ICAO AFI REGION

GUIDANCE ON THE IMPLEMENTATION OF HFDL AND VDL IN THE AFI REGION

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SCOPE OF THE DOCUMENT

This document has been developed by the ICAO AFI IIM COM3 Project team to present a comprehensive collection of information pertaining to the implementation of HFDL and VDL in the ICAO AFI Region. It is intended that the document will evolve into an AFI ICAO Document containing guidance material on AFI HFDL and VDL implementation.

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REFERENCES

ICAO Documentation

1. Manual On VHF Digital Link (VDL) Mode 2 (Doc 9776)
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2 INTRODUCTION

2.1. Background Information

The High Frequency data link (HFDL) design is based on the MIL-STD-188-110A and has been recently considered as suitable for Aeronautical Telecommunications Network (ATN) utilization. The propagation data collected through trials and prototype systems over the last few years indicates that HFDL can provide a level of performance suitable for the ATN environment.

The HFDL service allows aircraft that are equipped with an HFDL control function (HCF), HF data radios, an intermediate HF data unit, and compatible HF voice radios, to send and receive data packets via a network of HFDL ground stations.

A subnetwork of HFDL ground stations is required to extend air-ground communications coverage on a world-wide basis and provide an alternate or backup to SATCOM on routes over the oceanic regions. The actual number of ground stations needed is dependent upon several factors including system availability and capacity desired by the users and ground station operators.

This document also indicates that HFDL can provide very significant improvements over HF Voice Communications in terms of system availability, system capacity, ease of use, and information integrity.

2.2. HFDL

2.2.1. Purpose

The purpose of this document is to provide the reader with material to enhance the understanding of HFDL. This document provides the reader with guidance material to be considered when implementing HFDL system in several areas including the airborne avionics, the propagation media, and the terrestrial components.

2.2.2. Role of HFDL in CNS/ATM

HFDL has emerged as one of the requirements for the aeronautical industry as they progress with the implementation of data links both on the ground and airborne sides. A networked-based HFDL system satisfies future air traffic service (ATS) and aeronautical operational control (AOC) communication requirements in the oceanic regions in a cost efficient and reliable manner.

Furthermore, HFDL can provide data link service over other land areas where no current data link service (i.e., VHF) is currently available. In this case, HFDL provides a data link service where numerous VHF data link stations may be impractical due to cost or other factors.

HFDL may help in a reduction in the growth of requirements for HF voice services, as many current voice service requirements are accommodated via HFDL.

HFDL fulfils several key roles:

[a]. provides aircraft that are not SATCOM-equipped with a long-range, cost-effective data link;

[b]. serves as a data link for polar regions where SATCOM performance degrades; and

[c]. acts in combination with SATCOM as very high-performance system capable of meeting future ATN availability requirements.

HFDL is seen as a tool enabling communications, navigation, and surveillance/air traffic management (CNS/ATM) to be extended to new regions and to aircraft previously not able to afford a long-range data link.

2.2.3. HF as a long-range communication medium

2.2.3.1. HF propagation

The HF frequency band is affected by the neutral atmosphere or the ionosphere. In contrast, the HF band depends upon the ionosphere for its skywave coverage pattern to achieve beyond-line-of-sight (BLOS) communication ranges of 4 000 to 5 000 km and beyond (on multi-hop paths). HF coverage can be extended over the polar regions by appropriate ground station positioning.

The HF band is not influenced by the wide range of atmospheric phenomena like severe weather conditions. The HF band of 2.850 to 22.000 MHz is subject to several ionospheric influences which lead to signal distortion. These are dependent upon factors such as ionospheric layer shape and densities which are functions of geographical and time-varying conditions. The temporal effects include long-term solar epochal changes related to the eleven-year sunspot cycle, seasonal variations, day-to-day changes, and diverse variations. There are also signal-level fluctuations which arise over a continuum of time scales (i.e. seconds to hours).

The time scale and character of HF signal distortion will define the most appropriate countermeasure or mitigation scheme. Many approaches are now available for mitigation of deleterious HF effects and these include advanced signal processing, dynamic frequency management, and a variety of diversity measures to exploit the wide variety of ionospheric effects.

2.2.3.2. Networked sites

HFDL enables an aircraft to communicate with any number of internetworked HF ground stations that is providing coverage in that area. Messages are routed to and from the ground end user via dedicated communication circuits or packet switched data public or private networks. The HFDL system is expected to be inherently more reliable (higher availability), because ionospheric disturbances are much less likely to affect the communications from a point in the coverage area to all ground stations at the same time.

2.2.3.3. Automatic frequency management

The HFDL system on the aircraft automatically searches for a suitable (or even the best available) frequency from all HFDL operational ground station frequencies. To assist with the search, each HFDL ground station broadcasts system management uplink packets (called 'squitters') every 32 seconds on its operational frequencies. The squitters on each of the frequencies are staggered and synchronized to universal time co-ordinated (UTC) to allow a quick search through the frequencies. In order to speed up the search process, an aircraft may limit the search to all operational frequencies assigned to ground stations within 4 000 to 5 000 km of the current aircraft position.

Once a suitable frequency is found, the aircraft establishes a connection by sending a log-on message to the ground station and wait for a log-on confirmation uplink before continuing. Having established a connection, the aircraft may proceed to send data on time slots assigned for random access, or downlink slots specifically assigned to the particular aircraft, and to receive data on slots reserved for uplinks by the ground station. To facilitate the frequency and slot management process, thirteen slots are grouped into frames having a length of 32 seconds. The assignments for each of the thirteen slots in a 32-second frame are broadcast by the ground station in squitters using the first slot in the frame. The acknowledgments to all downlinks sent in the previous frame interval are also broadcast in the squitters.

An aircraft logged-on a particular frequency continues to use that frequency until it does not detect a useable squitter, which is broadcast every 32 seconds, or when the ground station does not acknowledge three consecutive downlinks sent by the aircraft. At that point the aircraft initiates a search for a new frequency and logs-on to the new frequency. The hand-off of the connection from one frequency to another and from one ground station to another is totally transparent to the aircraft user.

2.2.3.4. Digital signal processing

There is a perception that long rang HF communication is unreliable due to the irregular behaviour caused by ionospheric issues. This perception has been based upon years of experience prior to the advent of modern digital signal processing techniques. Early efforts in the use of HF as a transmission path for data links failed for reasons including problems with the signal-in-space waveform. The most recent HFDL trials began in early 1990s and highlighted progress made in HFDL modems employing new digital signal processing technologies. The modems employed phase shift keying (PSK) modulation, forward error correction, interleaving of coded data and adaptive channel equalization of received data. These techniques enabled the modems to compensate for the distortion of the HF channel.

