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European Standard (Telecommunications series)

Electromagnetic compatibility and Radio spectrum Matters (ERM); VHF air-ground and air-air Digital Link (VDL) Mode 4 radio equipment; Technical characteristics and methods of measurement for aeronautical mobile (airborne) equipment; Part 1: Physical layer

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Foreword

This European Standard (Telecommunications series) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM), and is now submitted for the Public Enquiry phase of the ETSI standards Two-step Approval Procedure.

The present document is part 1 of a multi-part deliverable covering the VHF air-ground and air-air Digital Link (VDL) Mode 4 radio equipment; Technical characteristics and methods of measurement for aeronautical mobile (airborne) equipment, as identified below:

Part 1: "Physical layer";

Part 2: "General description and data link layer";

Part 3: "Additional broadcast aspects";

Part 4: "Point to point functions".

The present document is accompanied by an equivalent ground-based standard, EN 301 842 [8] Parts 1 to 4, covering the VHF air-ground Data Link (VDL) Mode 4 radio equipment; Technical characteristics and methods of measurement for ground-based equipment.

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	6 months after doa
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Introduction

The present document states the technical specifications for Very High Frequency (VHF) Digital Link (VDL) Mode 4 aeronautical mobile (airborne) radio transmitters, transceivers and receivers for air-ground and air-air communications operating in the VHF band, using Gaussian-filtered Frequency Shift Keying (GFSK) modulation with 25 kHz channel spacing and capable of tuning to any of the 25 kHz channels from 118,000 MHz to 136,975 MHz as defined in ICAO VHF Digital Link (VDL) Standards and Recommended Practices (SARPs).

The present document may be used to produce tests for the assessment of the performance of the equipment. The performance of the equipment submitted for type testing should be representative of the performance of the corresponding production model.

The present document has been written on the assumption that:

- the type test measurements will be performed only once, in an accredited test laboratory and the measurements accepted by the various authorities in order to grant type approval;
- if equipment available on the market is required to be checked it may be tested in accordance with the methods of measurement specified in the present document or a documented alternative approved by the certifying authority.

1 Scope

The present document states the technical specifications, and means of testing compliance, for Very High Frequency (VHF) Digital Link (VDL) Mode 4 aeronautical mobile (airborne) radio transmitters, transceivers and receivers for air-ground and air-air communications operating in the VHF band, using Gaussian-filtered Frequency Shift Keying (GFSK) modulation with 25 kHz channel spacing and capable of tuning to any of the 25 kHz channels from 118,000 MHz to 136,975 MHz as defined in ICAO VHF Digital Link (VDL) Standards and Recommended Practices (SARPs).

The present document is designed to ensure that equipment certified to it will be compatible with the relevant ICAO VHF Digital Link (VDL) Standards and Recommended Practices (SARPs) and VDL Mode 4 Technical Manual (TM) [1].

NOTE: In clause 6.1.9 the requirement is more stringent than required in ICAO VDL SARPs [1].

Manufacturers should note that in future the tuning range for the transmitter may also cover any 25 kHz channel from 112,000 MHz to 117,975 MHz and the reciever(s) may cover any 25 kHz channel from 108,000 MHz to 117,975 MHz.

The present document applies to "aeronautical mobile (airborne)" equipment which will hereinafter be referred to as "mobile" equipment.

The scope of the present document is limited to mobile stations. The equivalent specification for ground stations is EN 301 842 [8].

The VDL Mode 4 system provides digital communication exchanges between aircraft and ground-based systems and other aircraft supporting surveillance and communication applications. The supported modes of communication include:

- broadcast and point-to-point communication;
- broadcast services including Automatic Dependent Surveillance - Broadcast (ADS-B), Traffic Information Service - Broadcast (TIS-B) and Flight Information Service - Broadcast (FIS-B) capabilities;
- air-air and ground-air services;
- operation without ground infrastructure.

The present document is derived from the specifications:

- VDL Mode 4 standards produced under the auspices of the International Civil Aviation Organization (ICAO) [1].
- Other relevant standards as defined in clause 2.

It is envisaged that manufacturers may provide equipment supporting:

- broadcast services only;
- point-to-point services only;
- both broadcast and point-to-point services.

The present document deals with tests of the physical layer necessary to support all types of equipment.

The present document includes:

- references, definitions, abbreviations and symbols are provided in clauses 2 and 3;
- clause 4 provides a general description and architecture of VDL Mode 4;
- clause 5 provides functional specifications applicable to the physical layer including transmitter/receiver requirements and the modulation scheme;
- clause 6 provides general equipment requirements;
- clause 7 provides general design requirements;
- clause 8 covers general test conditions, environmental tests and calibration;
- clause 9 provides detailed test procedures for the physical layer.

The full physical layer tests are provided which correspond closely to the standard set of tests used for other VDL systems.

Note that flight tests are defined in [7].

Mandating and Recommendation Phrases

a) **"Shall"**
The use of the word "Shall" indicates a mandated criterion; i.e. compliance with the particular procedure or specification is mandatory and no alternative may be applied.

b) **"Should"**
The use of the word "Should" (and phrases such as "It is recommended that...", etc.) indicate that though the procedure or criterion is regarded as the preferred option, alternative procedures, specifications or criteria may be applied, provided that the manufacturer, installer or tester can provide information or data to adequately support and justify the alternative.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication and/or edition number or version number) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

[1] ICAO Manual on VHF Digital Link (VDL) Mode 4, Part 2, Doc. 9816, First Edition 2004.

[2] ICAO Standards and Recommended Practices, Annex 10, Volume III, Part I, Chapter 6, Edition 2001.

[3] ISO/IEC 7498-1 (1994): "Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model".

[4] ISO/IEC 10731 (1994): "Information technology - Open Systems Interconnection - Basic Reference Model - Conventions for the definition of OSI services".

[5] ITU-T Recommendation X.25: "Interface between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit".

[6] EUROCAE ED-14D / RTCA DO-160D: "Environmental Conditions and Test Procedures for Airborne Equipment, July 1997, as amended by Change 1 (December 2000), by Change 2 (June 2001), and by Change 3 (December 2002)".

[7] ETSI EN 302 842-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); VHF air-ground and air-air Digital Link (VDL) Mode 4 radio equipment; Technical characteristics and methods of measurement for aeronautical mobile (airborne) equipment; Part 2: General description and data link layer".

[8] ETSI EN 301 842 (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); VHF air-ground and air-air Digital Link (VDL) Mode 4 radio equipment; Technical characteristics and methods of measurement for aeronautical mobile (airborne) equipment".

[9] EUROCAE ED-12B / RTCA DO-178B (1993): "Software Considerations in Airborne Systems and Equipment Certification.

3 Definitions and abbreviations

3.1 Definitions

3.1.1 Basic reference model definitions

The present document is based on the concepts developed in the open systems interconnect basic reference model and makes use of the following terms defined in ISO/IEC 7498-1 [3]:

- layer;
- sublayer;
- entity;
- service;
- service access point;
- service data unit;
- physical layer;
- data link layer.

3.1.2 Service conventions definitions

The present document makes use of the following terms defined in ISO/IEC 10731 [4]:

- service provider;
- service user;
- service primitive;
- request;
- indication;
- confirm.

3.1.3 General definitions

For the purposes of the present document, the following terms and definitions apply:

adjacent channel power: amount of the modulated rf signal power which falls within a given adjacent channel

NOTE: Adjacent channel power includes discrete spurious, signal sidebands, and noise density (including phase noise) at the transmitter output.

Adjacent Channel Rejection (ACR): receiver's ability to demodulate the desired signal and meet the BER requirement in the presence of an interfering signal in an adjacent channel

NOTE: The ratio (in dB) between the adjacent interfering signal level and the desired signal level necessary to achieve the specified minimum BER, is the adjacent channel rejection (ACR) ratio.

Aeronautical Mobile Service (AMS): mobile service between aeronautical stations and aircraft stations, or between aircraft stations, in which survival craft stations may participate

Aeronautical Telecommunications Network (ATN): internetwork architecture that allows ground, air/ground, and aircraft data subnetworks to interoperate by adopting common interface services and protocols based on the International Organization for Standardization Open Systems Interconnection Reference Model

aircraft address: unique combination of 24 bits available for assignment to an aircraft for the purpose of communications, navigation and surveillance.

NOTE: An aircraft may choose not to use this unique address and can use instead a non-unique address.

Automatic Dependent Surveillance-Broadcast (ADS-B): surveillance application transmitting parameters, such as position, track and ground speed, via a broadcast mode digital link for use by any air and/or ground users requiring it

NOTE: ADS-B is a surveillance service based on aircraft self-determination of position/velocity/time and automatic, periodic or random, broadcast of this information along with auxiliary data such as aircraft identity (ID), communications control parameters, etc. ADS-B is intended to support multiple high-level applications and associated services such as cockpit display of traffic information, traffic alert and collision avoidance functionality, enhanced traffic management in the air and on the ground, search and rescue support and others.

autotune function: function, performed by the Link Management Entity, that allows a ground VDL Mode 4 station to command an aircraft to change the operating characteristics of synchronization burst transmissions

Bit Error Rate (BER): expressed as the ratio between the number of erroneous bits received and the total number of bits transmitted.

burst: VHF Digital Link (VDL) specific services burst is composed of a sequence of source address, burst ID, information, slot reservation, and Frame Check Sequence (FCS) fields, bracketed by opening and closing flag sequences

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

burst length: number of slots across which the VDL Mode 4 burst is transmitted

Co-Channel Interference (CCI): co-channel interference protection defines the capability of a receiver to demodulate the desired signal and achieve the minimum specified BER performance in the presence of an unwanted signal at the same assigned frequency

NOTE: The ratio (in dB) between the wanted signal level and the unwanted signal level is the co-channel interference ratio. The co-channel interference ratio has a major impact on frequency re-use planning criteria.

conducted measurements: measurements which are made using a direct rf connection to the equipment under test

current slot: slot in which a received transmission begins

Data Link Entity (DLE): protocol state machine capable of setting up and managing a single data link connection

Data Link Service (DLS) sublayer: sublayer that resides above the VDL Mode 4 Specific Services (VSS) and the MAC sublayers

NOTE: The data link service (DLS) manages the transmit queue, creates and destroys data link entities (DLEs) for connection-oriented communications, provides facilities for the link management entity (LME) to manage the DLS, and provides facilities for connection-less communications.

data rate: Mode 4 nominal data rate is 19 200 bits/s

delayed burst: VDL Mode 4 burst that begins sufficiently after the beginning of a slot so that the transmitting VDL Mode 4 station is confident that no other VDL Mode 4 station that it could receive from and is within the guard range is transmitting in the slot

NOTE: The delayed VDL Mode 4 burst terminates by the end of the slot in which it began (its length is shortened to ensure completion by the nominal time).

DLS system: VDL system that implements the DLS and subnetwork protocols to carry Aeronautical Telecommunications Network (ATN) or other packets

frame: link layer frame is composed of a sequence of address, control, information and FCS fields, bracketed by opening and closing flag sequences

NOTE: A valid frame is at least 11 octets in length and contains an address field (8 octets), a link control field (1 octet) and a frame check sequence (2 octets). A frame may or may not include a variable-length information field.

Global Signalling Channel (GSC): channel available on a world wide basis which provides for communication control

ground base station: aeronautical station equipment, in the aeronautical mobile service, for use with an external antenna and intended for use at a fixed location

ground station coordination: coordination of transmissions from two or more ground stations uses the UTC-minute time frame

hand held: radio equipment with integral batteries, designed to be hand portable and operated hand held

NOTE: Provisions may be made for external connections and temporary installation into vehicles.

integral antenna equipment: radio communications equipment with an antenna integrated into the equipment without the use of an external connector and considered to be part of the equipment

NOTE: An integral antenna may be internal or external to the equipment. In equipment of this type, a 50 Ω rf connection point shall be provided for test purposes.

link: connects a mobile DLE and a ground DLE and is uniquely specified by the combination of mobile DLS address and the ground DLS address

NOTE: A different subnetwork entity resides above every link endpoint.

link establishment: process by which an aircraft and a ground LME discover each other, determine to communicate with each other, decide upon the communication parameters, create a link and initialize its state before beginning communications

link handoff: process by which peer LMEs, already in communication with each other, create a link between an aircraft and a new ground station before disconnecting the old link between the aircraft and the current ground station

link layer: layer that lies immediately above the physical layer in the Open Systems Interconnection protocol model

NOTE: The link layer provides for the reliable transfer of information across the physical media. It is subdivided into the data link sublayer and the media access control sublayer.

Link Management Entity (LME): protocol state machine capable of acquiring, establishing, and maintaining a connection to a single peer system

NOTE: An LME establishes data link and subnetwork connections, "hands-off" those connections, and manages the media access control sublayer and physical layer. An aircraft LME tracks how well it can communicate with the ground stations of a single ground system. An aircraft VDL management entity (VME) instantiates an LME for each ground station that it monitors. Similarly, the ground VME instantiates an LME for each aircraft that it monitors. An LME is deleted when communication with the peer system is no longer viable.

Media Access Control: sublayer that acquires the data path and controls the movement of bits over the data path

mobile: radio equipment designed for installation into vehicles

non-integral antenna equipment: radio communications equipment with a connector intended for connection to an antenna

physical layer: lowest level layer in the Open Systems Interconnection protocol model

NOTE: The physical layer is concerned with only the transmission of binary information over the physical medium (e.g. VHF radio).

primary time source: normal operation timing mode in which a VDL Mode 4 station maintains time synchronization to Universal Coordinated Time (UTC) second to within a two-sigma value of 400 ns

private parameters: parameters that are contained in exchange identity (XID) frames and that are unique to the VHF digital link environment

radiated measurements: measurements which involve the measurement of a radiated field

reference signal level: signal level used in the receiver performance specifications except otherwise stated

reference bit sequence: sequence of bits used in the transmitter performance specifications

secondary time source: timing source used in a failure mode, which applies when the primary time source fails, in which a VDL Mode 4 station maintains time synchronization to UTC second to within a two-sigma value of 15 µs

Self-organizing Time Division Multiple Access (STDMA): multiple access scheme based on time-shared use of a radio frequency (rf) channel employing:

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

2) a set of operating protocols that allows users to mediate access to these time slots without reliance on a master control station

slot: in VDL Mode 4, time is divided into a series of time slots of equal period. Each VDL Mode 4 burst transmission starts at the beginning of a slot

station: VDL Mode 4 Specific Services (VSS)-capable entity

NOTE: A station may be either a mobile station or a ground station. A station is a physical entity that transmits and receives bursts over the rf interface (either A/G or air-to-air (A/A)) and comprises, at a minimum: a physical layer, media access control sublayer, and a unique VSS address. A station which is also a DLS station has the same address.

subnetwork layer: layer that establishes, manages, and terminates connections across a subnetwork

superframe: group of slots that span a period of one minute

NOTE: The start of the current superframe is aligned with the start of the slot that is currently being used for transmission. The next superframe starts one minute after the current slot.

synchronization burst (or "sync" burst): VDL Mode 4 burst which announces, as a minimum, existence and position

NOTE: Ground stations announce existence, position, and the current time. Mobile stations lacking timing information can then derive the slot structure from ground synchronization bursts. Mobile stations lacking position information can derive position from both mobile and ground synchronization bursts. This periodic information is used in various ways including ADS-B, secondary navigation, and simplifying the LME algorithms.

