U(N)vect definition and commentary. Changed last paragraph to indicate when an aircraft should consider itself logged off and initiate a frequency search and log on.

5.2.4.2.3.1 Uplink Acknowledgment Field

Changed the algorithm for the ground station response to an Uplink Acknowledgment Field when it receives a downlink transmission.

5.2.4.2.3.2 Uplink LPDU Sequence Number Assignment

Replaced section with new text outlining assignment of Uplink LPDU Sequence Numbers.

5.2.4.2.3.3 Request Acknowledge

Added new paragraph to determine if an aircraft is still logged on.

5.2.4.2.4 Downlink Transmission of LPDUs and Flow Control

Added sentence indicating that all D(S) sequence number operations should be done using modulo 32 arithmetic. Changed "D(A)+8" to "D(A)+k" and added where k is the transmit window size in the D(A)vect definition. Added D(N)vect definition.

5.2.4.2.4.1 Downlink Acknowledgment Field

Changed "4" to "8" and "8" to "15" in the last sentence of the first paragraph. Replaced the sixth and seventh sentences of the second paragraph with text outlining the contents of the 12-bit acknowledgment field. Added text representing acknowledgments to downlinks sent using single and double slots.

5.2.4.2.4.2 Downlink MPDU Sequence Number Assignment

Replaced section with text on assigning Downlink MPDU Sequence Numbers.

5.2.5.1.1 Aircraft Log-On Procedure

Changed a reference in the first paragraph. Added a commentary before the fourth paragraph indicating that the initial transmit tuning should take place at a time other than when the squitter is being broadcast by the ground station. Added text to the fifth paragraph indicating that a positive acknowledgment is accomplished using FF_h as the Aircraft ID in the appropriate slot acknowledgment field. Added commentary after the fifth paragraph outlining the possibility of multiple aircraft attempting to Log-On to an HF Data Link Ground Station using the same random access downlink slot and recommendations on how to set the timer. Changed a reference in the sixth paragraph. Added commentary at the end of the section outlining recommendations for the HF Data Link Ground Station to implement procedures to log aircraft off of the channel and make Aircraft ID numbers available for reassignment.

5.2.5.1.3 Aircraft Log-Off Procedure

Replaced section with text indicating that the aircraft HF Data Link function is not required to log-off of the HF Data Link Ground Station.

5.2.5.1.5 HF Voice/Data Switching

Editorial change and added a reference to ARINC Characteristic 753, Section 10.3.1, in the fourth paragraph.

5.2.5.2 Link Management in Slave Mode

Added paragraph on the HFDR providing the 272 label to the opposite side radio and determining if the Dbase version is valid. Revised the definitions for bits 24 and 26 through 29, in Table 5-6.

5.2.5.4 HFDL System Table Management

Deleted numerous references to "service providers".

5.3.1 Data Link Layer Service Primitives

Added sub-section e. DL-DISCONNECT.confirm service primitive and definition. Added sub-section o. DL-Data_ACK.request service primitive and definition to request transmission of a downlink ACARS block using the acknowledged DLS protocol. Re-lettered the remaining sub-sections.

5.3.2 Airborne LME Service Primitives

Added sub-section e. LM_HFDL_Enable-Disable.request service primitive and definition.

6.2.4 Mapping Process Description

Added paragraph on Virtual Circuits.

ATTACHMENT 2-1 AIRBORNE STATION PROTOCOL LAYER INTERFACES

Updated diagram.

ATTACHMENT 2-7A DOWNLINK MPDU FORMAT

Updated diagram. Revised the RES REQ field.

ATTACHMENT 2-9A LPDU TYPES AND FORMAT DEFINITION

Updated diagram. Changed existing reference from "Log-on Request" to "Log-on Request (normal)". Added new Log-on Request (DLS) 1111 1101. Added Unnumbered Acknowledged Data LPDU type.

ATTACHMENT 2-10A UNNUMBERED DATA LPDU FORMAT DEFINITION

Updated diagram. Revised the HFNPDU Types and User Data Packets.