2.2.3.5. Automatic selection of data rates

HFDL allows for the transmission of data at rates of 300, 600, 1 200, and 1 800 bits/s. The HFDL function uses the slowest possible data rate available to support the message size of the downlink transmission. At any time, each link between the aircraft and ground station will have a maximum downlink and uplink data rate. The maximum uplink rate is determined by the aircraft and provided to the ground station. The maximum downlink rate is determined by the ground station and provided to the aircraft. These data rates are determined by evaluating the received signal. Insufficient or marginal signal-to-noise ratio will lead the aircraft to search for a new frequency from the same or different ground station which provides sufficient signal-to-noise ratio for establishment and use of the data link.

2.2.4. Performance

2.2.4.1. Availability

An HFDL availability of 95% or better can be achieved with three ground stations and two operational frequencies per ground station with no attempt made to optimize the selection of operational frequencies to counteract the effects of propagation disturbances. The availability should improve by adding more active frequencies per ground station, adapting the selection of operational frequencies to changing propagation, and adding more optimally located HFDL sites within regions.

2.2.4.2. Integrity

HFDL eliminates data errors using cyclic redundancy code (CRC) checksums appended to every packet. The CRC checksum allows the system to automatically detect all combinations of bit errors in the packet less than 17 bits wide, with the probability of not detecting bursts of errors wider than 17 bits being less than 1 in 10 million. Packets received with errors are discarded and not acknowledged. Unacknowledged packets are automatically retransmitted. HFDL uses the same 16-bit CRC checksums as those employed by other aeronautical data systems such as SATCOM and VHF data link. Hence, the achievable level of data integrity is the same.

2.2.5. HFDL system relationship to HF voice

The scarcity of spectrum to allocate enough voice channels in the aeronautical service bands has necessitated the development of data link systems.

HFDL efficiently utilises the available HF spectrum more than HF voice for several reasons:

[a]. HFDL employs short burst transmissions of less than 2.2 seconds duration in time slots of 2.47 seconds duration to send data packets with up to 213 bytes of user data.

[b]. A waypoint position report can be sent in a single 2.47 second slot.

[c]. A time division multiple access (TDMA) and a slot reservation protocol described in the Annex to the HFDL SARPs, provides for the assignment of slots for uplink and downlink transmission to and from individual aircraft in order to avoid mutual interference between transmissions from ground stations and from multiple aircraft on the same time slot.

[d]. A single voice contact to report a waypoint position report typically uses about 1 minute of channel time.

By using digital signal processing techniques such as adaptive equalization and forward error correction coding to combat effects such as multipath, impulse noise from lightning and fading, more useable spectrum is available with HFDL than with HF voice. Thus, frequencies which are unsuitable for voice communications have the potential to be used reliably for HFDL. Moreover, HFDL signal processing techniques may enable multipath channels to perform with good reliability.

The more efficient spectrum usage with HFDL translates into greater system capacity per operational frequency. The number of aircraft that can be provided service in a given geographical area during a given hour depends on the number of data packets sent to and from each aircraft during that hour and the number of frequencies propagating to any of the ground stations providing coverage in that area.

Table 1: Availability of HF voice communications compared with HFDL

Parameter	HF VOICE COMMUNICATIONS	HFDL
Availability of Communications	• < 80% availability	• >95% availability with coverage from 2 HFDL stations • >99% availability with coverage from 3 or 4 HFDL stations (Note: This will depend on the siting of the ground stations and the terrain. Hence some regions might need more ground stations than others)
Spectrum Usage	• 1-2 minutes per position report • Large fraction of available (propagating) frequencies unusable due to multipath and fading	• 2.5 seconds per position report • Adaptive equalization and forward error correction coding allow use of all available frequencies
Frequency Management	• Operator required to select/find good frequency • Ground can only contact aircraft if aircraft HF radio tuned to good frequency	• Automatic search and selection of good frequency based on channel quality measurement • Automatic hand-off of connection between ground stations
Data/message Integrity	• Prone to error when operator transcribes voice contact into a data message	• CRC checksums detect errors • Messages received with errors automatically retransmitted

2.2.6. HFDL System Relationship to SATCOM

HFDL can be combined with SATCOM to provide a high-level system availability instead of installing a dual redundant SATCOM system. This is as a result of the independent failure mechanisms between HFDL and SATCOM, whereas dual redundant SATCOM does not provide the same degree of diversity advantage.

There are two factors that are considered when computing the availability of radio communications systems such as SATCOM and HFDL.

- The availability of the equipment, which is a function of the mean time between failures (MTBF) and mean time to repair (MTTR); and
- The availability of the propagation path, which in the case of SATCOM may include the availability of the satellite.

The overall system availability is equal to the product of the two.

Table 2 below shows the total system availability formula of a single SATCOM installation and as well as that of a dual SATCOM installation.

Table 2: Availability of dual SATCOM installations

	Availability Formula
Single SATCOM Installation	A_1 = availability of single SATCOM installation A_s = availability of SATCOM propagation & Ground Station $A_1 = \frac{MTBF_s}{MTBF_s + MTTR} \times A_s$
Dual SATCOM Installations	A2 = availability of dual SATCOM installation As = availability of SATCOM propagation & Ground Station $A_2 = \frac{1.5 \times MTBF_s}{1.5 \times MTBF_s + MTTR} \ A_s$

Table 3 below shows the availability formula of a single HFDL installation as well as that of a SATCOM and HFDL installation.

Table 3: Availability of SATCOM and HFDL installations

	Availability Formula
Single HFDL Installation	A_1 = availability of single HFDL installation A_{hf} = availability of HF propagation & Ground Station $A_1 = \frac{MTBF_{hf}}{MTBF_{hf} + MTTR} \times A_{hf}$
SATCOM with HFDL Installations	A_2 = availability of SATCOM plus HFDL installation A_s = availability of SATCOM propagation & Ground Station A_{hf} = availability of HF propagation & HF Ground Station $A_2 = 1 - \left[1 - \frac{MTBF_s}{MTBF_s + MTTR} \times A_s\right] \times \left[1 - \frac{MTBF_{hf}}{MTBF_{hf} + MTTR} \times A_{hf}\right]$

2.3. VDL

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3 AFI HFDL Requirements

3.1 HFDL SYSTEM DESCRIPTION

3.1.1 Introduction

The HFDL system enables aircraft-based computers to exchange data with ground-based computers. The HFDL system comprises of four distinct sub-systems, namely:

- HFDL aircraft sub-system;
- HFDL ground station sub-system;
- HFDL ground communications sub-system; and
- HFDL ground management sub-system.

3.1.2 HFDL aircraft sub-system

[a]. HFDL aircraft sub-system components

The aircraft station sub-system [MN1]includes the aircraft HFDL equipment and the airborne elements of the HFDL protocol. It provides the interface to the aircraft data link avionics.