Time Division Multiple Access (TDMA): multiple access scheme based on time-shared use of an rf channel employing:

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

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

unicasted transmission: transmission addressed to a single station

VDL Mode 2: VHF data link using a differentially encoded 8 phase shift keying modulation scheme and carrier sense multiple access

VDL Mode 4: VHF data link using a Gaussian Filtered Frequency Shift Keying modulation scheme and self organizing time division multiple access

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

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

VDL Mode 4 Specific Services (VSS) sublayer: sublayer that resides above the MAC sublayer and provides VDL Mode 4 specific access protocols including reserved, random and fixed protocols

VSS user: user of the VDL Mode 4 Specific Services

NOTE: The VSS user could be higher layers in the VDL Mode 4 Technical Manual or an external application using VDL Mode 4.

VDL Management Entity (VME): VDL-specific entity that provides the quality of service requested by the ATN-defined subnetwork system management entity

NOTE: A VME uses the LMEs (that it creates and destroys) to acquire the quality of service available from peer systems.

VDL Mode 4 station: physical entity that transmits and receives VDL Mode 4 bursts over the rf interface (either A/G or air-to-air (A/A)) and comprises, as a minimum: a physical layer, Media Access Control sublayer and a VSS sublayer

NOTE: A VDL Mode 4 station may either be a mobile VDL Mode 4 station or a ground VDL Mode 4 station.

VDL Mode 4 atation address: 27-bit identifier used to uniquely identify a VDL Mode 4 station.

VDL atation: VDL-capable entity

NOTE: A station may either be a mobile station or a ground station. A station is a physical entity that transmits and receives frames over the air/ground (A/G) interface and comprises, at a minimum: a physical layer, media access control sublayer, and a unique DLS address. The particular initiating process (i.e. DLE or LME) in the station cannot be determined by the source DLS address. The particular destination process cannot be determined by the destination DLS address. These can be determined only by the context of these frames as well as the current operational state of the DLEs.

VDL system: VDL-capable entity

NOTE: A system comprises one or more stations and the associated VDL management entity. A system may either be a mobile system or a ground system.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

A/A	Air-to-air
A/G	Air/Ground
ACP	Adjacent Channel Protection
ACR	Adjacent Channel Rejection
ADS-B	Automatic Dependent Surveillance Broadcast
AM(R)S	Aeronautical Mobile (Route) Service
ATN	Aeronautical Telecommunication Network
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
CCI	Co-Channel Interference
dB	deciBel
dBm	deciBels with respect to 1mW
DCE	Data Circuit-terminating Equipment
DLE	Data Link Entity
DLS	Data Link Service
DTE	Data Terminal Equipment
FCS	Frame Check Sequence
FM	Frequency Modulation
GFSK	Gaussian Filtered Frequency Shift Keying
GSC	Global Signalling Channel
HDLC	High-Level Data Link Control
ICAO	International Civil Aviation Organization
ID	Identity
ISO	International Organization for Standardization
LME	Link Management Entity
MAC	Media Access Control
MER	Message Error Rate
NRZI	Non-Return to Zero Inverted
OSI	Open Systems Interconnection
PC	Personal Computer
ppm	parts per million
RF/rf	Radio Frequency
SARPs	Standards and Recommended Practices
STDMA	Self-organizing Time Division Multiple Access
T	the baud period or 1/baud rate
TDMA	Time Division Multiple Access
UTC	Universal Coordinated Time
VDL	VHF Digital Link
VHF	Very High Frequency
VME	VDL Management Entity
VSS	VDL Mode 4 Specific Services
VSWR	Voltage Standing Wave Ratio
XID	eXchange IDentity (frame)

4 General description and architecture of VDL Mode 4

4.1 General

A description of VDL Mode 4, the communication services provided, equipment classes, the structure of the standards material and guidance on equipment performance verification is provided in EN 302 842-2 [7] clause 4.

5 VDL mode 4 physical layer functional specifications

5.1 Overview

The mobile stations shall access the physical layer operating in simplex mode.

5.1.1 Functions

The tasks of the physical layer include the following:

- to modulate and demodulate radio carriers with a bit stream of a defined instantaneous rate to create an rf link;
- to acquire and maintain bit and burst synchronization between Transmitters and Receivers;
- to transmit or receive a defined number of bits at a requested time (packet mode) and on a particular carrier frequency;
- to measure received signal strength;
- to decide whether a channel is idle or busy, for the purposes of channel management;
- to offer a notification service about the quality of link.

5.1.2 Data reception

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

5.1.3 Data transmission

The VDL physical layer shall appropriately encode the data received from the data link layer and transmit it over the rf channel.

5.2 Modulation scheme

The modulation scheme shall be Gaussian Filtered Frequency Shift Keying (GFSK), which is a continuous-phase, frequency shift keying technique using two tones and a Gaussian pulse shape filter. The first bit transmitted (in the training sequence) shall be a high tone and the transmitted tone shall be toggled when transmitting a 0 (*i.e*. NRZI encoding). The training sequence shall be the 24 bit sequence 0101 0101 0101 0101 0101 0101. Binary *ones* and binary *zeros* shall be generated with a modulation index of 0,25 ± 0,03 and a BT product of 0,28 ± 0,03.

5.3 Tuning range and channel increments

The mobile shall be capable of tuning to any of the 25 kHz channels from 118,000 MHz to 136,975 MHz as defined in ICAO VHF Digital Link (VDL) Standards and Recommended Practices (SARPs). Manufacturers should note that in future the tuning range for the transmitter may also cover any 25 kHz channel from 112,000 MHz to 117,975 MHz and the reciever(s) may cover any 25 kHz channel from 108,000 MHz to 117,975 MHz.

6 VDL Mode 4 equipment requirements

Unless otherwise stated, all specifications shall be met under environmental conditions specified in clause 8. Unless otherwise stated, all specifications shall be met at the nominal data rate, with the transceiver tuned to any 25 kHz channel within the range 118,000 MHz to 136,975 MHz.

6.1 Receiver Requirements

For the purposes of the following requirements, the specified Bit Error Rate (BER) of the equipment shall be equal to or better than 1 in 10^4.

NOTE 1: Manufacturers may alternatively propose to use a requirement based on a Message Error Rate (MER) which is shown by the manufacturer to be equivalent to the BER stated above taking account of burst transmission length. Further guidance is provided in clause 9.1.9.

NOTE 2: Proof that BER requirements are met may be carried out by measuring average performance for many separate transmissions rather than analysis of a single transmission (see clause 9.2.1).

The reference signal level applied at the receiver input for all receiver requirements unless otherwise stated, is minus 93 dBm in the frequency range 118,000 MHz to 136,975 MHz.

6.1.1 Sensitivity

A maximum signal level of minus 98 dBm from a modulated VDL Mode 4 signal source shall produce the BER requirement specified in clause 6.1 in the frequency range 118,000 MHz through 136,975 MHz.

NOTE: This requirement is based on the minimum power level to achieve a BER of 10^{-4} at an air-air operating range of 120 NM for class A equipment, assuming 6 dB antenna/cable losses in the aircraft and noise figures in accordance with annex A.

6.1.2 Adjacent channel rejection

The minimum adjacent channel rejection (ACR) shall be determined in the presence of the reference signal level.

The ACR required to achieve the BER (clause 6.1) shall be equal to, or greater than, 40 dB. when tested using DSB-AM, VDL Mode 2 and VDL Mode 4 Type A undesired signals on each side of the wanted signal and at the nominal channel separation of 25 kHz from it.

The ACR required to achieve the BER (clause 6.1) shall be equal to, or greater than, 60 dB, when tested using DSB-AM, VDL Mode 2 and VDL Mode 4 Type A undesired signals on each side of the wanted signal and at a nominal channel separation of 100 kHz from it.

NOTE: Nominal channel separation is defined as the difference in the assigned channel frequencies of the desired and undesired signals, e.g. a nominal channel separation of 25 kHz deals with the first adjacent channels above and below the assigned frequency of the desired signal.

6.1.3 Rejection of signals within the VHF Aeronautical band

The BER requirement (clause 6.1) shall be achieved when the wanted signal, set at the reference level, is combined with an unmodulated interfering signal in the following conditions:

a) Level of the interfering signal set at minus 33 dBm at frequencies corresponding to centres of second and third adjacent channels.

b) Level of the interfering signal set at minus 27 dBm at frequencies corresponding to centres of fourth and higher adjacent channels.

The frequency range of the interfering signal shall be 118,000 MHz to 136,975 MHz, including the frequencies equivalent to the second higher and second lower channels to which the receiver is tuned but excluding the frequency range between these two channels.

6.1.4 Rejection of signals outside the VHF Aeronautical band

The BER requirement (clause 6.1) shall be achieved when one of the unwanted signals specified below is applied in turn and in addition to the reference signal level (clause 6.1).

NOTE 1: Each of the signals specified below are applied one at a time and not simultaneously.

Unwanted signal A:

Level: minus 33 dBm

Modulation: None

Frequency range: 108 MHz to 156 MHz (excluding 117,975 MHz to 137,025 MHz).

Unwanted signal B:

Level: minus 7 dBm

Modulation: None

Frequency range: 50 kHz to 1 215 MHz (excluding the range 87,5 MHz to 156 MHz)

NOTE 2: A maximum interfering level of minus 33 dBm is permitted at the receiver IF frequencies.

Unwanted signal C:

VDL Mode 4 assignable channels: 118,000 MHz to 136,975 MHz

Level: minus 5 dBm

Modulation: None

Frequency range: 87,5 MHz to 107,9 MHz

NOTE 3: Manufacturers should note that, should the range of VDL Mode 4 operation be extended down to 112,000 MHz, the requirements of this clause will also need to be met in the presence of the following unwanted signal.

VDL Mode 4 assignable channels: 112,000 MHz to 117,975 MHz

Modulation: None

Level and frequency range: See table below

Table 6.1

Frequency (MHz)	Level (dBm)
87,5 to 104,0	+15
106,0	+10
107,0	+5
107,9	0

NOTE 4: The level obeys a linear relationship between adjacent points designated by the frequencies in the above table.

6.1.5 Desired signal dynamic range

The receiver shall continue to achieve the BER requirement (clause 6.1) when the reference signal level is increased to a level of minus 7 dBm.

6.1.6 Symbol rate capture range

The BER requirement (clause 6.1) shall be achieved when the reference signal level is subject to a symbol rate offset of plus/minus 50 parts per million.

6.1.7 Frequency capture range

The receiver shall be capable of acquiring and maintaining a lock to any selected channel with the maximum permitted signal frequency offset.

The BER requirement (clause 6.1) shall be achieved when the reference signal level is subject to a frequency offset of plus/minus 967 Hz.

NOTE: This value is composed of the maximum transmitter frequency error at 136,975 MHz (±685 Hz) and the maximum Doppler shift (±282 Hz).

6.1.8 Doppler Rate

The BER requirement (clause 6.1) shall be achieved when the reference signal level, at the maximum limit of frequency capture range specified clause 6.1.7, is additionally subject to a carrier frequency change rate of plus/minus 300 Hz/s.

6.1.9 Co-channel interference

The BER requirement (clause 6.1) shall be achieved when an uncorrelated VDL Mode 4 interfering signal 10 dB below the reference signal is applied in addition to the reference signal level.

NOTE: The specified co-channel interference protection of 10 dB is more stringent than in ICAO VDL SARPS [1] with the aim of improving system performance in dense traffic environments.

6.1.10 Conducted spurious emission

When the receiver input is terminated in a resistive load equal to the nominal receiver input impedance, the level of any spurious emission appearing across the load shall not exceed -57 dBm over the frequency range of 50 kHz to 1 215 MHz and shall not exceed -64 dBm over the frequency range 108 MHz to 137 MHz.

6.1.11 FM Broadcast Intermodulation

6.1.11.1 Radio frequencies in the band 117,975 MHz to 137 MHz

The BER requirement (clause 6.1) shall be achieved in the presence of two unmodulated interfering signals within the frequency range of 87,5 MHz to 107,9 MHz. Each interfering signal shall separately present minus 5 dBm at the receiver input. The combined interfering signal shall be simultaneously applied to the receiver input in the presence of the reference signal.

6.1.11.2 Radio frequencies in the band 112 MHz to 117,975 MHz

NOTE: Manufacturers should note that, should the range of VDL Mode 4 operation be extended down to 112,000 MHz, the following requirement will also need to be met. Otherwise, it is not necessary to meet the requirements of this clause.

The BER requirement (clause 6.1) shall be achieved in the presence of two signals, third order intermodulation products caused by VHF FM broadcast signals having levels in accordance with the following:

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

for VHF FM broadcast signals in the range 107,7 MHz to 107,9 MHz, and

$$2N_1 + N_2 + 3\left\{24 - 20\log\frac{\Delta f}{0,4}\right\} \leq 0$$

for VHF FM broadcast signals below 107,7 MHz where the frequencies of the two VHF FM broadcast signals produce, within the receiver, a two signal, third-order intermodulation product on the desired VDL Mode 4 frequency.

N1 and N2 are the levels (dBm) of the two VHF FM broadcast signals at the VDL Mode 4 receiver input. Neither level shall exceed the desensitization criteria set forth in clause 6.1.4.

Δf = 108,1 - f1, where f1 is the frequency of N1, the VHF FM broadcast signal closer to 108,1 MHz.

6.1.12 In-band Intermodulation

The BER requirement (clause 6.1) shall be achieved in the presence of two interfering signals, displaced in frequency, from the desired signal.

Desired signal:

Level: minus 75 dBm.

Modulation: VDL Mode 4 modulation as defined in clause 5.2.

Unwanted signal A:

Level: minus 32 dBm.

Modulation: none.

Frequency: test frequency ±1 MHz.

Unwanted signal B:

Level: minus 32 dBm.

Modulation: VDL Mode 4 modulation as defined in clause 5.2.

Frequency: test frequency ±2 MHz.

NOTE: Manufacturers should consider improving on the above values.

6.2 Transmitter requirements

Two types of transmitter equipment are defined: Type A and Type B. All transmitter requirements shall apply to Type A and Type B transmitters unless otherwise stated

NOTE 1 : All transmitter measurements shall be made using conducted power unless otherwise stated.

NOTE 2 : Unless otherwise stated, the test reference bit sequence is specified as follows: The maximum "transmit" period is determined by the maximum "burst" length expected for messages transmitted by VDL Mode 4 equipment supporting the core functionality as defined here. This is a 2 slot message, giving a maximum burst length of 25,4 ms (excluding guard time) at the nominal symbol rate of 19 200 symbols/s.