ATTACHMENT 2-10C UNNUMBERED DATA LPDU WITH BROADCAST HFDL SYSTEM TABLE

Updated diagram. Revised the MPDU Header, Broadcast Unnumbered Data LPDU, and HFDL System Table HFNPDU Payload.

ATTACHMENT 2-10D LOG-ON REQUEST AND LOG-ON RESUME LPDU FORMAT DEFINITION

Updated diagram. Added Log-On Request (DLS) field to the LPDU Type.

ATTACHMENT 2-10F LOG-OFF REQUEST & LOG-ON DENIED LPDU FORMAT DEFINITION

Updated diagram. Revised the Aircraft Address field. Deleted the Log-Off Request D/L fields.

ATTACHMENT 2-12 DATA LINK LAYER

Updated Tables.

Table 1. Revised the DL-DISCONNECT.req and RLS_BDU.req events. Added DL_DATA_ACK.req event. Added a note to clarify prioritization in the processing of events.

Table 2. Revised the RLS_BDU.req event. Added the Unnumbered Acknowledged Data LPDU event. Deleted the Log-Off Request event. Added a note to clarify prioritization in the processing of events.

Table 3A was formerly **Table 3**. Corrected event name errors.

Table 3B. Added.

Table 4. Added MAC_ACK.req, RLS_BDU.req, and RLS_BDU.ind primitives. Revised N200 and N204 timers.

ATTACHMENT 2-13 DATA LINK LAYER

Revised Pause Desired and DL-PAUSE.ind events. Added note 4.

ATTACHMENT 2-14 HF DATA LINK CONTENTION SLOT SELECTION BACKOFF ALGORITHM STATE MACHINE

Added Table. Former Attachment 2-14 was renumbered as Attachment 2-15.

ATTACHMENT 2-15 ATTACHMENTS-TO-SECTIONS CROSS REFERENCE

Updated cross reference for Attachment 2-14.

ATTACHMENT 3-1 PACKET MODE-PRIORITIES

Row identified as 'Unspecified (ISO 8208 explicit)' and column 'SNC Priority in CALL_REQUEST value was changed from "225" to "255".

APPENDIX B REFERENCES

Updated References.

AERONAUTICAL RADIO, INC
2551 Riva Road
Annapolis, Maryland 21401

SUPPLEMENT 2
TO
ARINC SPECIFICATION 635
HF DATA LINK PROTOCOLS

Published: February 27, 1998

Prepared by the Airlines Electronic Engineering Committee

Adopted by the Airlines Electronic Engineering Committee: December 12, 1997

A. PURPOSE OF THIS SUPPLEMENT

This Supplement includes updates primarily to the Link Layer Protocols with a focus on Minimum Priority Accepted, Ground Station Location, and DLS Retransmission Protocol. The HFDL Bit Map Representations were revised and a new Appendix on Delayed Echo Application was added.

B. ORGANIZATION OF THIS SUPPLEMENT

This Supplement introduces a rework of ARINC Specification 635 to reflect an evolving HF Data Link System. The normal practice of publishing a separate Supplement to update the existing document has not been followed. The changes introduced by Supplement 2 resulted in the impracticality of producing a separate set of replacement pages. Supplement 2 is therefore available only as an integral part of ARINC Specification 635-2. The modified and added material on each page is identified by a "c-2" in the margins.

C. CHANGES TO ARINC SPECIFICATION 635 INTRODUCED BY THIS SUPPLEMENT

This section presents a complete tabulation of the changes and additions to the Specification introduced by this Supplement. Each change or addition is defined by the section number and the title that will be employed when the Supplement is eventually incorporated. In each case a brief description of the change or addition is included.

3.2.2.2.1 Layer 2, Higher Layer Entities

Added section.

4.2.2.6 TDMA Receive Slot Synchronization

Add the word "squitter" in the second paragraph.

4.2.3.1 Analog Waveform Definition

In the formula, just below the Commentary, changed N to N-1. Added pulse shape formula.

4.2.3.2 Data Packet Encoding

Revised Table 4-1, Modulation Employed to Encode Unknown Data Symbols, to align "Gray Code" with the 1800 and 1200 bps data rates.

5.2.1.3 Selection of Downlink Slot by Aircraft

Added subparagraphs a. and b. concerning priority of encapsulating LPDUs into MPDUs.