The following major components are part of the aircraft station sub-system:

- HFDL transmission and HF data unit (HFDU);
- Data modulation and demodulation;
- HFDL protocol and frequency selection; and
- Interface to the airborne data link processor.

[b]. HFDL capability

HFDL capability on the aircraft is provided by one of several methods, depending upon the equipment currently installed in the aircraft.

- installing an HF data unit (HFDU) which provides an interface between the management unit (MU) or HCF and a conventional HF/SSB voice radio; or
- installing a service bulletin upgrade into an existing HF/SSB voice radio which adds HF Data Radio (HFDR) functionality into a single line replaceable unit (LRU) and provides interfaces to the MU/HCF; or
- installing an HFDR as defined by HFDL SARPs.

Interfaces between the aircraft HF antenna couplers and HFDU, HFDR, or HF SSB transmitters and receivers are as specified in ARINC Characteristic 753[MN2]. The HFDR also interfaces to the HFDL control function which is implemented either by modifying existing radio control panels, or by additional supplemental HFDL control panels. The HFDU and the data modules in the HFDR implement the HF modem, data link layer, and HF subnetwork access. The MU/HCF is a router/end system which, in addition to interfacing to the HFDL equipment, also interfaces to other data link subnetwork data communications equipment (DCE) on board the aircraft as well as end systems such as a flight management computer (FMC), aircraft condition monitoring system, or cockpit display terminal.

3.1.3 HFDL ground station sub-system

The HFDL ground station sub-system [MN3]includes the ground HFDL equipment and the ground elements of the HFDL protocol. It also provides for the interface to the ground based HFDL end users. The following major components are part of the HFDL ground station sub-system:

[a]. HF transmission and reception:
- two to six HF/SSB transmitters with 1 kW power or greater, with one antenna per transmitter;
- two to six HF/SSB receivers with a single antenna shared by all receivers;

[b]. data modulation and demodulation:
- two to six HF modems (one for each transmitter/receiver pair) which implement the HFDL signal-in-space;

[c]. HF protocol and frequency selection:
- remote control and supervision equipment to tune and monitor the HF transmitters and receivers; and
- an HF ground station controller which implements:
  - the ground side of the HFDL protocol including the management of the log-on procedures and frequency scheduling; and
  - all the inter-ground and intra-ground station synchronization and generation of squitters;

[d]. interface to the ground communications sub-system.

Each ground station implements the ground side of the HFDL signal-in-space, the HFDL protocol, and the means to interface to the HFDL ground communications sub-system. Initially, a ground station may be equipped only with two or three transmitters, receivers, antennas and HF modems. Equipment can be incrementally added as more capacity is required.

3.1.4 HFDL ground communications sub-system

A ground communications infrastructure is required to interconnect HFDL ground stations, end users, and the HFDL management sub-system. Regional communication hubs may be used to internetwork regional HFDL ground stations and provide points of access to the HFDL system. Appropriate packet switched data networks will provide the connection between ground stations and hubs. The communications hubs would operate ATN routers to route messages between HFDL users and the HFDL ground stations which then relay the messages to the aircraft logged-on the ground station.

3.1.5 HFDL ground management sub-system

The HFDL ground management sub-system provides the means to operate, manage, and maintain the HFDL System. The HFDL management sub-system provides the following functionality:

- aircraft log-on status table management;
- system table management; and
- frequency management.

The frequency management function is unique to the HFDL system. In order to make efficient use of the limited spectrum available for HFDL and to maximize system availability, the HFDL ground stations should share frequency assignments and co-ordinate their use in real time based on actual propagation data. Initially, when there are very few users of the system, frequency management may be based on predictions of frequency propagation. Available HFDL frequencies may be assigned on a geographic basis. Each HFDL ground station would have a table of frequencies and associated operational times.

As HFDL system usage grows and capacity and availability become more of an issue, dynamic frequency management capabilities should be added to the system. Moreover, dynamic frequency management will be critical during disturbed propagation which arises as a result of increased solar and geomagnetic activity. For example, actual propagation measurements could be used to evaluate HF propagation patterns in real-time and provide input to a frequency management algorithm.

3.2 HFDL GROUND STATIONS

3.2.1 Ground station synchronization

HFDL system is designed to take advantage of time synchronization in the broadcast of squitters.
The squitters are used for the following functions:

- to mark the beginning of the 32 second frames,
- allow the airborne receiving system to determine availability of a communications channel, and
- to transmit system management information.

The ground stations are expected to transmit the squitters in an organized time staggered manner. This assures that within a station, there is a known pattern of transmissions. Additionally, the ground stations are expected to synchronize their squitter transmissions to Universal Time Co-ordinated (UTC). The total synchronization allows the airborne receiving systems to know when to expect a squitter on each frequency, thus allowing improved acquisition times

3.2.2 Antennas for HFDL ground stations

3.2.2.1 General

The ground station operators for the HFDL system, provides communications to and from aircraft, which are located at various distances from the ground station operators. These distances vary from very short to longer distances perhaps as far away as 4 000 to 5 000 km but are normally in the 2 500 km range. VHF frequencies generally cover communications of about 400 km (line-of-sight); however, there may be instances when HF might be used as an alternate communication medium within this range. Thus, the ground station operator (ground station antennas) should provide communications coverage for distances between less than 400 km to over 4 000 km. For purposes of definition here:

- a short-range antenna covers out to about 1 000 km,
- a moderate range antenna covers about 800 to 3 000 km, and
- a long-range antenna covers 3 000 km and beyond

The radio waves at HF band refracts off the ionospheric layers that exist around 100 to 300 km above the earth at different angles depending on the distance above earth of the ionospheric layer and the time of the day. Hence, maximum radiation must be directed by the antenna at the ionospheric refracting layers at desired elevation and azimuth angles, this must result in refracted radiation coverage to desired locations.

A given ground station operator may be able to use several antennas to provide required short to long-range communications. Antenna selections may include a short-range omnidirectional antenna combined with several moderate to long-range directive antennas. However, a ground station operator may also have limited land area available and may need to use a small number of antennas of a single type that provide satisfactory service to all ranges.

HF transmitting and receiving sites for a single ground station operator are usually spaced at least 5 to 20 km in order to provide high isolation between the HF transmitters and HF receivers and to allow a lower radio noise environment at the receive site.

Antennas for HFDL should cover the band 2 to 30 MHz. The highest aeronautical mobile frequency is 22 MHz.