The minimum "off" period is determined assuming that the transmitter will leave a suitable guard time at the end of the transmission before starting a new transmission. The typical guard time used in VDL mode 4 is 1,25 ms (for 200 NM guard range) which will therefore be taken as the minimum "off" period. The maximum duty cycle is therefore 25,4 ms in "transmit" mode followed by 1,25 ms "off".

NOTE 3: There is no requirement for simultaneous transmit and receive.

6.2.1 Channel Bit Rate

The data rate shall be 19,2 kbit/s plus or minus 50 ppm.

6.2.2 Protection of the transmitter

The protection of the transmitter represents the ability of the transmitter to be protected against malfunction due to faults in the antenna system. Worst case mismatches, are represented by a short and open circuit test. The transmitter shall operate normally after the completion of the test.

6.2.3 Manufacturer's declared output power

Type A: The transmitter mean output power, measured at the output of the transmitter, shall be 15 watts plus or minus 1 dB when delivered into a 50 ohms load, and measured during signal transmission (steady state power level), not averaged over the time intervals between signal transmissions.

Type B: The transmitter mean output power, measured at the output of the transmitter, shall be 4 watts plus or minus 1 dB when delivered into a 50 ohms load, and measured during signal transmission (steady state power lever), not averaged over the time intervals between signal transmissions.

NOTE 1: The difference between Type A and B is 7 dB. This gives Type A about 2,2 the nominal range of B.

NOTE 2: This requirement is based on the link budget as shown in annex A.

NOTE 3: The power levels are measured at the output of the transmitter, not at the antenna.

6.2.4 RF power rise time

The transmitter shall be within 90 % of the manufacturer declared output power level at the end of the transmitter power stabilization segment.

6.2.5 RF power release time

The transmitted power level shall decay at least by 20 dB below the manufacturer declared output power level within 300 microseconds after transmitting the final information symbol.

The transmitter power level shall be less than -90 dBm within 832 microseconds after transmitting the final information symbol.

6.2.6 Spurious emissions

The level of conducted spurious radio frequency energy emitted by the equipment shall not exceed those levels specified in ED-14D/DO-160D, clause 21 [6], for the aircraft category for which the equipment is designed. The use of later editions of ED-14D/DO-160D [6] must be agreed with the appropriate approval authority.

When the transmitter is "active" and terminated in a resistive load equal to the nominal output impedance, the power of any spurious emission at the output of the transmitter shall not exceed:

- 0,25 microwatts (minus 36 dBm) within a bandwidth of 1 kHz, on any frequency in the range 9 kHz to 150 kHz;
- 0,25 microwatts (minus 36 dBm) within a bandwidth of 10 kHz, on any frequency in the range 150 kHz to 30 MHz;
- 0,25 microwatts (minus 36 dBm) within a bandwidth of 100 kHz, on any frequency in the range 30 MHz to 108 MHz;
- 0,25 microwatts (minus 36 dBm) within a bandwidth of 100 kHz, on any frequency in the range 108 MHz to 111,775 MHz;
- 0,25 microwatts (minus 36 dBm) within a bandwidth of 10 kHz, on any frequency in the range 111,775 MHz to 111,9 MHz;
- 0,25 microwatts (minus 36 dBm) within a bandwidth of 10 kHz, on any frequency in the range 137,075 MHz to 137,2 MHz;
- 0,25 microwatts (minus 36 dBm) within a bandwidth of 100 kHz, on any frequency in the range 137,2 MHz to 1 GHz;
- 1 nanowatt (minus 60 dBm) within a bandwidth of 100 kHz, on any frequency in the range 1 GHz to 1,7 GHz.

Additionally, the level of spurious emissions at discrete frequencies (excluding harmonics) in the following bands shall not exceed 4 nW (minus 54 dBm):

- 47 MHz to 68 MHz;
- 88 MHz to 108 MHz;
- 162 MHz to 244 MHz;
- 328 MHz to 336 MHz;
- 470 MHz to 862 MHz.

Furthermore, the level of spurious emissions at discrete frequencies (excluding harmonics) in the band 1 GHz to 1,7 GHz shall not exceed 1 nW (minus 60 dBm).

Harmonic emission products shall be at least 60 dB lower than manufacturers declared output power (i.e. minus 60 dBc).

Any emission of harmonics of the transmit carrier frequency which is between 1 GHz and 1,7 GHz shall be less than -60 dBc.

When the transmitter is "idle" (i.e. transceiver in receive mode) and terminated in a resistive load equal to the nominal output impedance, the power of any spurious emission at the output of the transmitter shall not exceed:

- 2 nanowatts (minus 57 dBm) within a bandwidth of 1 kHz, on any frequency in the range 9 kHz to 150 KHz;
- 2 nanowatts (minus 57 dBm) within a bandwidth of 10 kHz, on any frequency in the range 150 kHz to 30 MHz;
- 2 nanowatts (minus 57 dBm) within a bandwidth of 100 kHz, on any frequency in the range 30 MHz to 1 GHz;
- 1 nanowatts (minus 60 dBm) within a bandwidth of 100 kHz, on any frequency in the range 1 GHz to 1,7 GHz.

NOTE 1: Spurious emissions are conducted RF emissions on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include parasitic emissions, intermodulation products and frequency conversion products.

NOTE 2: In order to ensure adequate protection of a GNSS receiver when a VDL transceiver is operated on the same aircraft, requirements are specified to ensure that the transmitter harmonic filter remains effective at frequencies in the band, 1 559 MHz to 1 610 MHz.

NOTE 3: The requirements in this clause are consistent with ED-14D/DO-160D [6].

6.2.7 Adjacent channel power

First adjacent channel power:

The RF power measured over the 25 kHz channel bandwidth of the first adjacent channel shall not exceed 2 dBm.

The RF power measured over a 16 kHz channel bandwidth centred on the first adjacent channel shall not exceed minus 18 dBm.

Second adjacent channel power:

The RF power measured over the 25 kHz channel bandwidth of the second adjacent channel shall not exceed minus 28 dBm.

Fourth adjacent channel power:

The RF power measured over a 25 kHz channel bandwidth centred on the fourth adjacent channel shall not exceed minus 38 dBm.

6.2.8 Wide-band noise

The RF power measured in a 25 kHz channel bandwidth shall reduce at a minimum rate of 5 dB per octave from the fourth adjacent channel to a maximum value of minus 53 dBm.

6.2.9 Frequency tolerance

The frequency of the RF carrier shall be within plus or minus 5 ppm of the selected frequency.

6.2.10 Load VSWR capability

When a 2:1 mismatch is applied to the transmitter output terminals by a length of feeder, which is varied in electrical length by up to half a wavelength, the requirements of clauses 6.2.7 and 6.2.8 shall be met. In addition, the power output shall not be less than -3 dB of the manufacturer's declared value (see clause 6.2.3).

6.2.11 Short power interrupt

The VDL Mode 4 Transceiver shall continue to operate all functions with the exception of the transmitter, throughout a power interruption not exceeding 200 ms in duration, according to the appropriate requirements of EUROCAE ED-14D/ RTCA DO-160D [6].

6.3 Transceiver timing requirements

6.3.1 Tuning time

The transmitter shall be capable of tuning to and operating on any 25-kHz channel in its operating range within 13 ms of the receipt of the last bit of the command to change frequency assignment.

NOTE: This requirement means that a station transmitting in slot N and receiving a command to operate on a different channel must be capable of operating on that new channel in slot N+2.

6.3.2 Start of transmission

The transmission of the first bit of data shall start 2 083,3 microseconds plus or minus 0,6 microseconds after the nominal start of transmission, measured at the equipment.

NOTE: The nominal start of transmission always coincides with the time of the start of a slot.

6.3.3 Receiver to transmitter turnaround time

A station shall be capable of beginning the transmission of the transmitter power stabilization sequence within 16 microseconds after terminating the receiver function.

NOTE: A station receiving in slot N must be capable of transmitting in the following slot (N+1).

6.3.4 Transmitter to receiver turnaround time

A station shall be capable of receiving and demodulating with nominal performance an incoming signal within 1 ms after completing a transmission.

NOTE: A station transmitting in slot N must be capable of receiving in the following slot (N+1).

7 General design requirements

7.1 Controls and indicators

The equipment shall have a visual indication that the device is switched on.

7.2 Class of emission and modulation characteristics

The equipment shall use GFSK modulation. The equipment shall be designed to operate satisfactorily with a channel separation of 25 kHz.

7.3 Warm up

After being switched on the equipment shall be operational within 5 s and shall meet the requirements of the present document within one minute under normal conditions.

NOTE: For testing purposes, a primary time source must be available.

7.4 Airworthiness

The equipment shall not, under normal or fault conditions, impair the airworthiness of the aircraft in which it is installed.

7.5 Intended function

The equipment shall perform its intended function, as defined by the manufacturer and its proper use shall not create a hazard to users of the airspace.

7.6 International Telecommunications Union Regulations

The equipment shall comply with the relevant International Telecommunications Union (ITU) Radio Regulations or such other requirements as are applicable.

7.7 Fire protection

All materials used shall be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire. Furthermore, plenum cable shall be used, where appropriate, to prevent toxic fumes in case of a fire.

NOTE: One means of showing compliance is contained in EASA CS-25 Appendix F (previously Joint Airworthiness Requirements (JAR), Part 25, Appendix F).

7.8 Operation of controls

The operation of controls intended for use during flight, in all possible positions, combinations and sequences, shall not result in a condition whose presence or continuation would be detrimental to the continued performance of the equipment. Controls shall be designed to maximize operational suitability and minimize pilot workload. Reliance on pilot memory for operational procedures shall be minimized.

7.9 Accessibility of controls

Controls which are not intended to be adjusted by the flight crew shall not be readily accessible. Controls that are normally adjusted in flight shall be readily accessible and properly labelled as to their intended function. The controls shall be operable with the use of only one hand.

7.10 Effects of tests

Unless otherwise stated, the design of the equipment shall be such that, during and after the application of the specified tests, no condition exists which would be detrimental to the subsequent performance of the equipment.

7.11 System requirements

7.11.1 Receiver operating range

All receivers contained within a VDL Mode 4 transceiver shall be capable of tuning to any of the 25 kHz channels from 118,000 MHz to 136,975 MHz as defined in [1]. Manufacturers should note that in future the tuning range for the reciever(s) may cover any 25 kHz channel from 108,000 MHz to 117,975 MHz.

7.11.2 Transmitter operating range

The transmitter contained within a VDL Mode 4 transceiver shall be capable of being tuned to any of the 25 kHz channels in the range from 118,000 MHz to 136,975 MHz as defined in [1c]. Manufacturers should note that in future the tuning range for the transmitter may also cover any 25 kHz channel from 112,000 MHz to 117,975 MHz.

7.11.3 Demodulator action

The demodulator shall be capable of re-synchronizing to the training sequence of a burst meeting the CCI criteria, and of subsequently demodulating the data contained in the burst, after it has commenced demodulating a weaker signal.

7.11.4 Automatic transmitter shut-down

A VDL Mode 4 station shall automatically shut-down power to any final stage amplifier in the event that output power from that amplifier exceeds -30 dBm for more than 250 ms. Reset to an operational mode for the affected amplifier shall require a manual operation.

7.12 Software management

If the equipment design is implemented using digital computer techniques, the computer software package should follow guidelines contained in EUROCAE document ED-12B. The RTCA equivalent document DO-178B, or later editions of both ED-12B and DO-178B [9], may be used with the agreement of the Approving Authority.

The software criticality level of the VDL Mode 4 Transceiver shall be determined from the intended use of the equipment. It is expected that for ADS-B and related applications of VDL Mode 4, the software criticality level should be at least level C.

7.13 VDL mode 4 transceiver configuration

The design of the VDL Mode 4 Transceiver may be required to support a variety of aircraft installations, and be capable of enhancement to support evolving operational requirements. In order to satisfy these demands, the equipment shall be capable of being configured locally in respect of:

a) ICAO 24 bit Aircraft Address;

b) applications supported;

c) air derived parameters supported;

d) utilization of geometric or barometric altitude;

e) installation configuration i.e. simplex/dual, and availability of cross-links between transceivers;

f) channel frequency selection.

7.14 Slot map management

The VDL Mode 4 transceiver shall be designed so as to ensure that under all expected operating conditions, the slot map is capable of storing all reservations required by the ICAO Technical Manual [1]. In exceptional circumstances, if it is necessary to discard a reservation due to lack of available memory, the affected slot shall be flagged as not available, and shall not be selected by the station for a transmission.

8 Test conditions, power sources and ambient temperatures

8.1 Introduction

NOTE: Throughout this clause a small subset of the full functional test procedures is used to test the equipment under environmental conditions. This subset has been selected to exercise the basic capability of the VDL Mode 4 equipment under busy conditions, together with all physical interfaces, and all timers.

The environmental tests and performance requirements described in this clause provide a laboratory means of determining the overall performance characteristics of the equipment under conditions representative of those which may be encountered in actual operations.

Unless otherwise specified, the test procedures applicable to a determination of equipment performance under environmental test conditions are contained in documents EUROCAE ED-14D/RTCA DO-160D [6].

Some of the performance requirements in clause 6 are not required to be tested to all of the conditions contained in ED-14D [6]. Judgement and experience have indicated that these particular performance parameters are not susceptible to certain environmental conditions and that the level of performance specified in clause 6 will not be measurably degraded by exposure to these conditions.

8.2 Receiver

8.2.1 Low temperature

(ED-14D [6], clause 4.5.1)

Whilst the equipment is being subjected to this test, establish compliance with the requirements of the following clauses:

6.1.1	Sensitivity
6.1.2	Adjacent channel rejection
6.1.3	Rejection of signals within the VHF Aeronautical band
6.1.4	Rejection of signals outside the VHF Aeronautical band
6.1.5	Desired signal dynamic range
6.1.6	Symbol rate capture range
6.3.4	Transmitter to receiver turnaround time

8.2.2 High temperature

(ED-14D [6], clauses 4.5.2 and 4.5.4)

a) When the equipment is subjected to the high short-time operating temperature and loss of cooling test, establish compliance with the requirement of the following clauses:

6.1.1	Sensitivity
6.3.4	Transmitter to receiver turnaround time

b) When the equipment is subjected to the high operating temperature test (ED-14D [6], clause 4.5.3), establish compliance with the requirements of the following clauses.