5.2.1.3.1 Contention/Random Access Slot Selection

Replaced text with new contention/random access slot selection algorithm.

5.2.1.7 Squitter SPDU Format

In Subsection a., SPDU ID, defined bits 2, 3, and 4, and revised commentary. In Subsection b., Ground Station Address, revised the 8-bit definition. In Subsection f., Minimum Priority Accepted, added text and commentary to allow additional downlink throughput.

5.2.2 Data Link Layer Packet Encapsulation

Under Subsection c2, Reservation Request, added Subsection 7, Aircraft Delay for Next Use of Random Access Downlink Slot.

5.2.2.1 LPDU Encapsulation

In Subsection a., LPDU Type, fourth paragraph changed "acknowledged" to " unacknowledged" and added text on acknowledging downlink LPDUs in the squitter acknowledgment codes.

5.2.2.2 Log-On Request and Log-On Resume LPDUs

Added ICAO 24-bit Aircraft Address text.

5.2.2.4 Log-On Denied and Log-Off Request LPDUs

Added subsection f, Other.

5.2.2.5.1 HFDL System Table

In Subsection h2., Ground Station Location, added text on coding of the sign bit. Added commentary with example calculation used to determine the fractional latitude and longitude values used in the Broadcast System Table.

5.2.2.5.3 Performance Data

Under COMMENTARY, removed reference to Attachment 2-10D. In Subsection h., Aircraft Position, added coding for when position information is not available. In Subsection i3, Ground Station ID, noted that bit 8 is not defined. In Subsection i10, Frequency Change Code, noted coding if frequency change occurs when the aircraft is on the ground.

5.2.2.5.4 Frequency Data

Under Subsection i2, Propagating Frequencies, added sentence indicating that encoded values should represent the most recent frequency search.

5.2.3 LPDU Prioritization and Preemption

In Table 5-4, LPDU Priorities, deleted the performance data enable and disable uplink rows from the Unnumbered DATA LPDU Type field.

5.2.4.1 Direct Link Service Mode Protocol

Revised Subsection a., DLS/ACARS to ATN Transition, to indicate if a ground station is DLS/ACARS or RLS capable. Added new subsection on DLS Retransmission Protocol after the Squitter Acknowledgments subsection.

5.2.5.2 Link Management in Slave Mode

Revised last sentence in first paragraph. Deleted second paragraph and Table 5-6.

6.2.6.1 Overall Buffer Size

In Table 6-1, HFDL Buffer Size, deleted the 150 bps row.

ATTACHMENT 2-5 HF SIGNAL-IN-SPACE MINIMUM PACKET ERROR RATE PERFORMANCE WITH 1.8 SECOND INTERLEAVER

Revised values in the SNR column.

ATTACHMENT 2-8A SQUITTER SPDU FORMAT

Revised SQID and Ground Station Address fields.

ATTACHMENT 2-8C HFDL BIT MAP FOR TRANSMISSION OF SPDUs AND MPDUs

Revised the bit map examples.

ATTACHMENT 2-10A UNNUMBERED DATA LPDU FORMAT DEFINITION

Corrected number of bytes for Frequency Data HFNPDU from “6-36” to “19-49”. Deleted REQUEST DATA from HFDL System Table Request HFNPDU field. Deleted ACARS Data HFNPDU field.

ATTACHMENT 2-14 HF DATA LINK CONTENTION SLOT SELECTION BACKOFF ALGORITHM STATE MACHINE

Editorial revisions.

ATTACHMENT 2-15 ATTACHMENT-TO-SECTIONS CROSS REFERENCE

Corrected Attachment 2-8C, 2-10C, and 2-10G titles.

ATTACHMENT 3-1 PACKET-MODE PRIORITIES

Changed SNC Priority 13 from “Reserved” to “HF Data Link Management”. Changed associated Q-Number from “Invalid/reject” to “13”.

APPENDIX C - DELAYED ECHO APPLICATION.

Added appendix.