3.2.2.2 Antennas for transmitting sites

For transmission of HF radio waves, a horizontally polarized (HP) antenna is generally the better choice over a vertically polarized (VP) antenna because the ground refraction loss for HP waves is small and the ground refraction loss for VP waves is relatively large. The HP antennas typically have at least a 6-dB advantage over the VP antennas in terms of power gain unless extensive ground screens are used under the VP antennas. A VP monopole antenna with a good ground screen can provide satisfactory low angle coverage; however, this antenna has a null overhead and is not satisfactory at ranges shorter than 800 km, where typically high angle coverage is needed. A VP monopole antenna may be an adequate choice if the ground station operator does not have any short path communications requirements.

3.2.2.3 Antennas for receiving sites

A highly efficient receiver antenna is generally not needed because of the relatively high levels of manmade and atmospheric radio noise at HF. For receiving, it is much more important to use antennas with a high directive gain so that the signal level picked-up by the antenna is enhanced relative to the noise. Under the assumption that equal noise power density is being received from all directions, which is usually the case, the total noise power received by the antenna is independent of the antenna directivity. Thus, the received signal to noise is increased by increasing receive antenna directivity.

3.3 GROUND STATION NETWORKING/INTEROPERATION

3.3.1 Overall system concept

The goal of the ICAO CNS/ATM concept is to implement a global system which offers an improvement over current communications, navigation, surveillance and air traffic management solutions. The current concept for the communications solution relies on satellite communications (SATCOM) for global coverage and line-of-sight systems for high-traffic volume communications in the terminal area. Furthermore, the cost-effective communications solutions to satisfy the CNS/ATM concept are expected to have a high degree of availability, i.e. 99.4 % or higher. To achieve these levels of communications availability in the oceanic regions, aircraft are being equipped with dual SATCOM installations. However, if the actual availability does not meet the expected system availability, a second data link system capable of reliable communications in the oceanic region is required.

HFDL can provide communications in the oceanic and polar regions. A combination of SATCOM with HFDL should provide higher availability of communications than a dual SATCOM installation. In order to fulfil these expectations, the HFDL system should be capable of achieving a higher degree of availability over the current HF voice system, and the recurring per message unit charges should be competitive with those of SATCOM. The HFDL system should also use of the spectrum efficiently and utilize a sufficiently low number of frequencies to allow for a smooth transition from a voice-based HF communication system to a primarily data link-based system with reduced HF voice communications traffic.

An HFDL system with recurring per message unit costs that are competitive with those for SATCOM requires that the number of HFDL ground stations be kept to the minimum number required to achieve the expected coverage, system availability, and capacity. Too many HFDL ground stations result in excess capacity, high recurring per message unit costs and inefficient use of the spectrum. The location of the HFDL ground stations is also important because of their impact on the overall system coverage and availability. Thus, the current practice of individual states operating HF ground station to provide full area radio coverage for air traffic services (ATS) in a flight information region (FIR) is likely an efficient solution. An HF voice ground station for each FIR would be replaced with one in which states responsible for ATS share the communications services provided by fewer optimally located HFDL ground stations much in the same way they may share the communications services provided by SATCOM Ground Earth Station (GES) facilities. As with SATCOM, the control of ATS will remain with the state responsible for the FIR. A reduced number of HF ground stations will result in a more efficient and more cost-effective HFDL communications system.

To achieve a significantly higher system availability over the current HF voice system, the practice of each aircraft communicating with the HF ground station facility covering the FIR should be replaced with a more effective global solution. Each aircraft should communicate with the ATS controllers responsible for an FIR via a link to any HFDL ground station utilizing any assigned frequency which is propagating at that time. This method of operation allows the system to take advantage of propagating frequencies that would not be available to the current voice system. The availability of the proposed HFDL system should be improved considerably when the aircraft is within 4 000 to 5 000 km of three or more HFDL ground stations. This concept of multiple HFDL ground station coverage with multiple frequencies is often referred to as space and frequency diversity and is used effectively in several different communications systems.

The HFDL system should employ frequency reuse as much as possible without compromising the integrity and performance of the system to achieve efficient use of the spectrum and allow for the coexistence of HF voice and data link systems. The nature of HF propagation allows HF radio signals to propagate over very long distances. Frequencies above 8 MHz generally propagate during the day while frequencies below 8 MHz generally propagate during the night. Hence, in the future, the same HFDL frequencies may be assigned to more than one ground station to achieve frequency reuse. Since data link systems are controlled automatically; information needs to be exchanged between the computers in real time. Furthermore, in order to be able to maintain system capacity during a variety of propagation conditions, assigned frequencies may need to be monitored at all HFDL ground stations. This can best be accomplished if all HFDL ground stations are able to share and co-ordinate an available pool of HFDL assigned frequencies.

3.3.2 Ground station networking and HF propagation

HFDL trials and research has shown that the optimum design for the worldwide HFDL system requires that HFDL ground stations be located to take advantage of the nature of the HF medium itself, rather than rigid structures based on geopolitical boundaries such as used in traditional FIRs. This methodology depends on a departure from the traditional approach to providing HF based ATS services.

Practical considerations for HFDL ground stations locations may be determined by several factors, including:

a) communications coverage of aeronautical routes requiring HFDL support;
b) ability of a site to provide aeronautical frequencies;
c) availability of acceptable HF transmission and reception facilities;
d) availability and cost of telecommunications connections; and
e) interest and co-operation among ground station operators.

With the application of frequency reuse concepts to a network, approximately sixteen HFDL ground stations should be able to provide coverage on a world-wide basis with better than 99.4 per cent system availability and the capacity for over 2 000 aircraft.

3.3.3 Ground station interoperation

To handle the transition to ATN, at least one of the communications hubs should operate a FANS-1/A service processor to provide HFDL network service access points to FANS-1/A users. At least one of the hubs should also operate as an HF network manager, responsible for real-time management of the frequencies shared by the HFDL ground stations and network performance monitoring. The protocol between the HFDL ground stations and the communication hubs may be connection-oriented (e.g. X.75) or connectionless (e.g. ISO 8473). Data terminal equipment (DTE) addresses, which are exchanged during call set-up, are used to route packets between HFDL ground stations and the appropriate communication hub.

For example, assume the regional communication hubs are located in North Africa, Central Africa and in the SADC. States responsible for ATS would access the HFDL network via the nearest communication hub using dedicated leased circuits or suitable packet data networks which form part of the ATN. Similarly, aircraft operators whose aircraft are equipped with HFDL would also access the network via the nearest communication hub in similar fashion.

3.3.4 HF operational changes

Two critical changes must be made to existing HF operations to ensure the success of the HFDL system. First, aircraft operating in an HFDL environment will no longer be handed off at HF ground station operator boundaries. Instead, aircraft will log-on to new HFDL ground stations as signal strength on the existing HFDL ground station channel fades.

Second, HF ground station operators should provide their frequencies to a regional pool of frequencies managed from a central HFDL system management entity. The success of the HFDL system is dependent on successfully adoption of these concepts by the international community.