6.1.1	Sensitivity
6.1.2	Adjacent channel rejection
6.1.3	Rejection of signals within the VHF Aeronautical band
6.1.4	Rejection of signals outside the VHF Aeronautical band
6.1.5	Desired signal dynamic range
6.1.6	Symbol rate capture range
6.3.4	Transmitter to receiver turnaround time

8.2.3 Altitude, decompression and overpressure

Altitude, (ED-14D [6], clause 4.6.1)

Whilst the equipment is being subjected to this test, establish compliance with the requirements of the following clauses:

6.1.1	Sensitivity
6.1.2	Adjacent channel rejection

Decompression, ED-14D [6], clause 4.6.2

Immediately following this test establish compliance with the requirements of following clauses:

6.1.1	Sensitivity
6.1.2	Adjacent channel rejection

Overpressure, ED-14D [6], clause 4.6.3

When the equipment has been subjected to this test, establish compliance with the requirements of the following clauses:

6.1.1 Sensitivity
6.1.2 Adjacent channel rejection

8.2.4 Temperature variation

(ED-14D [6], clause 5)

Whilst the equipment is being subjected to this test, establish compliance with the requirements of the following clauses:

6.1.1 Sensitivity
6.1.2 Adjacent channel rejection

8.2.5 Humidity

(ED-14D [6], clause 6)

After the equipment has been subjected to this test and following the application of primary power for 15 minutes, immediately :

Establish compliance with the requirements of the following clauses:

6.1.1 Sensitivity
6.1.2 Adjacent channel rejection

8.2.6 Shock

(ED-14D [6], clause 7)

Following the application of the operational shocks, establish compliance with the requirements of the following clauses:

6.1.1 Sensitivity
6.1.2 Adjacent channel rejection

Following the application of the crash safety shocks, the equipment shall remain in the mounting and no part of the equipment or its mounting shall have become detached and free of the shock test table.

NOTE: The application of this test may result in damage to the equipment. It may therefore, be conducted after the other tests and clause 7.10 - "Effects of Tests" - does not apply.

8.2.7 Vibration

(ED-14D [6], clause 8)

Whilst the equipment is being subjected to this test, establish compliance with the requirement of the following clauses:

6.1.1 Sensitivity
6.1.2 Adjacent channel rejection

8.2.8 Explosion proofing

(ED-14D [6], clause 9)

Whilst the equipment is being subjected to this test, it shall not cause detonation of the explosive mixture within the test chambers under normal and fault conditions.

NOTE: The application of this test may result in damage to the equipment. It may, therefore, be conducted after the other tests and clause 7.10 -" Effects of Tests", - does not apply.

8.2.9 Waterproofness

(ED-14D [6], clause 10)

After the equipment has been subjected to this test establish compliance with requirements of the following clauses:

6.1.1 Sensitivity
6.1.2 Adjacent channel rejection

8.2.10 Fluid susceptibility

(ED-14D [6], clause 11)

a) Following the 24 hour "spray" test, operate the receiver for at least 10 minutes to establish that no significant failures have occurred.

b) After subjecting the receiver to a temperature of plus 65 degrees C, for 160 hours, return the receiver to room temperature and operate for 2 hours. Following this period, establish compliance with the requirements of the following clauses:

6.1.1 Sensitivity
6.1.2 Adjacent channel rejection

8.2.11 Sand and dust

(ED-14D [6], clause 12)

After the equipment has been subjected to this test, establish compliance with the requirements of the following clauses:

6.1.1 Sensitivity
6.1.2 Adjacent channel rejection

8.2.12 Fungus resistance

(ED-14D [6], clause 13)

After the equipment has been subjected to this test:

a) Establish compliance with the requirements of the following clauses:

6.1.1 Sensitivity
6.1.2 Adjacent channel rejection

b) Examine for evidence of deterioration.

8.2.13 Salt spray

(ED-14D [6], clause 14)

After subjection to this test, establish compliance with the requirements of the following clauses:

6.1.1 Sensitivity

6.1.2 Adjacent channel rejection

8.2.14 Magnetic effect

(ED-14D [6], clause 15)

Determine the magnetic effect of the equipment and establish that it meets the requirements of the category to which it is declared.

8.2.15 Power input

(ED-14D [6], clause 16)

a) When subjected to this test, for the category corresponding to the type of aircraft electrical supply system used, the equipment shall meet the requirements of the following clauses for "Normal Operating Conditions" as defined in document ED-14D [6] clauses 16.5.1, Normal Operating Conditions (ac) and 16.5.2, Normal Operating Conditions (dc):

 6.1.1 Sensitivity

 6.1.2 Adjacent channel rejection

b) When subjected to the "Abnormal Operating Conditions" of the power supply as defined in clauses 16.5.3 and 16.5.4 of ED-14D [6], the receiver shall continue to provide the minimum BER (clause 6.1).

NOTE: For equipment operating on DC power, the gradual reduction to zero of the primary power voltage (s) shall produce no detrimental effects (see clause 7.10 - "Effects of Tests").

8.2.16 Voltage spike

The following paragraphs refer to the applicable test conditions specified in clause 17 of ED-14D [6]:

Category A requirements (if applicable)

The equipment shall be subjected to the test conditions specified in clause 17.3 and shall meet the requirements of the following clauses:

6.1.1 Sensitivity

6.1.2 Adjacent channel rejection

Category B requirements (if applicable)

The equipment shall be subjected to the test conditions specified in clause 17.4 (of ED-14D [6]) and shall meet the requirements of the following clauses immediately following the ten second test period of the Intermittent Transient test and, during the Repetitive Transient test:

6.1.1 Sensitivity

6.1.2 Adjacent channel rejection

8.2.17 Audio frequency conducted susceptibility, power inputs

(ED-14D [6], clause 18)

Whilst the equipment is being subject to this test, establish compliance with the requirements of the following clauses:

- 6.1.1 Sensitivity
- 6.1.2 Adjacent channel rejection

8.2.18 Induced signal susceptibility

(ED-14D [6], clause 19)

Whilst the equipment is being subjected to this test, establish compliance with the requirements of the following clauses:

- 6.1.1 Sensitivity
- 6.1.2 Adjacent channel rejection

8.2.19 Radio frequency susceptibility (radiated and conducted)

(ED-14D [6], clause 20)

Whilst the equipment is being subjected to this test, establish compliance with the requirements of the following clauses:

- 6.1.1 Sensitivity
- 6.1.2 Adjacent channel rejection

NOTE: The radiated and conducted RF test signal should exclude the frequency to which the receiver is tuned and the response within its resonant passbands.

8.2.20 Emission of radio frequency energy

(ED-14D [6], clause 21)

Establish compliance with the requirements of clause 6.1.10.

8.3 Transmitter

8.3.1 Low temperature

(ED-14D [6], clause 4.5.1)

Whilst the equipment is being subjected to this test, establish compliance with the requirements of the following clauses:

- 6.2.1 Channel Bit Rate
- 6.2.3 Manufacturer's declared output power
- 6.2.4 RF power rise time
- 6.2.6 Spurious Emissions
- 6.2.7 Adjacent channel power
- 6.3.3 Receiver to transmitter turnaround time

8.3.2 High temperature

(ED-14D [6], clauses 4.5.2 and 4.5.4)

When the equipment is subjected to the high short-time operating temperature and loss of cooling test, establish the following performance limits:

a) The declared output power, is degraded by less than 6 dB.

b) Adjacent channel power, remains as specified in clause 6.2.7

c) Wide-band noise, remains as specified in clause 6.2.8.

d) There shall be no evidence of materials exuding or dripping from the equipment components.

When the equipment is subjected to the high operating temperature test, establish compliance with the requirements of the following clauses:

6.2.1 Channel Bit Rate

6.2.3 Manufacturer's declared output power

6.2.4 RF power rise time

6.2.6 Spurious Emissions

6.2.7 Adjacent channel power

6.3.3 Receiver to transmitter turnaround time

8.3.3 Altitude, decompression and overpressure

Altitude (ED-14D [6], clause 4.6.1)

a) Whilst the equipment is being subjected to this test, establish compliance with the requirements of the following clauses:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

b) Ensure that there is no evidence of corona or arcing without modulation and with the maximum level of modulation for which the equipment is declared.

Decompression, ED-14D [6], clause 4.6.2

Immediately after this test, establish compliance as follows:

a) Has the output power deteriorated by less than 1,5 dB?

b) Are the requirements of the following clauses achieved?

6.2.7 Adjacent channel power

Overpressure, ED-14D [6], clause 4.6.3

When the equipment is subjected to this test, establish compliance with the requirements of the following clauses:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

8.3.4 Temperature variation

(ED-14D [6], clause 5)

Whilst the equipment is being subjected to this test, establish compliance with the requirements of the following clauses:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

8.3.5 Humidity

(ED-14D [6], clause 6)

After the equipment has been subjected to this test and following the application of primary power for 15 minutes, immediately establish compliance with the requirements of the following clauses:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

8.3.6 Shock

(ED-14D [6], clause 7)

Following the application of the operational shocks, establish compliance with the requirements of the following clauses:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

Following the application of the crash safety shocks, the equipment shall remain in its mounting and no part of the equipment or its mounting shall have become detached and free of the shock test table.

NOTE: The application of this test may result in damage to the equipment. It may therefore, be conducted after the other tests and clause 7.10 - " Effects of Tests" - does not apply.

8.3.7 Vibration

(ED-14D [6], clause 8)

Whilst the equipment is being subjected to this test, establish compliance with the requirements of the following clauses:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

8.3.8 Explosion proofing

(ED-14D [6], clause 9.3)

Whilst the equipment is being subjected to this test, it shall not cause detonation of the explosive mixture within the test chambers under normal and fault conditions.

NOTE: The application of this test may result in damage to the equipment. It may, therefore, be conducted after the other test and clause 7.10 - "Effects of Tests" - does not apply.

8.3.9 Waterproofness

(ED-14D [6], clause 10)

After the equipment has been subjected to this test establish compliance with requirements of the following clauses:

6.2.7 Adjacent channel power

8.3.10 Fluid susceptibility

(ED-14D [6], clause 11)

a) Following the 24 hour "spray" test, operate the transmitter for at least 10 minutes to establish that no significant failures have occurred.

b) After subjecting the transmitter to a temperature of plus 65 degrees C, for 160 hours, return the transmitter to room temperature and operate for 2 hours. Following this period, establish compliance with the requirements of the following clauses:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

8.3.11 Sand and dust

(ED-14D [6], clause 12)

After the equipment has been subjected to this test, establish compliance with the requirements of the following clauses:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

8.3.12 Fungus resistance

(ED-14D [6], clause 13)

a) After the equipment has been subjected to this test, establish compliance with the requirements of the following clauses:

6.2.3 Manufacturer's declared output power
6.2.7 Adjacent channel power

b) Examine for evidence of deterioration.

8.3.13 Salt spray

(ED-14D [6], clause 14)

After the equipment has been subjected to this test, establish compliance with the requirements of the following clauses:

6.2.3 Manufacturer's declared output power
6.2.7 Adjacent channel power

8.3.14 Magnetic effect

(ED-14D [6], clause 15)

Determine the magnetic effect of the equipment and establish that it meets the requirements of the category to which it is declared.

8.3.15 Power input

(ED-14D [6], clause 16)

a) When subjected to this test, for the category corresponding to the type of aircraft electrical supply system used, the equipment shall meet the requirements of the following clauses for "Normal Operating Conditions" as defined in document ED-14D [6] clauses 16.5.1 and 16.5.2:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

b) When subjected to the "Abnormal Operating Conditions" of the power supply also defined in document ED-14D [6], clauses 16.5.3 and 16.5.4, a 3 dB reduction in manufacturers' declared output is permissible.

NOTE 1: For equipment operating on DC power, the gradual reduction to zero of the primary power voltage (s) shall produce no detrimental effects (see clause 7.10 - "Effects of Tests").

NOTE 2: In respect of clauses 16.5.2.3 and 16.5.2.4 of ED-14D [6] (Momentary power interruptions), the tests may be carried out following the power interruptions.

8.3.16 Voltage spike

(ED-14D [6], clause 17)

The following paragraphs refer to the applicable test conditions specified in clause 17.0 of ED-14D [6]:

Category A: The equipment shall be subjected to the test conditions specified in clause 17.3 and shall meet the requirements of the following clauses:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

Category B: The equipment shall be subjected to the test conditions specified in clause 17.4 and shall meet the requirements of the following clauses immediately following the ten second test period of the Intermittent Transient test and during the Repetitive Transient test:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

8.3.17 Audio frequency conducted susceptibility, power inputs

(ED-14D [6], clause 18)

Whilst the equipment is being subjected to this test, establish compliance with the requirements of the following clauses:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

8.3.18 Induced signal susceptibility

(ED-14D [6], clause 19)

Whilst the equipment is being subjected to this test, establish compliance with the requirements of the following clauses:

6.2.3 Manufacturer's declared output power

6.2.7 Adjacent channel power

8.3.19 Radio frequency susceptibility (conducted and radiated)

(ED-14D [6], clause 20)

Whilst the equipment is being subjected to this test, establish compliance with the requirements of the following clauses:

6.2.3	Manufacturer's declared output power
6.2.7	Adjacent channel power

8.3.20 Emission of radio frequency energy

(ED-14D [6], clause 21)

Establish compliance with the requirements of clause 6.2.6.

9 Detailed test procedures for the physical layer

The following test procedures are considered to be satisfactory means of establishing compliance with the requirements of the present document. However, with the agreement of the appropriate authority, alternative test procedures, which provide equivalent information, may be used if they can be proven by the manufacturer to be equivalent or better.

9.1 General requirements

9.1.1 Test Conditions

Unless otherwise specified the following test conditions shall apply:

a) Unless otherwise specified, all tests should be conducted under conditions of ambient room temperature, pressure and humidity, as defined in ED-14D/DO-160D [6], clause 3.5. The ambient room temperature shall be not less than 10°C.

b) Unless otherwise specified, the supply voltage and (in the case of equipment designed for AC operation) frequency, shall be within 2 % of the nominal value at which the equipment is designed to operate. In the case of equipment designed for operation from an AC source of variable frequency (e.g. 300 Hz to 1 000 Hz), unless otherwise specified, tests shall be conducted with the input frequency adjusted to within 5 % of a selected frequency and within the range for which the equipment is designed. The input voltage shall be measured at the input terminals of the equipment under test.

c) A reasonable warm-up period for stabilization is permissible, during testing the " ON " time shall not be less than 5 minute. In addition, it shall be possible to verify that the equipment under test has passed the selftest procedure.

d) Where the test specifies a change of RF signal between stated limits, this shall be performed at a rate which will avoid transient disturbances.

9.1.2 Alignment, adjustment and calibration prior to test

Prior to being subjected to tests to establish compliance with the minimum performance requirement, the equipment shall be aligned and adjusted in accordance with the manufacturer's instructions. Subsequent alignment or adjustment during approval test procedures shall be permissible only in exceptional circumstances. Full details of such circumstances and of the action taken shall be recorded in the type test report.

9.1.3 Recording of test results

When test results are being recorded for incorporation in the type test report, it is not sufficient to note merely that the requirement was met. Except where tests are obviously GO/NO GO in character (e.g. determination of whether or not mechanical devices function correctly) the actual numerical values obtained for each of the parameters tested shall be recorded.