AERONAUTICAL RADIO, INC.
2551 Riva Road
Annapolis, Maryland 24101-7465

SUPPLEMENT 3
TO
ARINC SPECIFICATION 635
HF DATA LINK PROTOCOLS

Published: December 29, 2000

Prepared by the Airlines Electronic Engineering Committee

Adopted by the Airlines Electronic Engineering Committee: August 11, 2000

A. PURPOSE OF THIS SUPPLEMENT

This Supplement provides updates to the Link Layer Protocols. Updates to the Network Layer Protocols are made by reference to the ICAO SARPs.

B. ORGANIZATION OF THIS SUPPLEMENT

The first part of this document, printed on golden-rod paper contains descriptions of changes introduced into this Specification by this Supplement. The second part consists of replacement white pages for the Specification, modified to reflect the changes. The modified and added material on each page is identified by a "c-3" in the margins. Existing copies of ARINC Specification 635 may be updated by simply inserting the replacement white pages where necessary and discarding the pages they replace. The golden-rod pages are inserted inside the rear cover of the Specification.

C. CHANGES TO ARINC SPECIFICATION 635 INTRODUCED BY THIS SUPPLEMENT

This section presents a complete tabulation of the changes and additions to the Specification introduced by this Supplement. Each change or addition is defined by the section number and the title that will be employed when the Supplement is eventually incorporated. In each case a brief description of the change or addition is included.

4.2.3.1 Analog Waveform Definition

Changed the carrier modulation from "1800 Hz" to "1800 symbols $\pm$ 10 ppm (i.e., 0.018 symbols per second)."

5.2.1.2 Assignment of Slots by the Ground Station

Added a new final paragraph concerning the assignment of multiple slots to an aircraft.

5.2.1.2.1 Transmission of MPDUs in Assigned Uplink Slots

Reordered Items a., b., and c. Added clarity to subsection b. concerning FIFO ordering of LPDU's within an MPDU.

5.2.1.3 Selection of Downlink Slot by Aircraft

Editorial revision to fourth paragraph.

5.2.1.7 Squitter SPDU format

Revised references in subsections d. and g.

5.2.2 Data Link Layer Packet Encapsulation

Revised reference in second commentary. Revised subsection b. to reflect ground station identifier instead of ground station address.

5.2.2.2 Log-On Request and Log-On Resume LPDUs

Added Section reference for the ICAO 24-bit Aircraft Address.

5.2.2.4 Log-On Denied and Log-Off Request LPDUs

Added Item c, Other (reason code $03_{h)}$; Item f, Other (reason code 06_h); and Item g, Temporary Transceiver Shutdown (reason code 07_h).

5.2.2.5 Unnumbered Data LPDU

Revised reference.

5.2.2.5.1 HFDL System Table

Revised references in subsections b., c3., h1., and i.

5.2.2.5.3 Performance Data

Added text to second paragraph to clarify the downlink transmission rate for Performance Data.

Revised section reference in subsections b. and i3.

Expanded subsection e., the description of the 24-bit ICAO Aircraft Address.

Expanded subsection h., to identify time that position data was gathered (not time it was sent).

Deleted last sentence in subsection i3.

Expanded subsection i5., to clarify that the Frequency Search Counts field is used to identify the number of 32 second frames that the aircraft HFDL function was out of communications during the previous and current flight legs. Added Commentary.

Added Commentary to Item i7.

Expanded subsection i10., Frequency Change Code, to indicate that code 3_h can be set when in extended operation of the opposite side radio for voice communication.

5.2.2.5.4 Frequency Data

Revised references in subsections b., g., and i1. Expanded subsection c2., to describe the variable length of Frequency Data.

5.2.3 LPDU Prioritization and Preemption

Revised reference in third paragraph. Added note to Table 5-4.

5.2.4.2.3.1 Uplink Acknowledgement Field

Revised section reference.

5.2.5.1.1 Aircraft Log-On Procedure

Revised section references in three places.

5.2.5.1.2 Aircraft Log-On Resume Procedure

Added subsection f.

5.2.5.4 HFDL System table Management

Revised section reference in fifth paragraph.

6.2.2 HFDL SubNetwork Layer Structure

Deleted last sentence.

6.2.3 HFSNL Protocol Definition

Changed section title from “HFSND Protocol Description” to “HFSNL Protocol Definition” and replaced contents of entire section.