3.3.4.1 Number of HF ground stations per geographic region

It is possible to achieve communication availability of 80% (per cent) or better for a single ground station over a region with a 5 000 km radius under prescribed conditions. At the higher latitudes, (viz., geomagnetic latitudes > 60 degrees), the availability of coverage with one ground station decreases significantly during periods of geomagnetic activity. These regions of the ionosphere expand and contract with changing levels of magnetic activity. Hence, a precise determination of which paths may suffer from poor availability cannot be predicted. At midlatitudes, large ionospheric storms may occasionally limit the number of propagating bands, and this may present some difficulty for individual links over which no path diversity measures can be exercised.

The number of HF ground stations needed per geographic region depends on the desired system availability. For two or more ground stations, one may achieve 92 - 95 per cent communication availability under benign conditions excluding the regions influenced by auroral phenomena. Availability of 99% or higher can be achieved with three ground stations, and even higher with four ground stations. Propagation measurements made at midlatitudes during a large magnetic storm have shown that station diversity and the occurrence of sporadic E propagation modes are two factors which may limit or even eliminate outages during ionospheric storm conditions at midlatitudes.

For example, frequency assignments in six (6) to eight (8) different bands between 4 MHz and 22 MHz are necessary to provide an availability of 99.4% or better with 3 or more ground stations. Sufficient coverage also depends on other factors including magnetic activity, the geomagnetic latitude of the aircraft track, and the aircraft local time.

In general, if frequencies in each of the aeronautical mobile bands are available in concert with four ground stations, then the following service availabilities are achievable in designated geophysical regions:

a) polar (99.2 per cent);
b) auroral (99.5 per cent);
c) trough (99.92 per cent); and
d) midlatitude (99.94 per cent).

The incremental improvement in service availability is finite, but clearly exhibits a diminishing return beyond three to four stations when long-term average availabilities are examined. The lower availabilities normally experienced at high latitude paths and occasionally at midlatitude paths can be mitigated by employing station selection flexibility and dynamic frequency management.

3.3.4.2 Minimum number of operational frequencies to serve the peak load per region

Propagation studies show that eleven frequencies and four ground stations may provide optimum service availabilities for an HFDL system. However, it is possible to achieve acceptable service with fewer stations and a reduced set of assigned operational frequencies. Under some conditions, the system may deliver availability's approaching 99.4% with 6 to 8 frequency bands using three ground stations. The actual number of frequencies needed in each band depends on the number of aircraft that are to be provided service at the peak hour and the number of messages sent per aircraft per hour.

"*HFDL simulation studies indicate that a single HF propagating frequency can provide simultaneous service to at least twenty-six aircraft sending an average of eleven downlinks per hour and receiving an average of six uplinks per hour, with a mean 34-second transfer delay through the network and a 95 percentile transfer delay of less than 120 seconds*."

The actual required communication performance (RCP) standards for HFDL should impact the actual number of aircraft supported on each frequency. Simulations studies show that by managing the number of slots used for random access and by using the polling method, up to forty aircraft may be supported. Thus, one frequency between 4 to 8 MHz propagating to/from any of the HF ground stations in the geographic area can typically provide service to twenty-six to forty aircraft at night, one propagating frequency between 8 to 10 MHz can typically provide the same service in the early evening/early morning hours, and one propagating frequency between 12 to18 MHz can typically provide the same service during the late morning and afternoon hours. To provide service to 130 aircraft, five frequencies propagating to/from any of the HF ground stations in the geographic area are needed. Twice as many propagating frequencies are needed to service 260 aircraft.

3.3.4.3 Number of operational frequencies per station and geographic region

3.3.4.4 Number of operational frequencies needed on a global basis

3.3.4.5 Dynamic frequency management

3.3.4.6 HFDL geographic regions ground stations

3.3.4.7 HFDL coverage and flight information region considerations

3.3.5 HFDL operational issues

3.3.5.1 Sharing HF propagation knowledge between the voice and data systems.

3.3.5.2 HFDL use on the ground

3.4 SYSTEM IMPLEMENTATION AND GROWTH

3.4.1 Transition/capacity growth

3.4.2 Coverage transition

3.4.3 Implementation scenario

4 AFI VDL Requirements

4.1 VDL SYSTEM DESCRIPTION

4.1.1 Introduction

4.1.2 VDL aircraft sub-system

4.1.3 VDL ground station sub-system

4.1.4 VDL ground communications sub-system

4.1.5 VDL ground management sub-system

4.2 VDL GROUND STATIONS

4.2.1 Ground station synchronization

4.2.2 Antennas for VDL ground stations

4.2.2.1 General

4.2.2.2 Antennas for transmitting sites

4.2.2.3 Antennas for receiving sites

4.3 GROUND STATION NETWORKING/INTEROPERATION

4.3.1 Overall system concept

4.3.2 Ground station networking and VHF propagation

4.3.3 Ground station interoperation

4.3.4 VHF operational changes

4.3.5 VDL operational issues

4.3.5.1 Sharing VHF propagation knowledge between the voice and data systems.

4.3.5.2 VDL use on the ground

4.4 SYSTEM IMPLEMENTATION AND GROWTH

4.4.1 Transition/capacity growth

4.4.2 Coverage transition

4.4.3 Implementation scenario

5 RECOMMENDATIONS

6 APPENDIX

6.1. Appendix A: HFDL Operational Concepts

6.1.1. OPERATIONAL CONCEPT (SCENARIOS)

a. HFDL operational concepts

This section provides a description of a future HFDL equipped flight as a means of introducing HFDL operational concepts. It should be emphasized that there are several different methods for implementing some of the technical aspects of the HFDL system and this description is provided only to explain some of the more important features of the HFDL system.

b. Airline Operational Control (AOC) operational concept

HFDL provides the medium for efficient, long range exchange of safety information for AOC reasons. Routine long-range AOC communication involves elements of international travel and increasing use of twin-engine aircraft in an Extended Twin Engine Operations (ETOPS) environment. HFDL provides the AOC data exchange that the operator needs to deal with routine, urgency and emergency situations efficiently. HFDL provides relief from cumbersome voice contact and telephone patches.

i. Flight crew need for AOC data link

The need for long range data exchange varies widely by airline. However, as a minimum, HFDL permits the flight crew the timely access to the operator's flight-following personnel for flight position, schedule tracking and fuel burn projections. In addition, HFDL provides the flight crew the means to request automatic terminal information service (ATIS) and weather information and NOTAM for alternate and destination airports from the airline host computer and an increasing number of airports while in areas where line of sight data is not available. HFDL allows the exchange of fixed format messages such as[hijack] or free text messages between the flight crew, dispatchers, and maintenance personnel. Key stroke errors can be minimized by an airline transmitting route changes to compatible flight management systems (FMSs). These types of messages are typically short (less than 100 characters) and are routinely sent throughout the course of a flight. The system design provides a transparent selection of air/ground medium. HFDL, so integrated, becomes invisible to the flight crew as media transitions are automatically performed by the avionics system.