9.1.4 Connected load

Unless otherwise specified, all tests shall be performed with the equipment output terminals connected to a load having the impedance for which the equipment is designed. Concerning the RF load, a fifty ohm impedance is recommended.

9.1.5 Test instrument precautions

All equipment used in the performance of the tests should be identified by make, model and serial number where appropriate, and its latest calibration date. The specification of the accuracy of the test equipment is left to the calibration process prescribed by the agency which certifies the testing facility.

Due precautions shall be taken to prevent errors resulting from the improper employment of test instruments and the introduction of stray RF voltages into the equipment circuits during the tests.

Precautions shall also be taken to prevent errors due to noise sidebands of signal generators.

Test equipment connected to the antenna terminals of the equipment under test shall be of the same impedance as the nominal antenna impedance for which the equipment is designed.

9.1.6 Simultaneous application of two signals to the receiver input

Certain precautions are necessary to ensure the validity of tests which involve the simultaneous application of two signals to the receiver input. The two signal sources should have output circuits such that, at the specified signal levels, intermodulation between them does not occur.

9.1.7 Test frequencies

All tests shall be conducted at 118,000 MHz, at the highest assignable channel (136,975 MHz), and at one mid-band channel, for example, 127,500 MHz.

9.1.8 Equipment configuration

Replacement or substitution of components or circuit modules within the equipment under test is not permitted once the test procedures have started.

The VDL Mode 4 Transceiver shall undergo all testing with its operational software installed in the equipment. The software version number shall reflect the revision that is intended for approval.

The configuration data (see clause 7.13) shall be set up so as to be representative of a real aircraft installation. This configuration data set shall be completely documented. The configuration setup shall not be altered during the entire testing procedure.

9.1.9 Detailed physical and MAC layer test procedures

The following test procedures (clauses 9.2, 9.3 and 9.4) are considered to be satisfactory means of establishing compliance with the requirements of clause 6. However, alternative procedures which provide equivalent information may be used.

NOTE: Instead of BER tests as outlined below MER tests might be used. The Message Error Rate (MER) is defined as the total number of messages lost by the VDL receiver plus those messages which do not pass the cyclic redundancy check (CRC), divided by the total number of messages sent. When using MER test procedures, single slot transmissions should be applied with a 2 % MER, which is equivalent to a BER of 1 in 10 000. The percentage
MER = 100 x [1- (probability of message success)] = 100 x [1- (1 - BER)(number of bits in message)].

9.2 Receiver

9.2.1 BER test

A BER test shall involve a VHF signal generator representing the desired source signal and an external BER test fixture which receives each burst payload from the receiver under test.

BER mode

A method for placing the receiver into the BER mode shall be provided by manufacturers. The BER mode is distinct from the operational mode.

The BER mode is used to measure the BER requirement (see clause 6.1).

1) The receiver shall forward each burst payload to the external BER test fixture without error detection or correction procedures.

2) The test payload shall be forwarded to the external BER test fixture only if the burst was successfully detected via the standard 24 bit synchronization sequence.

VHF signal generators

Receiver test procedures require the use of a high performance VHF signal generator in order to permit high precision measurement. This VHF signal generator shall be capable of the specified modulation format and transmission waveform.

1) The VHF signal generator shall support transmission of VDL test bursts consisting of the ramp up period plus the standard 24 bit synchronization sequence followed by a variable length test message, up to the maximum length of 19 200 bits.

2) An external interface to the VHF signal generator shall be provided in order that the test payload can be provided via an external BER test fixture (e.g. a computer and test software or arbitrary waveform generator interfaced to a VHF signal generator).

External BER test fixture

1) The test payload provided by the external BER test fixture shall be mapped directly into the burst payload in Mode 4 format. The formatting shall include cyclic redundancy check (CRC), and header.

2) Unless otherwise stated, tests shall be conducted with maximum length VDL Mode 4 messages.

3) The external BER test fixture generating the test payload for transmission by the VHF signal generator, and receiving/processing the received test payload must be synchronized either explicitly (via a direct connection) or implicitly (by knowledge of the test payload).

4) Calculation of cumulative BER statistics shall begin once synchronization of the external BER test fixture between the transmitting and receiving burst payload has been accomplished. The receiving external BER test fixture shall detect the loss of an entire burst implicitly by lack of a burst payload message in the given burst period. Each test should include a running count of synchronization failures in addition to the cumulative BER.

5) BER statistics shall be generated from a sample size large enough to enable an average BER to be calculated within a reasonable error range. For a BER of 1 in 10^4 it is sufficient to generate statistics from a series of transmissions which provide at least 1 x 10^5 bits. The test is passed if the average BER is within 60 % of the target BER.

Interfering (or undesired) source

Tests for CCI, ACR and other related tests shall be performed with a variety of interfering signals applied in a continuous (non-pulsed) manner. The signal generator will be required to simulate the following interfering sources:

1) VDL Mode 4 waveform (FSK, symbol rate 19,200 Hz, 1 bit per symbol, frequency deviation 2 400 Hz, Gaussian filter and BT = 0,28).

2) VDL Mode 2 waveform (narrow band FM, maximum deviation of plus/minus 5,25 kHz, 400 Hz sine wave modulation).

3) Unmodulated.

The signal generator used to produce interfering signals must be at least 10 dB to 15 dB better in performance than the equipment under test.

Figure 9.1 shows the basic test set up for receiver BER tests.

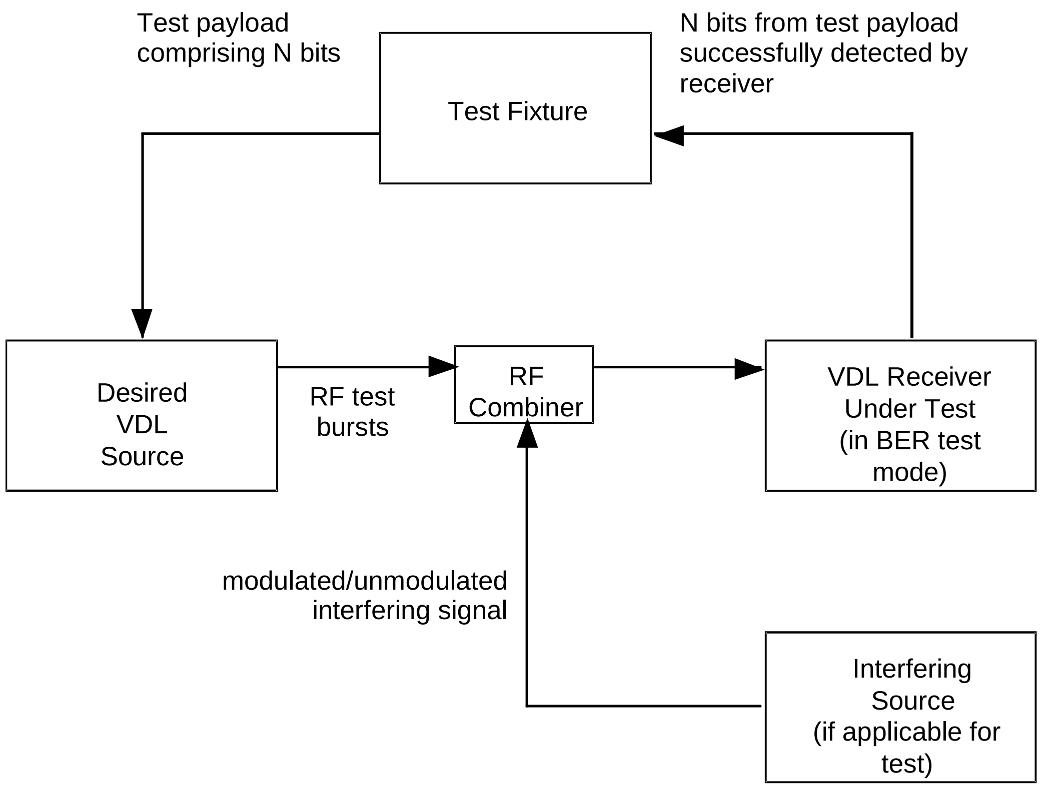

Figure 9.1: Receiver BER measurement

9.2.2 Sensitivity

Equipment Required

- VHF Signal Generator.
- External BER test fixture.

Measurement Procedure

Step 1: Connect the equipment as shown in figure 9.1 but notice that the RF combiner is not required for this test. Set the receiver under test into the BER mode.

Step 2: Set the Desired VDL Source, (a VHF signal generator) to generate an input signal to the receiver at one of the test frequencies (see clause 9.1.7).

Step 3: Modulate the Desired signal with the test payload (maximum burst length) provided by the external BER test fixture. Adjust the level of the signal generator to the maximum signal level (see clause 6.1.1) at the receiver input terminals.

Step 4: Repeat Steps 2 and 3 at the two remaining test frequencies.

Step 5: Using the external BER test fixture, determine the BER of the demodulated data at the receiver output. Check the Sensitivity requirement (see clause 6.1.1) is achieved at all of the three test frequencies (see clause 9.1.7).

9.2.3 Adjacent channel rejection

Equipment Required

- 2 VHF Signal Generators.
- External BER test fixture.
- RF combiner.

Measurement Procedure

Step 1: Connect the equipment as shown in figure 9.1 and set the receiver to the BER mode.

Step 2: Adjust the Desired VDL Source (generator A), to produce an input signal to the receiver at one of the test frequencies (see clause 9.1.7).

Step 3: Modulate generator A with the test payload (maximum burst length of symbols) provided by the external BER test fixture. Adjust signal generator A to produce the reference signal level (see clause 6.1) at the receiver input terminals.

Step 4: Use the second VHF signal generator (named B), to generate an adjacent channel interfering input signal to the receiver (see clause 9.1.1).

Step 5: Tune generator B to the first upper adjacent channel frequency. Set generator B to produce a VDL Mode 2 or VDL Mode 4 interfering signal (see clause 9.1.1). Apply the desired input signal and the adjacent interfering signal to the receiver input via the RF combiner.

Step 6: Adjust the level of signal generator B until the BER is reduced to the minimum requirement(see clause 6.1). Record the interfering signal level at the receiver input terminals.

Step 7: Repeat Step 5 and 6 for the lower adjacent channel.

Step 8: Determine the ratio between the interfering and desired signal levels for both upper and lower adjacent channels. Record the highest of these two values.

Step 9: Repeat Steps 4 to 8 at the two remaining test frequencies (see clause 9.1.7) and for all types of interfering signal.

Step 10: Check that the ACR requirement (defined in clause 6.1.2) is achieved in all cases.

NOTE 1: The noise sidebands of the interfering signal must not interfere with the desired signal in the receiver passband. The isolation offered by the RF combiner must be sufficient to prevent intermodulation between the VHF generators.

NOTE 2: In step 5, the generator B is used to simulate the characteristics of an interfering VDL Mode 2 or 4 signal. This is considered to be the most demanding test of adjacent channel rejection. Adjacent channel AM-DSB signals are expected to have a less damaging effect on reception of VDL signals, and hence are not tested here.

NOTE 3: For step 6, an acceptable alternative procedure is to adjust either desired signal or undesired signal in 1 dB steps, record the BER performance and then construct a performance curve. The appropriate threshold value can then be derived from the performance curve.

9.2.4 Rejection of signals in the VHF aeronautical band

Equipment Required:

- 2 VHF Signal Generators.
- External BER test fixture.
- RF combiner.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.1 and set the receiver to the BER mode.

Step 2: Adjust the Desired VDL Source, generator A, to produce an input signal to the receiver at one of the test frequencies (clause 9.1.7).

Step 3: Modulate generator A with the test payload (maximum burst length of symbols) using the external BER test equipment. Adjust signal generator A to provide the reference signal level (see clause 6.1) at the receiver input terminals.

Step 4: Set the second signal generator (named B), to produce an unmodulated (cw) interfering signal to the receiver input.

Step 5: Tune generator B to a channel frequency in the range defined in clause 6.1.3. Adjust the level of the signal generator B to the unmodulated interfering signal power value (also defined in clause 6.1.3) at the receiver input terminals.

Step 6: Apply the wanted input signal and the unmodulated interfering signal to the receiver input via the RF combiner and determine the BER of the demodulated data with the external BER test fixture.

Step 7: Repeat Step 5 and 6 at the following adjacent 25 kHz channels: 2, 3, 4, 5, 10, 20, 40 and 100 which also fall within the band 118 MHz to 136,975 MHz.

Step 8: Repeat Step 7 at the two remaining test frequencies (clause 9.1.7).

Step 9: Check that the BER requirement (clause 6.1) is achieved in all cases.

NOTE: The noise sidebands of the interfering signal must not to interfere with the desired signal in the receiver passband. The isolation offered by the RF combiner must be sufficient to prevent intermodulation between the VHF generators.

9.2.5 Rejection of signals outside the VHF aeronautical band

Equipment Required:

- 2 VHF Signal Generators.
- External BER test fixture.
- RF combiner.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.1 and set the receiver to the BER mode.

Step 2: Use the Desired VDL Source (generator A), to produce an input signal to the receiver at one of the test frequencies (see clause 9.1.7).

Step 3: Modulate generator A with the test payload (maximum burst length of symbols) using the external BER test fixture. Adjust signal generator A to provide the reference signal level (see clause 6.1) at the receiver input terminals.

Step 4: Use the second signal generator (named B), to generate one of the specified interfering signals at the receiver input.

Step 5: Tune generator B to any frequency defined in clause 6.1.4. Adjust the level of generator B to provide the interfering signal level also defined in clause 6.1.4 at the receiver input terminals.

Step 6: Apply the desired input signal and the interfering signal to the receiver input via the RF combiner and determine the BER with the external BER test fixture.

Step 7: Repeat Step 5 and 6 for all other test frequencies.

Step 8: Repeat Steps 4 to 7 at the remaining two test frequencies (clause 9.1.7).

Step 9: Check that the BER requirement (see clause 6.1) is achieved in all cases.

NOTE 1: The noise sidebands of the interfering signal must not interfere with the desired signal in the receiver pass band. The isolation offered by the RF combiner must be sufficient to prevent intermodulation between the VHF generators.

NOTE 2: Any interfering signal found to reduce the BER below the minimum requirement should be investigated using a spectrum analyser connected to the combiner output. This should determine whether the RF combiner/test setup is producing an on-channel signal into the receiver under test.

NOTE 3: Alternative procedures or theoretical calculation may be used to reduce the number of discrete frequencies which need to be tested.

9.2.6 Desired signal dynamic range

Equipment Required:

- VHF Signal Generator.
- External BER test fixture.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.1 but notice that the RF combiner is not needed for this test. Set the receiver to the BER mode.

Step 2: Adjust the Desired VDL Source (generator A) to generate an input signal, to the receiver, at one of the test frequencies (see clause 9.1.7).

Step 3: Modulate generator A with the test payload (maximum burst length of symbols) using the external BER test fixture. Adjust generator A to provide the maximum reference signal level (see clause 6.1.5) at the receiver input terminals.