6.2.4 Mapping Process Description

Replaced first paragraph with reference to the rules for mapping ISO 8208 packets into HFNPDU’s and vice versa.

6.2.6.1 Overall Buffer Size

Reference in the first paragraph deleted.

ATTACHMENT 2-1 - AIRBORNE STATION PROTOCOL LAYER INTERFACES

Attachment number and titled corrected. The title was incorrectly identified as Unnumbered Data LPDU Format Definition.

ATTACHMENT 2-8A - SQUITTER SPDU FORMAT

Corrected the number of bits from 7 to 8 in the Flush byte.

ATTACHMENT 2-8C - HFDL BIT MAP REPRESENTATIONS

Editorial change to introduction and notes: changed “most bit” to “most significant bit”.

ATTACHMENT 2-10A - UNNUMBERED DATA LPDU FORMAT DEFINITION

Added the two byte Request Data payload to the HFDL System Table Request HFNPDU.

ATTACHMENT 2-10C – UNNUMBERED DATA LPDU WITH BROADCAST HFDL SYSTEM TABLE

Corrected “kHz” to be “MHz” in the fifth and sixth fields of the Frequency Field to be consistent with the description in section 5.2.2.5.1 HFDL System table subparagraph (h 4) “Frequency Fields”.

ATTACHMENT 2-15 - ATTACHMENTS-TO-SECTIONS CROSS REFERENCE

References updated.

AERONAUTICAL RADIO, INC
2551 Riva Road
Annapolis, Maryland 21401

SUPPLEMENT 4
TO
ARINC SPECIFICATION 635
HF DATA LINK PROTOCOLS

Published: December 22, 2003

Prepared by the Airlines Electronic Engineering Committee

Adopted by the Airlines Electronic Engineering Committee: September 9, 2003

A. PURPOSE OF THIS SUPPLEMENT

This Supplement provides updates or corrections primarily to Section 5 Air/Ground Services and Protocols of Layer 2 - Link Layer as well as Attachments 1-2, 2-2, 2-6, and 2-9A to be consistent with the ICAO Manual on HFDL Technical Specifications and to improve the ability to analyze the performance of the aircraft HFDL within the system.

B. ORGANIZATION OF THIS SUPPLEMENT

This Document, printed on goldenrod paper, contains descriptions of changes introduced into Specification 635 by this supplement. The material in Supplement 4 is integrated into ARINC Specification 635 to form an updated version of the standard.

Changes introduced by Supplement 4 are identified using change bars and are labeled by a “c-4” symbol in the margin.

C. CHANGES TO ARINC SPECIFICATION 635 INTRODUCED BY THIS SUPPLEMENT

This section presents a complete tabulation of the changes and additions to the Specification introduced by this Supplement. Each change or addition is defined by the section number and the title that will be employed when the Supplement is eventually incorporated. In each case a brief description of the change or addition is included.

5.2.1.3 Selection of Downlink Slot by Aircraft

Reinstated Item c, which was previously eliminated during the development of Supplement 2.

5.2.1.6 Data Rate and Interleaver Selection

Corrected the MPDU/SPDU size entry in Table 5-2 from “271-630 bytes” to “316-630 bytes.”

5.2.2.5.3 Performance Data

Subsections i1 and i10 were revised to improve the ability to analyze the performance of the Aircraft HFDL within the system.

A commentary was added to i10 stating that vendor specific information is contained in the PD Version and Frequency Change Code fields.

Item c was revised to refer to Section 5.2.2(c) only by deleting the exception case.

5.2.4.2 Reliable Link Service Mode Protocol

Editorial note was added to Item c to reference Table 5-5. Changed “D(A)+8” to “D(A)+k” in the third row of Table 5-5.

5.2.4.2.3 Uplink Transmission of LPDUs and flow Control

Reinstated the “U(A)vect” description which was inadvertently omitted from Supplement 3. Updated the U(A)vect and U(N)vect descriptions. Revised the U(R)vect description.

5.2.4.2.4 Downlink transmission of LPDUs and Flow Control

Updated the D(A)vect and D(N)vect descriptions. Revised the D(R)vect description.