ii. Operator need for AOC HFDL

The HFDL medium is useful for many purposes other than flight crew use. Some airlines send automatic position reports, weather reports, and real time, automatic engine performance monitoring. These messages are rather long (over 100 characters) and are sent frequently during the en-route phase of the flight. Infrequent, but important reports are needed during en-route flight phases, such as when an engine or APU exceeds a normal operation or is shut down. Ground maintenance personnel may use HFDL to poll certain engine functions on demand.

iii. Synergy and comparison with SATCOM

HFDL provides full compatibility with SATCOM as a complementary air-ground medium. HFDL combined with SATCOM provides a lower acquisition cost alternative to a dual SATCOM system. HFDL may provide lower recurring cost of operation than SATCOM and in some cases, VHF data link. HFDL provides a technical advantage over SATCOM by eliminating single points of failure which are inherent in SATCOM (the satellite link itself) by providing potential communications with multiple ground stations.

iv. Typical HFDL flight scenario

The HFDL operational concepts are presented in terms of a possible flight at some point in the future. HFDL operational concepts associated with the flight are presented from the perspective of the airline using HFDL to support airline operational control (AOC) and from the HFDL ground station operator. These concepts are presented given the following scenario: Flight 14 (FL14) is an Atlanta to Frankfurt flight departing Atlanta at 7:35 PM. This aircraft is equipped with VHF and HFDL (ACARS), two HF data radios and an HFDL capability.

a) Initial log-on

FL14 uses an "out" event (all passenger doors closed and the anti-collision strobe lights on) to trigger the initial log-on to the HFDL system. This log-on is transparent to the flight crew. There are a variety of other possibilities for automatically triggering the log-on process to include loss or failure of the VHF data link or use of geographic filters.

Note. — The HFDL function is disabled when the aircraft is at the gate as a safety feature. When an HF Transmitter is keyed a high voltage differential could be generated between the aircraft and the ground. This *voltage differential could produce a spark during refuelling operations if the aircraft is not properly grounded.*

The HFDL function in the HF data radio initiates the log-on process by scanning for HFDL squitters. Every HFDL ground station (GS) broadcasts uplink squitters on each operational frequency. The squitters are broadcast every 32 seconds and provide a means for aircraft to determine which frequencies are usable. The squitter indicates the start of a 32-second HFDL frame consisting of thirteen slots. The squitters also serve several other functions including HFDL system timing, distribution and synchronization, and broadcasting time slot assignments for uplink and downlink transmission. The downlink slots may be assigned to individual aircraft in response to reservation requests or may be designated for use by all aircraft in a random-access fashion. Some HFDL avionics implementations may continuously scan for squitters even when the HFDL function has been disabled while the aircraft is at the gate. This permits a much faster log-on sequence once the HFDL function is enabled.

The aircraft HFDL function maintains a list of HF frequencies in use by the HFDL system. The aircraft HFDL function scans this list from the highest to the lowest frequency and listens for a squitter on each frequency for at least 35 seconds. This implementation of the HFDL function selects the first acceptable frequency as opposed to searching the entire frequency list and choosing the best available frequency. A 12 MHz frequency squitter from the Long Island GS is received without error, with available downlink slots, and the signal quality is acceptable. The squitter includes the identification of the transmitting GS. An HFDL frame has thirteen slots and could consist of a squitter, two uplink slots, three assigned downlink slots and seven random access downlink slots. The GS configures each frame to support the expected uplink and downlink traffic. The HFDL function generates a log-on request message and randomly selects one of the available random-access downlink slots for the downlink transmission.

The HFDL function uses the slowest possible data rate that can support the message size of the downlink transmission. The four data rates available are 300, 600, 1 200, and 1 800 bits/s. At any given time, each link between an aircraft and a GS will have maximum downlink and uplink data speeds which can be supported. The maximum uplink rate is determined by the aircraft and provided to the GS in the downlink protocol data unit (PDU). The maximum downlink rate is determined by the GS and provided to the aircraft in the uplink PDU. These data rates are determined by evaluating the received signal-to-noise ratio on each reception of a PDU.

The GS responds with a log-on confirm PDU which includes the aircraft identification (AID) number and maximum downlink transmission rate. Receipt of the log-on confirm results in an HF DATA icon being displayed on the engine identification crew alerting system (EICAS) to let the flight crew know they have an HFDL connection established.

b) Downlink message processing

Once the aircraft HFDL function has completed the log-on process, the aircraft can send and receive messages via HFDL. The first downlink sent by the aircraft is an ACARS media advisory message. This message is sent to the ground station operator and the airline to provide information needed to maintain data link addressing and routing tables. The HFDL function encapsulates the ACARS media advisory message in the HFDL protocol and randomly selects one of the available random-access downlink slots identified in the squitter and transmits the PDU. The GS acknowledges receipt of the downlink PDU by sending the AID in one of the next two squitters in the slot acknowledgment field. If the GS does not acknowledge the PDU, the aircraft HFDL function assumes that another HFDL equipped aircraft competing for the same downlink slot interfered with the GS reception of the message. The aircraft HFDL function then invokes an exponential back-off algorithm to identify a new HFDL frame for the next downlink attempt. The aircraft HFDL function once again randomly selects one of the available random access downlink slots identified in the squitter and transmit the PDU. In the event that another PDU is unacknowledged, the HFDL function repeats the process one more time. If this third attempt is unacknowledged, the HFDL function reinitiates the log-on process and look for a new HF channel. Even though FL14 has now successfully logged into the 12 MHz HF Channel at the Long Island GS, the aircraft is only sending and receiving ACARS messages over the

VHF data link. The MU/HCF is configured to use HFDL only if VHF data link is not available. The media advisory message is an exception to this rule. The ACARS media advisory message is sent over the most recently acquired datalink.

c) ***Uplink message processing***

The aircraft HFDL function receives an uplink PDU from the Long Island GS. The uplink PDU is received without error and in accordance with HFDL protocol. The resulting ACARS Acknowledgment message is forwarded to the communications management unit/HCF. The uplink PDU contained a downlink slot assignment. The aircraft HFDL function acknowledges receipt of the uplink PDU in the downlink PDU generated for the downlink slot assignment. The aircraft HFDL function generates a downlink PDU even if there are no downlink messages ready, by providing HFDL performance data.

d) ***Frequency change***

The frequency used by the aircraft HFDL function will probably change during the course of the flight. These changes can be initiated either by the GS or by the aircraft HFDL function.