Step 4: Apply the modulated signal to the receiver and determine the BER of the demodulated data at the receiver output with the external BER test fixture.

Step 5: Repeat Steps 2 to 4 at the two remaining test frequencies.

Step 6: Check that the BER requirement (see clause 6.1) is achieved in all cases.

9.2.7 Symbol rate capture range

Equipment Required:

- VHF Signal Generator.
- External BER test fixture.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.1 but notice that the RF combiner is not needed for this test. Set the receiver to the BER mode.

Step 2: Tune the Desired VDL Source (generator A) to generate an input signal to the receiver at one of the test frequencies (clause 9.1.7). Adjust generator A to provide the reference signal level (clause 6.1) at the receiver input terminals.

Step 3: Tune the VHF signal generator to the receiver channel frequency and modulate it with the test payload (maximum burst length of symbols) provided by the external BER test fixture.

Step 4: Adjust the transmitted data clock offset of the external BER test fixture to the maximum offset specified in clause 6.1.6.

Step 5: Apply the modulated signal to the receiver and determine the BER of the demodulated data at the receiver output with the external BER test fixture.

Step 6: Repeat Steps 4 and 5 after adjusting the transmitted data clock offset to the minimum offset specified in clause 6.1.6.

Step 7: Repeat Steps 2 to 6 at the two remaining test frequencies (clause 9.1.7).

Step 8: Check that the BER requirement (clause 6.1) is achieved in all cases.

9.2.8 Frequency capture range

Equipment Required:

- VHF Signal Generator.
- External BER test fixture.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.1 but notice that the RF combiner is not needed for this test. Set the receiver to the BER mode.

Step 2: Set the Desired VDL Source (generator A) and the external BER test fixture to generate a receiver input signal.

Step 3: Tune generator A to one of the test frequencies (clause 9.1.7) plus the frequency offset defined in clause 6.1.7 and modulate it with the test payload (maximum burst length of symbols) provided by the external BER test fixture. Adjust generator A to provide the reference signal level (clause 6.1) at the receiver input terminals.

Step 4: Apply the modulated signal to the receiver and determine the BER of the demodulated data at the receiver output with the external BER test fixture.

Step 5: Repeat Steps 3 and 4 for the negative frequency offset (clause 6.1.7).

Step 6 Repeat Steps 3 to 5 at the two remaining test frequencies (clause 9.1.7).

Step 6: Check that the BER requirement (clause 6.1) is achieved in all cases.

9.2.9 Doppler rate

Equipment Required

- VHF Signal Generator.
- External BER test fixture.

Measurement Procedure

Step 1 Connect the equipment as shown in figure 9.1 but notice that the RF combiner is not needed for this test. Set the receiver to the BER mode.

Step 2 Use the Desired VDL Source (generator A) and the external BER test fixture to generate an input signal to the receiver.

Step 3 Tune generator A to one of the test frequencies (clause 9.1.7). Modulate this carrier with the test payload (maximum burst length) provided by the external BER test fixture. Adjust generator A to provide the reference signal level (clause 6.1) at the receiver input terminals.

Step 4 Apply the modulated signal to the receiver and vary the carrier frequency at a rate of plus/minus 300 Hz/s within the range specified in clause 6.1.8. Determine the BER of the demodulated data at the receiver output with the external BER test fixture.

Step 5 Record the BER value.

Step 6 Repeat Steps 2 to 5 at the remaining test frequencies (clause 9.1.7).

Step 7 Check that the BER requirement (clause 6.1) is achieved in all cases.

9.2.10 Co-channel interference

Equipment Required:

- 2 VHF Signal Generators.
- External BER test fixture.
- RF combiner.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.1 and set the receiver to the BER mode.

Step 2: Use the Desired VDL Source (named A), to generate a desired input signal to the receiver.

Step 3: Tune the generator A to one of the test frequencies (clause 9.1.7) and modulate the carrier with the test payload (maximum burst length of symbols) provided by the external BER test fixture. Adjust generator A to provide the reference signal level (clause 6.1) at the receiver input terminals.

Step 4: Use the second signal generator (named B), to generate a co-channel interfering input signal to the receiver.

Step 5: Tune the signal generator B to the receiver channel frequency and configure it to produce a VDL Mode 4 waveform (see clause 9.1.1). Adjust generator B to produce an interfering signal level as specified in clause 6.1.9 below the reference signal level (clause 6.1) at the receiver input terminals.

Step 6: Apply the desired signal and the co-channel interfering FM modulated signal to the receiver input via the RF combiner and measure the BER of the demodulated data at the receiver output with the external BER test fixture.

Step 7: Repeat Steps 2 to 6 at the two remaining test frequencies (clause 9.1.7).

Step 8: Check that the BER requirement (clause 6.1) is achieved in all cases.

9.2.11 Conducted spurious emission

Equipment Required:

- Resistive load equal to the nominal input impedance of the receiver.
- Calibrated spectrum analyser to cover the frequency range defined in clause 6.1.10.

Measurement Procedure:

Step 1: Connect the RF output of the equipment under test directly into the RF input of the spectrum analyser. Exercise caution, do not allow the transmitter to radiate.

Step 2: Tune the mobile station to one of the test channels (clause 9.1.7).

Step 3: Using the calibrated spectrum analyser, measure the power level of any spurious emissions across the matching resistive load at the input of the receiver over the frequency range defined in clause 6.1.10.

Step 4: Record the frequency and power level of all signals which exceed the limit specified in clause 6.1.10.

Step 5: Repeat Steps 2 to 4 at the two remaining test channels (clause 9.1.7).

Step 6: Check that the requirements of clause 6.1.10 are achieved.

9.2.12 FM broadcast intermodulation

Equipment Required

- 3 VHF Signal Generators.
- External BER test fixture.
- RF combiner.

Measurement Procedure

Step 1 Connect the equipment as shown in figure 9.2.

Step 2 Use a signal generator (named A), to generate the desired input signal to the receiver.

Step 3 Tune generator A to one of the test frequencies as listed in table 9.1 and modulate the carrier with the test payload (maximum burst length of symbols) provided by the external BER test fixture. Adjust generator A to provide the reference signal level (clause 6.1) at the receiver input terminals.

Step 4 Tune the interfering signal generators (named B and C) to the test frequency combinations (see note 2) listed in table 9.1. Both interfering signal generators shall provide an unmodulated carrier (see note 3). Adjust signal generators B and C to produce equal levels specified in clause 6.1.11 and outlined in table 9.1 at the receiver input terminals.

Step 5 Apply the desired signal and the two interfering signals to the receiver input via the RF combiner and determine the BER of the demodulated data at the receiver output with the external BER test fixture.

Step 6 Repeat Steps 2 to 5 at the remaining test frequencies.

Step 7 Check that the BER requirement (clause 6.1) is achieved in all cases.

NOTE 1: The noise sidebands of the interfering FM modulated signals must not to interfere with the desired signal in the receiver passband. The isolation offered by the RF combiner must be such that it prevents intermodulation between the generators.

NOTE 2: Third order intermodulation frequencies are defined as:

$$F_A = 2F_B \pm F_C \;\; or \;\; F_B \pm 2F_C$$

NOTE 3: The use of two CW carrier as FM intermodulation interference to the VDL receivers can be considered as worst case. This case occurs, when both FM stations simultaneously have momentary pauses in its audio, e.g. momentary dead time between words, sentences, or pauses in speech or music. If one or both signals were modulated, the intermodulation energy would be spread wider in the spectrum and would, therefore, introduce less interference in the bandwidth of the VDL receiver.

NOTE 4: Manufacturers should note that, should the range of VDL Mode 4 operation be extended down to 112,000 MHz, tests should be carried out for all conditions set out in table 9.1, Otherwise, only test conditions for Generator A frequencies of 120,0 MHz and 120,3 MHz shall be carried out.

Table 9.1: Test Conditions for Intermodulation Rejection Tests

Generator C Frequency (MHz)	Generator B Frequency (MHz)	Generator A Frequency (MHz)	Power at the VDL Rx Input (dBm)
107,9	103,8	112,0	-24
105,5	99,0	112,0	-7,7
102,1	92,1	112,0	-0,5
107,9	100,8	115,0	-24,0
102,1	89,2	115,0	-0,5
107,9	97,9	117,9	-24,0
104,5	91,1	117,9	-4,9
107,9	95,8	120,0	-5,0
107,9	87,5	128,3	-5,0

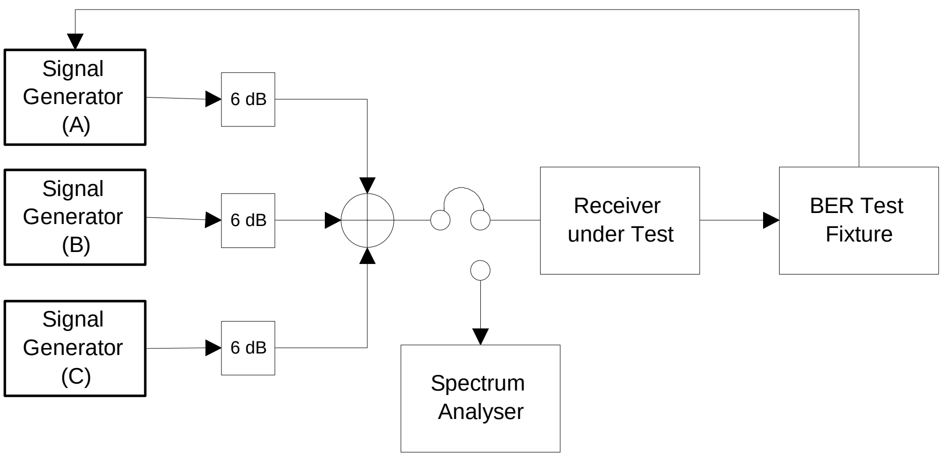

Figure 9.2: Intermodulation measurement

9.2.13 In-band intermodulation

Equipment Required:

- 3 VHF Signal Generator.
- External BER test fixture.
- RF combiner.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.2.

Step 2: Use a signal generator (named A), to generate the desired input signal to the receiver.

Step 3: Tune generator A to one of the test frequencies (clause 9.1.7) and modulate the carrier with the test payload (maximum burst length of symbols) provided by the external BER test fixture. Adjust generator A to provide a level of minus 75 dBm. at the receiver input terminals.

Step 4: Tune interfering signal generator B to a frequency 1 MHz above the selected test frequency. Set signal generator B to produce an unmodulated carrier, input to the receiver input terminals at a level of minus 32 dBm.

Step 5: Tune interfering signal generator C to a frequency 2 MHz above the selected test frequency. Set signal generator C to produce a simulated Mode 4 signal, input to the receiver input terminals at a level of minus 32 dBm.

Step 6: Apply the desired signal and the two interfering signals to the receiver input via the RF combiner and determine the BER of the demodulated data at the receiver output with the external BER test fixture.

Step 7: Repeat Steps 3 to 6 for the remaining frequency combinations by retuning generators B and C.

Step 8 Repeat Steps 2 to 7 at the two remaining test channels (clause 9.1.7).

Step 9: Check that the BER requirement (clause 6.1) is achieved in all cases.

NOTE: In the absence of the desired signal (i.e. Generator A switched "off"), the intermodulation products produced by any interaction between the interfering signal generators B and C, must be less than minus 105 dBm at the receiver input. Additional band-pass filters, inserted between each generator and the RF combiner, may be necessary to reduce the intermodulation product.

9.3 Transmitter

9.3.1 Channel bit rate

This requirement (clause 6.2.1) may be satisfied by written evidence.

In this case, the manufacturer shall declare crystal stability, aging and temperature coefficients.

NOTE: The evidence shall demonstrate that consideration has been given to the temperature variation which the equipment will be subjected and the frequency range for which the equipment is designed to operate.

9.3.2 Manufacturer's declared output power

Equipment Required:

- Transmission generator, PC with suitable software.
- Attenuator 30 dB, 30 W.
- Power meter, with pulse power measurement facility.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.3.

Step 2: Tune the transmitter to one of the test frequencies (clause 9.1.7).

Step 3: Key the transmitter under test "on" and modulate the carrier with continuous maximum length Mode 4 messages from the transmission generator.

Step 4: Set the power meter to capture the Mode 4 transmitted signal and determine the transmitter output power during the message period.

Step 5: Repeat Steps 2 to 4 at the two remaining test channels.

Step 6: Check that the manufacturer's declared output power is not less than the requirement for the appropriate type of transmitter under test (clause 6.2.3) and remains so at all three test channels.

NOTE: Output power delivered into a 50 ohms load shall be measured during signal transmission (steady state power level) and shall not be averaged over the time intervals between signal transmissions.

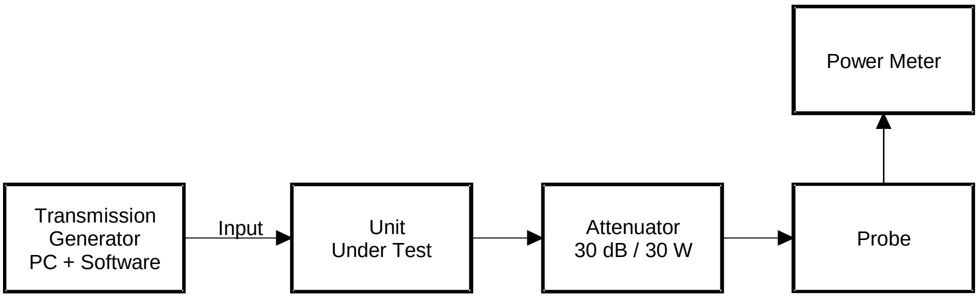

Figure 9.3: Output power measurement

9.3.3 RF power rise time

Equipment Required:

- Transmission Generator, PC with suitable software.
- Attenuator 30 dB, 30 W.
- Spectrum analyser.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.4.

Step 2: Key the transmitter under test "on" and modulate the carrier with a Mode 4 message on time slot N.

Step 3: Synchronize the spectrum analyser at the beginning of time slot N.

Step 4: Record the RF level at the end of the stabilization segment (832 microseconds after the beginning of time slot N).

Step 5: Check that the RF power rise time defined in clause 6.2.4 is achieved.

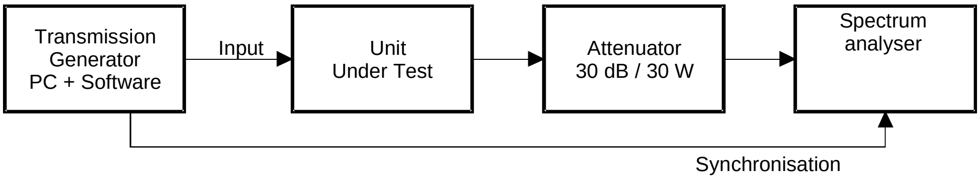

Figure 9.4: RF power rise and release time measurement

9.3.4 RF power release time

Equipment Required:

- Transmission Generator, PC with suitable software.
- Attenuator 30 dB, 30 W.
- Spectrum analyser.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.4.