5.2.5.1.2 Aircraft Log-On Resume Procedure

Additional commentary was added to inform the reader that the minimum threshold for the maximum uplink data rate computed by the aircraft should be one which is sufficient to support the protocol operation (DLS/RLS).

6.2.3 HSFNL Protocol Definition

Updated references to ICAO Manual on HFDL Technical Specifications.

6.2.4 Mapping Process Description

Updated references to ICAO Manual on HFDL Technical Specifications.

ATTACHMENT 1-1 – AIRBORNE SUBSYSTEM BLOCK DIAGRAM

Block Diagram was updated.

ATTACHMENT 1-2 - HFDL REFERENCE MODEL

Corrected “(DTE) ISO 8208” to be “(DCE) ISO 8208” in the Airborne HFDL Subnetwork Access Sub-layer block.

ATTACHMENT 2-2 - HF DATA LINK SIGNAL-IN-SPACE DEFINITION

Corrected the M1 sequence to be “1 of 8 shifts” rather than “1 of 10 shifts.”

ATTACHMENT 2-6 - SLOTTED FRAME

Corrected the prekey duration to be “249 ms” rather than “250 ms”.

ATTACHMENT 2-9A - LPDU TYPES AND FORMAT DEFINITION

Corrected the Numbered Data bit 1 to be “0” instead of “1”.

ARINC IA Project Initiation/Modification (APIM) Guidelines for Submittal

(Thursday, January 08, 2004)

1. ARINC Industry Activities Projects and Work Program

A project is established in order to accomplish a technical task approved by one or more of the committees (AEEC, AMC, FSEMC) Projects generally but not exclusively result in a new ARINC standard or modify an existing ARINC standard. All projects are typically approved on a calendar year basis. Any project extending beyond a single year will be reviewed annually before being re-authorized. The work program of Industry Activities (IA) consists of all projects authorized by AEEC, AMC, or FSEMC (The Committees) for the current calendar year.

The Committees establish a project after consideration of an ARINC Project Initiation/Modification (APIM) request. This document includes a template which has provisions for all of the information required by The Committees to determine the relative priority of the project in relation to the entire work program.

All recommendations to the committees to establish or reauthorize a project, whether originated by an airline or from the industry, should be prepared using the APIM template. Any field that cannot be filled in by the originator may be left blank for subsequent action.

2. Normal APIM Evaluation Process

Initiation of an APIM

All proposed projects must be formally initiated by filling in the APIM template. An APIM may be initiated by anyone in the airline community, e.g., airline, vendor, committee staff.

Staff Support

All proposed APIMs will be processed by committee staff. Each proposal will be numbered, logged, and evaluated for completeness. Proposals may be edited to present a style consistent with the committee evaluation process. For example, narrative sentences may be changed to bullet items, etc. When an APIM is complete, it will be forwarded to the appropriate Committee for evaluation.

The committee staff will track all ongoing projects and prepare annual reports on progress.

Committee Evaluation and Acceptance or Rejection

The annual work program for each Committee is normally established at its annual meeting. Additional work tasks may be evaluated at other meetings held during the year. Each committee (i.e., AMC, AEEC, FSEMC) has its own schedule of annual and interim meetings.

The committee staff will endeavor to process APIMs and present them to the appropriate Committee at its next available meeting. The Committee will then evaluate the proposal. Evaluation criteria will include:

- Airline support – number and strength of airline support for the project, including whether or not an airline chairman has been identified
- Issues – what technical, programmatic, or competitive issues are addressed by the project, what problem will be solved
- Schedule – what regulatory, aircraft development or modification, airline equipment upgrade, or other projected events drive the urgency for this project

Accepted proposals will be assigned to a subcommittee for action with one of two priorities:

- High Priority – technical solution needed as rapidly as possible
- Routine Priority – technical solution to proceed at a normal pace

Proposals may have designated coordination with other groups. This means that the final work must be coordinated with the designated group(s) prior to submittal for adoption consideration.