e) ***GS initiated frequency change.***

As FL 14 crosses into North Carolina, the aircraft HFDL function receives a squitter with the change notice flag set. This flag triggers the aircraft HFDL function into reinitiating the log-on process. At the same time the change notice code bits are set, the GS updates the operational frequency data within the squitter. In this case, the aircraft HFDL function frequency search algorithm first tries the operational frequencies of the current GS. The operational frequencies of the current GS, as well as operational frequencies from two adjacent GSs, are broadcast within each squitter. If the operational frequencies of the current GS cannot be heard, then the aircraft HFDL function tries the operational frequencies of the two adjacent GSs. The FL14 aircraft HFDL function first listens on the other operational frequencies transmitting from the Long Island GS. In this case, the aircraft hears the new squitter on the 6 MHz frequency and initiates a log-on-resume process.

f) ***Aircraft initiated frequency change.***

As FL14 heads north into Canada, the signal strength of the squitters heard on the 6 MHz frequency degrades below the acceptable threshold. The aircraft HFDL function then initiates a search for another frequency. The aircraft HFDL function first listens on the other operational frequencies transmitting from the Long Island GS. In this case, the aircraft does not hear any of the other transmitting frequencies from the Long Island GS. The aircraft HFDL function then listens on the frequencies for the adjacent GSs. The FL14 HFDL function can receive the squitter on the 3 MHz frequency transmitting from the Newfound land GS and FL14 initiates the log-on process.

g) ***Flight crew use of HF voice.***

Prior to departing radar-controlled airspace, the Gander air traffic control (ATC) authorities provide FL14 with an HF selective calling (SELCAL) code via VHF voice radio and verify the SELCAL is functional. Once out of VHF range, the flight crew of FL14 may use HF voice for ATC or AOC voice communications. If HF voice is used, the aircraft HFDL function disables downlink HFDL transmissions. Downlink HFDL transmissions remain disabled for the duration of the HF voice use and for a specified period after the last use of the HF voice. Once downlink HFDL transmissions are no longer disabled, the aircraft HFDL function initiates a log-on process starting with the last frequency it was logged on. If the squitter is acceptable and the ground station address is the same, the aircraft HFDL function sends a log-on-resume message. If the squitter is for a new ground station, the aircraft HFDL function sends a log-on-request message to the GS.

h) ***Transition to VHF data link***

Once FL14 nears the coast of the United Kingdom, it enters VHF data link coverage. At this point the MU no longer uses the HFDL for downlink message traffic. The AOC will have received a media advisory message and will no longer use HFDL for uplink message traffic. The aircraft HFDL function continues to maintain the HFDL.

i) ***Flight arrival***

The “in” event (first passenger door open or anti-collision strobe lights off) of FL14 arriving at the gate is used to disable the aircraft HFDL function.

c. HFDL Ground station operator operational concept

HFDL service for the flight scenario over the North Atlantic is provided by four networked HFDL Ground Stations (GSs) (located in Sweden, Iceland, Newfoundland, and Long Island. Each GS has three HF transmitter/receiver pairs dedicated for HFDL. These three HF channels are always operational at each site. Each GS has a global positioning system (GPS) based time source. This common time source is used to synchronize the transmission times of all the GSs. If practical, each GS is connected to two intermediate routers to provide diverse communication paths. The intermediate routers are connected to the ground station operator network interface router. The Iceland and Sweden HFDL ground stations are connected to a intermediate router in London and the Newfoundland and Long Island HFDL ground stations are connected to an intermediate router in Chicago. The HFDL ground network infrastructure interconnects the GSs with the ground station operator back-end processor (BEP) and the HFDL management function. The HFDL management function manages the GSs and the frequency assignments for each of the four GSs.

i. Initial log-on

Each GS broadcasts an uplink squitter on each operational (transmitting) frequency. The squitters are broadcast every 32 seconds and provide a means for aircraft to determine which frequencies are usable. The squitter indicates the start of an HFDL frame. The squitters also serve several other functions including HFDL System timing, distribution and synchronization, and broadcasting time slot assignments for uplink and downlink transmission. The downlink slots may be assigned to individual aircraft in response to reservation requests or may be designated for use by all aircraft in a random-access fashion. The squitter includes the identification of the transmitting GS. An HFDL frame comprises thirteen slots and could consist of a squitter, two uplink slots, three assigned downlink slots, and seven random access downlink slots. The GS configures each frame to support the expected uplink and downlink traffic.

The GS receives a log-on request from FL14 (the aircraft is identified by the 24-bit ICAO identifier as opposed to the flight ID) and checks for the availability of an aircraft identification (AID)number. The ground station assigns each aircraft on a particular HF frequency with a unique 8-bit identification number. This aircraft ID is used in all subsequent message exchanges. If there are no aircraft IDs available, the GS responds with a log-on denied message. System design, aircraft flight patterns, and HF propagation characteristics reduce the possibility a ground station will ever exhaust all channels aircraft ID numbers.

In this case, there are aircraft IDs available, and the GS responds with a log-on confirm uplink. The GS adds the aircraft to the software table containing the list of operational aircraft and sends an Q0 label message to the BEP. The BEP uses the Q0 message to update its aircraft routing table. The GS also sends an aircraft log-on notification message to each of the other GSs. This message contains the aircraft ICAO 24-bit identification number (provided in the log-on PDU header) and is used to remove outdated records from the operational aircraft table of other GSs.

The GS also stores the maximum uplink transmission rate for the aircraft in the operational aircraft table. This rate is determined from the received signal-to-noise ratio (SNR) on each reception of a downlink. The maximum uplink transmission rate is used by the GS to determine the maximum size of an uplink message and is used by the HF data modem to set data and inter leaver rates for the uplink transmission.

ii. Channel capacity

The only limit placed on channel capacity by the GS is the restriction of 256 operational aircraft pe r channel imposed by the 8-bit aircraft identification field within the squitter. The GS sets the frequency utilization bit in the squitter after twenty-five aircraft have logged into the channel. The aircraft HFDL function will not log into a HF channel with this bit set unless it is the only HF channel the HFDL function can use. It is possible to have situations which produce excessive loading on a single channel. Aircraft may have to log-on to an already loaded channel because it is the only channel the aircraft can hear. In this case there may be aircraft on the loaded channel that may very well be able to hear other squitters but remain on the loaded channel because the signal strength is still acceptable.

The GS does not directly manage load sharing between transmitting HF frequencies. The GS also does not have the capability to change aircraft to a new frequency to balance the load on the GS. However, the GS can set the frequency utilization bit in the squitter once an HF channel has twenty-five aircraft logged-on. The ground stations broadcast the squitters but have no knowledge of what frequencies the aircraft can receive. The aircraft listens to the squitters and selects the optimum frequency for a given situation.