Step 2: Key the transmitter under test "on" and modulate the carrier with a minimum length Mode 4 message on time slot N.

Step 3: Synchronize the spectrum analyser at the beginning of time slot N.

Step 4: Put a marker at the end of the data segment of the message.

Step 5: Record the RF level 300 microseconds and 832 microseconds after the marker.

Step 6: Check that the RF power release time defined in clause 6.2.5 is achieved.

9.3.5 Spurious emissions

Equipment Required:

- Transmission Generator, PC with suitable software.
- Attenuator 30 dB, 30 W.
- Notch filter or band pass filter, to suppress the on-channel signal by at least 60 dB.
- Spectrum analyser with power band marker function.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.5.

Step 2: Tune the transmitter to one of the test frequencies.

Step 3: Using the filter to reject the on-channel signal in order to increase the dynamic range of the measurement without overloading the spectrum analyser. Measure the frequency response of the filter and take this into account when calculating spurious measurement results.

Step 4: Set the transmission generator to produce continuous maximum length Mode 4 messages and key the transmitter under test "on".

Step 5: Adjust the spectrum analyser reference level to provide the maximum dynamic range for display and set the input attenuator to minimum required to ensure that no signal at the analyser input exceeds the maximum allowable level.

Step 6: Measure the power level at each visible spurious signal using power band markers appropriate to the bandwidths specified in clause 6.2.6. Use the filter to reject the carrier in order to increase the dynamic range of the measurement without overloading the spectrum analyser.

Step 7: Measure the frequency response of the filter and take this into account when presenting spurious measurement results. If a bandpass filter is used, it will need to be tuned to several measurement frequencies, covering the overall measured frequency range.

Step 8 Repeat Steps 2 to 7 for the other test frequencies specified in clause 6.2.6.

Step 8: Check that the results do not exceed the limits specified in clause 6.2.6.

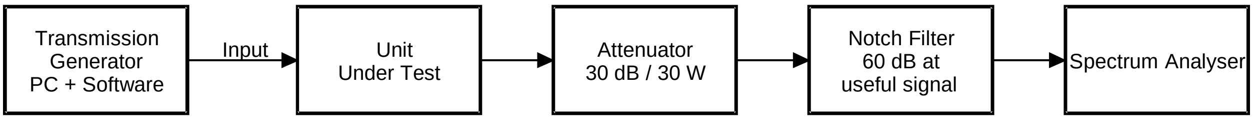

Figure 9.5: Spurious emissions measurement

9.3.6 Adjacent channel power

9.3.6.1 Method of measurement for the first adjacent channel

Equipment Required:

- Transmission Generator, PC with suitable software.
- Attenuator 30 dB, 30 W.
- Spectrum analyser with power band marker function.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.6.

Step 2: Tune the transmitter to one of the test frequencies (clause 9.1.7).

Step 3: Key the transmitter under test "on" and modulate it with the transmission generator to produce continuous maximum length Mode 4 messages.

Step 4: Adjust the attenuator in the analyser to the minimum value which does not overload the input stage of the unit.

Step 5: Using 100 kHz span display the Mode 4 signal envelope. Use the analyser IF signal power as the trigger source for the display and set averaging to 10.

Step 6: Using the power band marker function of the analyser measure the power in a 16 kHz bandwidth, of the first upper adjacent channel.

Step 7: Repeat Steps 2 to 5 for the first lower adjacent channel.

Step 8: Record the highest of the two measured values. Check that the first adjacent channel power is lower than the first adjacent channel power requirement defined in clause 6.2.7.

Step 9: Repeat Steps 2 to 8 at the two remaining test frequencies (clause 9.1.7).

Step 10: Repeat Steps 2 to 9 with the spectrum analyser set to peak hold and verify that the adjacent channel power measurements satisfy the requirements of clause 6.2.7 when compensating for the increased power measurement due to peak measurement versus average measurement.

NOTE: As an example, Agilent Application Note 1303, page 18, shows that the peak measurement can be 10 dB greater than the average value under some circumstances. Manufacturers are cautioned to verify the appropriate peak to average ratio for their test setup.

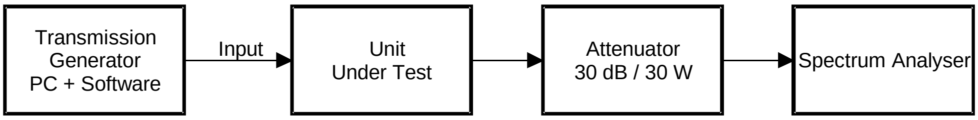

Figure 9.6: First adjacent channel power measurement

9.3.6.2 Method of measurement for the second adjacent channel

Equipment Required:

- Transmission Generator, PC with suitable software.
- Attenuator 30 dB, 30 W.
- VHF crystal filter with a 3 dB bandwidth of 25 kHz and, with attenuation in excess of 50 dB at ±50 kHz.
- Spectrum analyser with power band marker function.

Measurement Procedure:

Important: o protect the analyser and the crystal filter, ensure that the transmitter cannot be keyed "on", at the frequency of the crystal filter used for this test.

Step 1: Connect the equipment as shown in figure 9.7.

Step 2: Tune the transmitter to one of the test frequencies (clause 9.1.7).

Step 3: Offset the tuned frequency of the transmitter under test to 50 kHz above the VHF crystal filter centre frequency. Key the transmitter under test "on". Use the transmission generator to produce continuous maximum length Mode 4 messages.

Step 4: Set the analyser span to 50 kHz and centre frequency to the centre frequency of the VHF crystal filter. Decrease the analyser input attenuator to the minimum level at which the attenuated RF signal from the transmitter under test does not overload the analyser. Use the analyser IF signal power as the trigger source for the display and set averaging to 10.

Step 5: Set the analyser's power band marker function to 40 kHz. Notice that the measurement bandwidth is defined by the VHF crystal filter and setting the power band marker to the same bandwidth will give an erroneous result.

Step 6: Determine the second lower adjacent channel power.

Step 7: Repeat Steps 2 to 5 with the transmitter under test tuned to 50 kHz below the crystal filter. Determine the second upper adjacent channel power.

Step 8: Record the second adjacent channel power as the highest of the two measured values.

Step 9: Check that the second adjacent channel power is less than the second adjacent channel power requirement (defined in clause 6.2.7).

Step 10: Repeat Steps 2 to 9 at the two remaining test frequencies.

Step 11: Repeat Steps 2 to 10 with the spectrum analyser set to peak hold and verify that the adjacent channel power measurements satisfy the requirements of clause 6.2.7 when compensating for the increased power measurement due to peak measurement versus average measurement.

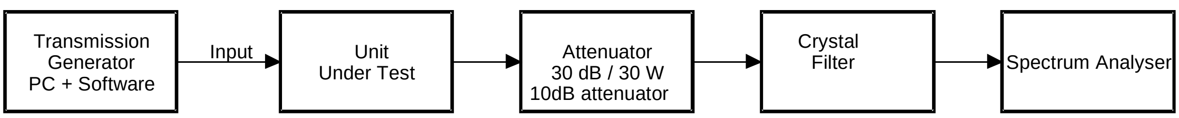

Figure 9.7: Second and fourth adjacent channel power measurement

9.3.6.3 Method of measurement for the fourth adjacent channel

Equipment Required:

- Transmission Generator, PC with suitable software.
- Attenuator 30 dB, 30 W.
- VHF crystal filter with a 3 dB bandwidth of 25 kHz and, with attenuation in excess of 50 dB at ± 50 kHz.
- Spectrum analyser with power band marker function.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.6.

Step 2: Tune the transmitter to one of the test frequencies (clause 9.1.7).

Step 3: Offset the tuned frequency of the transmitter under test to 100 kHz above the VHF crystal filter centre frequency. Key the transmitter under test "on". Use the transmission generator to produce continuous maximum length Mode 4 messages.

Step 4: Set the analyser span to 50 kHz and centre frequency to the centre frequency of the VHF crystal filter. Decrease the analyser input attenuator to the minimum level at which the attenuated rf signal from the transmitter under test does not overload the analyser. Use the analyser IF signal power as the trigger source for the display and set averaging to 10.

Step 5: Set analyser's power band marker function set to 40 kHz. Notice that the measurement bandwidth is defined by the VHF crystal filter and setting the power band marker to the same bandwidth will give an erroneous result.

Step 6: Determine the fourth lower adjacent channel power.

Step 7: Repeat Steps 2 to 5 with the transmitter under test tuned to 100 kHz below the crystal filter. Determine the fourth upper adjacent channel power.

Step 8: Record the fourth adjacent channel power as the highest of the two measured values.

Step 9: Check that the fourth adjacent channel power is less than the fourth adjacent channel power requirement defined in clause 9.2.7.

Step 10: Repeat Steps 2 to 9 at the two remaining test frequencies (clause 9.1.7).

Step 11: Repeat Steps 2 to 10 with the spectrum analyser set to peak hold and verify that the adjacent channel power measurements satisfy the requirements of clause 6.2.7 when compensating for the increased power measurement due to peak measurement versus average measurement.

9.3.6.4 Alternative Measurement Procedure for Adjacent Channel Power (ACP)

Step 1: Connect the equipment as shown in figure 9.7.

Step 2: Tune the transmitter to one of the test frequencies.

Step 3: Start the transmission generator that produces transmit blocks and simulates the transmit/receive duty cycle.

Step 4: Use an attenuator to protect the measurement equipment and a notch filter centred on the carrier frequency, if the dynamic range of the spectrum analyser is not sufficient. Set the spectrum analyser resolution bandwidth (Br) much narrower than the channel bandwidth and the video bandwidth (Bv) equal to ten times Br in order to avoid errors due to video averaging of noise.

Step 5: Measure and store the RF signal spectrum centred on the carrier frequency with a frequency span wide enough to display all the modulation spectrum between the -80 dB points, referred to the peak value.

Step 6: Convert the logarithmic trace values from the spectrum analyser to linear spectral power densities by the relation:

$$P_i = \frac{10^{\frac{PidBm}{10}}}{B_n}$$

where P_{idBm} = Trace values (dBm).

B_n = Effective noise bandwidth of the spectrum analyser (Hz).

P_i = Spectral power densities (mW/Hz).

NOTE: $B_n = k \times Br$, where k is a constant specified for each spectrum analyser.

Step 7: Perform an integration of the linear spectral power densities. For computation of the linear spectral power values in the first, second and fourth adjacent channels, use the formula:

$$P_{ch} = B_{ch} \times \frac{1}{N} \times \sum_{i=1}^{N} P_i$$

where P_{ch} = power in the considered channel.

B_{ch} = assigned bandwidth of the first , second or third adjacent channel.

N = Number of power samples within the limits of the assigned bandwidth, $B_{ch.}$

Step 8: Perform the adjacent channel measurement for the first, second and fourth adjacent channels on both sides of the carrier frequency (lower and upper adjacent channels).

Step 9: Check that the adjacent channel power on either side of the carrier for the first, second and fourth adjacent channels are lower than the respective adjacent channel power requirements defined in clause 6.2.7.

Step 10: Repeat Steps 2 to 9 with the spectrum analyser set to peak hold and verify that the adjacent channel power measurements satisfy the requirements of clause 6.2.7 when compensating for the increased power measurement due to peak measurement versus average measurement.

9.3.7 Wideband noise

Equipment Required:

- Transmission Generator, PC with suitable software.
- Attenuator 30 dB, 30 W.
- Notch filter with a minimum of 30 dB on-channel attenuation.
- Spectrum analyser with power band marker function.

Measurement Procedure:

Step 1: Connect the equipment as shown in figure 9.8.

Step 2: Tune the transmitter to one of the test frequencies (clause 9.1.7).

Step 3: Use the filter to attenuate the carrier in order to increase the dynamic range of the measurement without overloading the spectrum analyser. Measure the frequency response of the filter and take this into account when presenting noise measurement results.

Step 4: Key the transmitter under test using the transmission generator with repetitive maximum length Mode 4 messages.

Step 5: Adjust the spectrum analyser reference level to provide the maximum dynamic range for display and set the input attenuator to minimum. Ensure that no signal at the analyser input exceeds the maximum allowable level.

Step 6: Record the transmitter noise level versus the frequency displacement using the power band marker function of the analyser.

Step 7: Check that the wide-band noise does not exceed the limit specified in clause 6.2.8.

Step 8: Repeat Steps 2 to 7 at the two remaining test frequencies (clause 9.1.7).

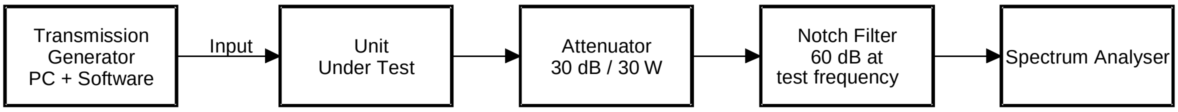

Figure 9.8: Wideband noise measurement

9.3.8 Frequency tolerance

9.3.8.1 Definition

The frequency error is the difference between the measured carrier frequency and its nominal value.

9.3.8.2 Method of measurement

The carrier frequency shall be measured in the absence of modulation, with the transmitter connected to a coaxial termination. Measurements shall be made under extreme test conditions.

9.3.8.3 Limits

The frequency error shall be within the limits defined in clause 6.2.9.

9.3.9 Load VSWR capability

Equipment Required:

- Transmission Generator, PC with suitable software.
- 30 dB directional coupler.
- Adjustable delay line.
- 2:1 VSWR Resistive load.
- Spectrum analyser.

Measurement Procedure:

Step 1 Connect the equipment as shown in figure 9.9.

Step 2 Tune the transmitter to one of the test frequencies.

Step 3 Key the transmitter under test with the transmission generator with repetitive maximum length Mode 4 messages.

Step 4 Vary the VSWR phase angle of the load with the delay line and measure the minimum average forward RF output power from the Transmitter using the spectrum analyser.

Step 5 Check that the minimum average forward RF output power is greater than the limit defined in clause 6.2.10.

Step 6 Repeat Steps 2 to 5 at the two remaining test frequencies.