Proposals that are not accepted may be classified as follows:

- Deferred for later consideration - the project is not deemed of sufficient urgency to be placed on the current calendar of activities but will be reconsidered at a later date
- Deferred to a subcommittee for refinement – the subcommittee will be requested to, for example, gain stronger airline support or resolve architectural issues
- Rejected – the proposal is not seen as being appropriate, e.g., out of scope of the committee

3. APIM Template

The following is an annotated outline for the APIM. Proposal initiators are requested to fill in all fields as completely as possible, replacing the italicized explanations in each section with information as available. Fields that cannot be completed may be left blank. When using the Word file version of the following template, update the header and footer to identify the project.

ARINC IA Project Initiation/Modification (APIM)

Name of proposed project APIM #: _____

Name for proposed project.

Suggested Subcommittee assignment

Identify an existing group that has the expertise to successfully complete the project. If no such group is known to exist, a recommendation to form a new group may be made.

Project Scope

Describe the scope of the project clearly and concisely. The scope should describe "what" will be done, i.e., the technical boundaries of the project. Example: "This project will standardize a protocol for the control of printers. The protocol will be independent of the underlying data stream or page description language but will be usable by all classes of printers."

Project Benefit

Describe the purpose and benefit of the project. This section should describe "why" the project should be done. Describe how the new standard will improve competition among vendors, giving airlines freedom of choice. This section provides justification for the allocation of both IA and airline resources. Example: "Currently each class of printers implements its own proprietary protocol for the transfer of a print job. In order to provide access to the cockpit printer from several different avionics sources, a single protocol is needed. The protocol will permit automatic determination of printer type and configuration to provide for growth and product differentiation."

Airlines supporting effort

Name, airline, and contact information for proposed chairman, lead airline, list of airlines expressing interest in working on the project (supporting airlines), and list of airlines expressing interest but unable to support (sponsoring airlines). It is important for airline support to be gained prior to submittal. Other organizations, such as airframe manufacturers, avionics vendors, etc. supporting the effort should also be listed.

Issues to be worked

Describe the major issues to be addressed by the proposed ARINC standard.

Recommended Coordination with other groups

Draft documents may have impact on the work of groups other than the originating group. The APIM writer or, subsequently, The Committee may identify other groups which must be given the opportunity to review and comment upon mature draft documents.

Projects/programs supported by work

If the timetable for this work is driven by a new airplane type, major avionics overhaul, regulatory mandate, etc., that information should be placed in this section. This information is a key factor in assessing the priority of this proposed task against all other tasks competing for subcommittee meeting time and other resources.

Timetable for projects/programs

Identify when the new ARINC standard is needed (month/year).

Documents to be produced and date of expected result

The name and number (if already assigned) of the proposed ARINC standard to be either newly produced or modified.

Comments

Anything else deemed useful to the committees for prioritization of this work.

Meetings

The following table identifies the number of meetings and proposed meeting days needed to produce the documents described above.

Activity	Mtgs	Mtg-Days
Document a	*# of mtgs*	*# of mtg days*
Document b	*# of mtgs*	*# of mtg days*

For IA staff use

IA staff assigned: ____

Forward to committee(s) (AEEC, AMC, FSEMC): __________________

Potential impact: ____
(A. Safety B. Regulatory C. New aircraft/system D. Other)

Committee resolution: ____
(1. Authorized 2. Deferred 3. More detail needed 4. Rejected)

Assigned Priority: ____

A. – High (execute first) B. – Normal (may be deferred for A.)

ARINC Standard – Errata Report

1. Document Title

ARINC Characteristic 741P1-10: *Aviation Satellite Communication System Part 1 Aircraft Installation Provisions,* December 24, 2003

2. Reference

Page Number:______ Section Number: _____________ Date of Submission: _____________

3. Error

(Reproduce the material in error, as it appears in the standard.)

4. Recommended Correction

(Reproduce the correction as it would appear in the corrected version of the material.)

5. Reason for Correction

(State why the correction is necessary.)

6. Submitter (Optional)

(Name, organization, contact information, e.g., phone, email address.)

Note: Items 2-5 may be repeated for additional errata. All recommendations will be evaluated by the staff. Any substantive changes will require submission to the relevant subcommittee for incorporation into a subsequent Supplement.

Please return comments to fax +1 410-266-2047 or standards@arinc.com