The HFDL channel access protocol provides a limited load balancing capability. The excess channel loading results in increased competition for the random-access slots. If an airborne HFDL transceiver cannot access a channel after three attempts, the channel access protocol searches for another channel. This process should result in off-loading of some of the aircraft from the overloaded HF channel overtime.

iii. Downlink message processing

The GS receives a downlink PDU from FL14. The message is received without error and in accordance with the HFDL protocol. The resulting message is forwarded to the ground station operator BEP. The GS acknowledges receipt of the downlink PDU by sending the aircraft ID in one of the next two squitters in the slot acknowledgment field.

iv. Uplink message processing

The BEP receives the ACARS media advisory message from FL14, reformats the message for the ground network, sends the message to the AOC, and generates an ACARS acknowledgment message. The BEP knows which channel and ground station it received the FL14 ACARS media advisory message from and sends the acknowledgment message back to the Long Island GS.

The GS encapsulates the ACARS acknowledgment message in the HFDL protocol and assigns a slot for the uplink message. The GS also assigns a downlink slot for the aircraft in the next available frame. The downlink slot assignment is communicated to the aircraft in the appropriate squitter by placing the aircraft ID for FL14 into the appropriate slot assignment field. The aircraft HFDL function acknowledges receipt of the message in the next downlink message sent in response to the downlink slot assignment by the GS. By assigning a downlink slot, the GS increases the speed uplink messages can be processed.

If the aircraft HFDL function responds to the downlink slot assignment request yet does not acknowledge receipt of the message in the assigned downlink slot, the GS assigns a second downlink slot to the aircraft in the next squitter. If the aircraft still responds with a downlink message in the assigned downlink slot, yet does not acknowledge the message, the GS retransmits the message and repeats the above process.

If the aircraft HFDL function does not respond with any message in the assigned downlink slot, the GS assigns another downlink slot. If the aircraft still does not respond, the GS repeats the slot assignment one more time. In the event of a third non-response, the GS assumes the aircraft HFDL function is no longer operational for this HF channel and removes the aircraft from the operational aircraft table.

v. GS initiated frequency change

As FL 14 crosses into North Carolina, the GS begins the process of changing to a better frequency. The propagation models and HF sounders used to develop the HFDL frequency management plan have determined that the 12 MHz HF channel will go off the air at 8:00 PM local time and the HF transmitters and receivers will switch to a 6 MHz frequency. The GS reads a frequency selection table, which is the physical representation of the HFDL frequency management plan, to determine when to switch HF frequencies. This table is periodically updated by the HFDL system management function.

At 8:00 pm the GS sets the change notice code in the squitter to indicate the GS is changing the HF frequency within four frames. At the same time the change notice code bits are set, the GS updates the operational frequency data within the squitter. This continues for another three frames with the squitters indicating a change notice. At the completion of the fourth frame, the GS changes the HF transmitter frequency and starts transmitting squitters on the new HF frequency.

vi. Aircraft polling

The GS keeps the operational aircraft table updated to ensure enough aircraft IDs are available to support new aircraft logging on to the system. In addition to using the aircraft log-on event to update the tables, the GS periodically polls aircraft to determine if they are still operational. Polling is used if an aircraft has not sent a downlink within the last 30 minutes. The GS assigns the aircraft a downlink slot using the next available squitter. The aircraft responds with a downlink message in the assigned slot, even if a message is not in the queue. If the aircraft HFDL function responds with a downlink, the time field is updated in the operational aircraft table. If the aircraft does not respond, the GS repeats this polling process two more times. If the aircraft HFDL function does not respond to three polling requests, the GS removes the aircraft from the operational aircraft table.

Once FL14 arrives in Frankfurt, the aircraft HFDL function is disabled. The GS polling process determines that FL14 is no longer listening to the channel, removes the aircraft from the operational aircraft table, and releases the aircraft ID number for reassignment to another aircraft.

d. Air traffic services (ATS) operational concept

The use of HFDL for air traffic services (ATS) is foreseen as growing incrementally with time, as the current (early 1996) North Atlantic HFDL system evolves from its current status as a system supporting data link trials. In order to be considered a fully operational data link medium for support of a particular ATS service, the system will have to meet certain qualification criteria, which are:

- the demonstration of the ability of HFDL to meet required communications performance (RCP) criteria; namely, the performance, availability and integrity parameters required for each particular ATS service to be supported;
- the utilization of appropriately designated spectrum for ATS service, namely the AM(R)S (reference Article 50 of the ITU radio regulations and Appendix 27 Aer2, thereto);
- design approval of airborne equipment and its installations to include safety assessment considerations evaluated from an end-through-end perspective; and
- operational authorization based on the verification and validation of derived safety and interoperability requirements/procedures which apply to the aircraft, space, and ground domains.

As HFDL is a new technology and certain aspects of the above criteria will require some time for their qualification, an incremental approach to the utilization of HFDL for ATS is considered to be the most effective. It is foreseen that trials of several ATS applications will be conducted, using ATS applications with corresponding incremental progression of benefits to the users. Eventually, the performance, availability and integrity parameters of which HFDL is capable will be determined by analysis, simulation and test; and HFDL will be deemed an acceptable means, either solely or in conjunction with other communications media, of ATS data link communications operation.

i. **Typical ATS scenarios**

It is assumed that the HFDL system used for ATS during the trials periods is essentially the same as that described in Section 3.2, AOC operational concept. Within the HFDL air/ground subnetwork, the aircraft log-on and log-off processes are similar, as are also the several link management exchanges described therein. It is assumed that the initial utilization of HFDL will be as an alternative RF medium for ACARS operations as described in that section. Benefits linked to ATS will be constrained by the evolution of the data link (e.g. a FANS-1 like ACARS/ARINC 622 followed by a “Data-3”/ATN implementation) as well as the proof of HFDL per se through trials and demonstration periods. However, it can be assumed that rapid progress will be made in the implementation of the Aeronautical Telecommunications Network (ATN) during the trials period, resulting in an evolution of supporting subnetworks and end systems for ATS corresponding to the evolution of HFDL applications.

e. **HFDL Coverage**

6.2. Appendix B: VDL Operational Concepts

6.2.1. OPERATIONAL CONCEPT (SCENARIOS)

a. VDL operational concepts
b. Airline Operational Control (AOC) operational concept
    i. Flight crew need for AOC data link
    ii. Operator need for AOC VDL
    iii. Synergy and comparison with SATCOM
    iv. Typical VDL flight scenario
c. VDL Ground station operator operational concept
    vii. Initial log-on
    viii. Channel capacity
    ix. Downlink message processing
    x. Uplink message processing
    xi. GS initiated frequency change
    xii. Aircraft polling
d. Air traffic services (ATS) operational concept
    i. Typical ATS scenarios
e. VDL Coverage

6.3. Appendix C

6.4. Appendix D

6.5. Appendix E