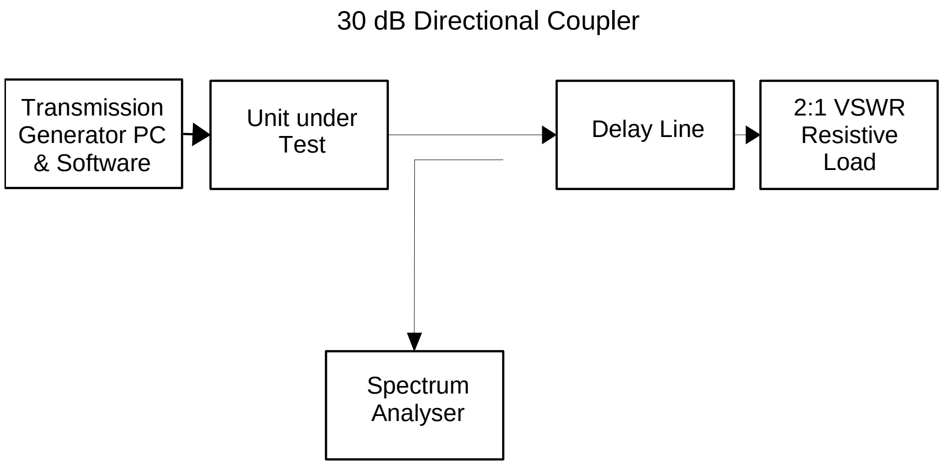

Figure 9.9: Load VSWR Capability

9.4 Physical layer, system parameters

9.4.1 Receiver to transmitter turn-around time

Measurement Procedure:

Step 1: Limit the periodic dither range of the periodic streams from the equipment to ±2.

Step 2: Establish a series of periodic streams from the equipment under test.

Step 3: Use the test equipment to generate a periodic reservation in the slot before each system under test periodic stream.

Step 4: Ensure that the timing of the bursts from the test equipment result in termination of the bursts 16 microsecond before the nominal slot start time.

Step 5: Monitor the movement of the streams from the system under test to ensure that the reservations made by the test equipment are respected by the system under test.

NOTE 1: This shows that the system under test successfully decodes information in the slot before transmitting itself.

NOTE 2: An alternative test of compliance for this requirement is contained in [7] (test case Physical_SysParams)

9.4.2 Transmitter to receiver turn-around time

Measurement Procedure:

Step 1: Limit the periodic dither range of the periodic streams from the system under test to ±2.

Step 2: Establish a series of periodic streams from the equipment under test.

Step 3: Use the test equipment to generate a periodic reservation in the slot after each periodic stream from the equipment under test.

Step 4: Ensure that the timing of the bursts from the test equipment result in the start of the bursts 1 ms after completion of the transmission from the equipment under test.

Step 5: Monitor the movement of the streams from the equipment under test to ensure that the reservations made by the test equipment are respected by the equipment under test.

NOTE 1: This shows that the equipment successfully decodes information in the slot after transmitting itself. Note that ideally the transmissions from the equipment should be longer than the normal sync burst length in order to ensure that the test equipment does not produce signals earlier than the slot boundary. A bespoke message format could be used.

NOTE 2: The test equipment should produce a signal at the reference level and the output of the system under test should be measured to monitor the successful received message rate - this should be shown to be greater than the equivalent of a BER at nominal performance.

NOTE 3: An alternative test of compliance for this requirement is contained in [7] (test case Physical_SysParams)

9.4.3 Tuning time

Measurement Procedure:

Step 1: Tune the transmitter to one of the test frequencies (clause 9.1.7).

Step 2: Establish a series of transmissions from the equipment under test spaced by 13,33 ms.

NOTE: This can be done sending a stream of data to the equipment under test and requesting transmission using the random access protocol (further details on this method of testing may be found in [7].

Step 3: Send a command to the equipment under test to change frequency.

Step 4: Monitor the new frequency and ensure that transmissions are made on this new frequency within 13 ms after receipt of the command to change channel.

Step 5: Repeat the test starting at each of the remaining two test frequencies.

Annex A (informative): VDL Mode 4 link budget

The physical layer parameters specified in these MOPS, are based on a link budget assessment for Mode 4. This is summarized in this clause for normal power Type A transmitters.

These are illustrative calculations providing an overall methodology and base assumptions that are consistent with those that are accepted for VDL's in general. It is recognized that the receiver figures such as noise figure and implementation losses could indeed vary from one manufacturer to another and for this reason the base assumptions are typical values accepted by the radio community that account as much as possible of these variations. Finally the budgets themselves are not intended to address any specific architecture implementations so it is emphasized that the scope of these link budgets is to provide a guideline framework necessary to substantiate the key figures such as power and sensitivity.

Analytic assumptions are listed below:

- VDL Mode 4 uses GFSK modulation at a rate of 19,2 kbps. Theory indicates that BER < 10^{-4} can be achieved at Eb/No > 18 dB using noncoherent detection and Viterbi algorithm for sequence estimation (i.e. to compensate for intersymbol interference).

- VDL Mode 4 is intended to operate in the 118 MHz to 137,000 MHz band. In ICAO a plan for the implementation of a VDL band foresees the allocation of two VDL Mode 4 frequencies (136,825 MHZ and 136,925 MHz) in the upper COM band by 2008. Link budgets are thus performed at the worst case, 137 MHz.

- VDL SARPs [1] indicate that transmit power should be managed so as to generate an RF field strength of between at least 35 microvolts/m and 60 microvolts/m at the edge of the service volume (assuming free space propagation). This is equivalent to an allowed variation in EIRP around 10 W, in the horizontal plane of the aircraft, with a minimum of 5 W and a maximum of 15 W. Calculations for the receiver function of the ground station assume successful reception of a signal from a transmitter with an EIRP at the low end of this scale (i.e. 5 W).

- Mobile VHF antenna gain is generally observed to exceed -4 dBi at least 95 % of the time. This value is used in the link budget calculations. Ground stations are assumed to have antenna gain of 6 dBi.

- Cable loss can vary from 2 dB to 3 dB depending on the size of the aircraft. A worst case of 3 dB is assumed. Cable loss for ground stations is taken as 2 dB.

- The receiver noise figure can vary from 8 dB (best case) to 14 dB (worst case). This may depend to some degree on the level of equipage selected by a user. Ground stations are expected to operate near 8 dB, whereas mobile stations are expected to operate in the range of 10 dB to 14 dB depending on equipment capability. A worst case of 14 dB is assumed for the mobile station and 10 dB is assumed for the ground station in the link budget calculation.

Implementation losses for typical DSP-based equipment are taken as 1,2 dB for the receiver and 1 dB for the transmitter, for both ground stations and mobile stations.

Tables A.1a and A.1b show the link budget for a downlink transmission, using the assumptions set out above, for class A (15 W) and class B (4 W) equipage respectively.

Table A.1a: VDL Mode 4 downlink budget FOR CLASS A EQUIPMENT

Frequency (MHz)		Range (NM)				
137,000		40,0	80,0	120,0	160,0	200,0
Transmitter output power (Mobile)						
Power emitted at Transmitter	*W*	15,0	15,0	15,0	15,0	15,0
terminal	*dBm*	41,8	41,8	41,8	41,8	41,8
Transmitter feeder line loss	*dB*	3,0	3,0	3,0	3,0	3,0
Transmitter Antenna Gain	*dBi*	-4,0	-4,0	-4,0	-4,0	-4,0
SARPs Signal-in-Space						
EIRP emitted at transmitter	*dBm*	34,8	34,8	34,8	34,8	34,8
Standard free path loss	*dB*	112,6	118,6	122,1	124,6	126,5
Excess path loss	*dB*	0,0	0,0	0,0	0,0	0,0
EIRP at receiver antenna	*dBm*	-77,8	-83,8	-87,3	-89,8	-91,8
Signal power at receiver terminal (Ground)						
Receiver antenna gain	*dBi*	6,0	6,0	6,0	6,0	6,0
Receiver cable loss	*dB*	2,0	2,0	2,0	2,0	2,0
Power at receiver input terminal (C)	*dBm*	-73,8	-79,8	-83,3	-85,8	-87,8
Noise at receiver terminal (Ground)						
Receiver noise figure	*dB*	10,0	10,0	10,0	10,0	10,0
External noise figure	*dB*	8,0	8,0	8,0	5,0	5,0
Receiver noise floor (kTo)	*dBm/Hz*	-174,0	-174,0	-174,0	-174,0	-174,0
System noise power density (No)	*dBm/Hz*	-162,75	-162,75	-162,75	-163,44	-163,44
System Margin						
C/No	*dBHz*	88,95	82,93	79,41	77,61	75,67
Baud rate	*dBHz*	42,83	42,83	42,83	42,83	42,83
Available Es/No	*dB*	46,12	40,10	36,58	34,78	32,84
Theoretical Es/No	*dB*	18,0	18,0	18,0	18,0	18,0
Transmitter Implementation loss	*dB*	1,0	1,0	1,0	1,0	1,0
Receiver Implementation loss	*dB*	1,2	1,2	1,2	1,2	1,2
Required Es/No	*dB*	20,2	20,2	20,2	20,2	20,2
Residual System Margin	*dB*	25,9	19,9	16,4	14,6	12,6

Table A.1b: VDL Mode 4 downlink budget FOR CLASS B EQUIPMENT

Frequency (MHz)		Range (NM)			
137,000		40,0	80,0	120,0	160,0
Transmitter output power (Mobile)					
	W	4,0	4,0	4,0	4,0
Power emitted at Transmitter terminal	*dBm*	36,0	36,0	36,0	36,0
Transmitter feeder line loss	*dB*	3,0	3,0	3,0	3,0
Transmitter Antenna Gain	*dBi*	-4,0	-4,0	-4,0	-4,0
SARPs Signal-in-Space					
EIRP emitted at transmitter	*dBm*	29,0	29,0	29,0	29,0
Standard free path loss	*dB*	112,6	118,6	122,1	124,6
Excess path loss	*dB*	0,0	0,0	0,0	0,0
EIRP at receiver antenna	*dBm*	-83,5	-89,6	-93,1	-95,6
Signal power at receiver terminal (Ground)					
Receiver antenna gain	*dBi*	6,0	6,0	6,0	6,0
Receiver cable loss	*dB*	2,0	2,0	2,0	2,0
Power at receiver input terminal (C)	*dBm*	-79,5	-85,6	-89,1	-91,6
Noise at receiver terminal (Ground)					
Receiver noise figure	*dB*	10,0	10,0	10,0	10,0
External noise figure	*dB*	8,0	8,0	8,0	5,0
Receiver noise floor (kTo)	*dBm/Hz*	-174,0	-174,0	-174,0	-174,0
System noise power density (No)	*dBm/Hz*	-162,75	-162,75	-162,75	-163,44
System Margin					
C/No	*dBHz*	83,21	77,19	73,67	71,87
Baud rate	*dBHz*	42,83	42,83	42,83	42,83
Available Es/No	*dB*	40,38	34,36	30,84	29,04
Theoretical Es/No	*dB*	18,0	18,0	18,0	18,0
Transmitter Implementation loss	*dB*	1,0	1,0	1,0	1,0
Receiver Implementation loss	*dB*	1,2	1,2	1,2	1,2
Required Es/No	*dB*	20,2	20,2	20,2	20,2
Residual System Margin	*dB*	20,2	14,2	10,6	8,8

NOTE 1: These link budgets are constructed on a method similar to that found in the VDL MASPS (RTCA Do-224A).

NOTE 2: The external noise figure refers to the noise present in the operating environment and is independent of the noise generated internally to the receiver. Different environments generate different levels of noise and in these link budgets the extreme range cases are assumed to be in remote regions where man made noise is minimal. The figure is calculated from the formula 52 - 29log10(f[MHz]) + NENV, where NENV is 15 dB and 18 dB for rural and urban environments respectively (TSB-88-A, TIA/EIA, 1999.)

The link margins in the table above are calculated on the basis of the classical free-space propagation model. At long ranges and low elevations an excess loss contribution due to ground reflected waves applies. The Johnson-Giehart model is used to derive this excess path contribution in table A.2 below. This model considers the dependence of the atmosphere's refractive index (and hence the direction of the ground reflected component) on aircraft altitude. tables A.3a and A.3b provide the link margins taking account of the excess path loss.

Table A.2: Excess path loss 95 % (prob 1 hr. avg)

	Range (NM)				
Altitude (ft)	**40**	**80**	**120**	**160**	**200**
5 000	0,6	16,2	-	-	-
18 000	0	0,8	2,7	19,0	-
33 000	0	0	0,3	4,0	11,9
45 000	0	0	0,1	1,8	5,7
NOTE: Dashed entries indicate beyond line of sight. All values in dB.					

Table A.3a: DOWNLINK MARGIN (class a) considering excess path loss

	Range (NM)				
Altitude (ft)	**40**	**80**	**120**	**160**	**200**
5 000	24,4	2,7	-	-	-
18 000	25,9	18,1	12,7	-5,8	-
33 000	25,9	19,9	15,1	9,2	-0,7
45 000	25,9	19,9	15,3	11,4	5,5
NOTE: Dashed entries indicate beyond line of sight. All values in dB.					

Table A.3b: DOWNLINK MARGIN (class B) considering excess path loss

	Range (NM)			
Altitude (ft)	**40**	**80**	**120**	**160**
5 000	19,6	-2,0	-	-
18 000	20,2	13,4	7,9	-10,2
33 000	20,2	14,2	10,3	-31,2
45 000	20,2	14,2	10,5	7,0
NOTE: Dashed entries indicate beyond line of sight. All values in dB.				

NOTE 3: The sensitivity figure of -100 dBm is the signal at the receiver required to produce a margin of 0 dB when the external noise figure = 0 dB.

NOTE 4: The proposed method of measuring the receiver sensitivity is to apply a signal at the required sensitivity level directly to the receiver input. This seems the easiest method. An alternative, which was used in older versions of Mode 2 MOPS, is to apply a reference signal and an appropriate level of Additive White Gaussian Noise (AWGN). The appropriate level of AWGN is given by kTo + effective noise figure. From table A.1a this is given by -173,98 + 20,94 = -150,04 dBm/Hz. The appropriate reference signal would be -93,5 dBm (for Class A equipement)).

The specifications for performance against interference (see clause 6) require an input power level at the receiving antenna of -81 dBm. Taking account of the receiver antenna gain and the receiver cable loss, this equates to a reference signal level applied at the receiver input -81 dBm (note that the assumed ground antenna gains and cabling losses cancel out).

The equivalent link budget for the uplink case is constructed on the same method, as shown in table A.4 (Class A equipment) and table A.4b (Class B equipment).

Table A.4a: VDL MODE 4 UPLINK LINK BUDGET FOR CLASS A EQUIPMENT

Frequency (MHz)		Range (NM)				
137,000		40,0	80,0	120,0	160,0	200,0
Transmitter output power (Ground)						
Power emitted at Transmitter terminal	*W*	25,0	25,0	25,0	25,0	25,0
	dBm	44,0	44,0	44,0	44,0	44,0
Transmitter feeder line loss	*dB*	2,0	2,0	2,0	2,0	2,0
Transmitter Antenna Gain	*dBi*	6,0	6,0	6,0	6,0	6,0
SARPs Signal-in-Space						
EIRP emitted at transmitter	*dBm*	48,0	48,0	48,0	48,0	48,0
Standard free path loss	*dB*	112,6	118,6	122,1	124,6	126,5
Excess path loss	*dB*	0,0	0,0	0,0	0,0	0,0
EIRP at receiver antenna	*dBm*	-64,6	-70,6	-74,1	-76,6	-78,6
Signal power at receiver terminal (Mobile)						
Receiver antenna gain	*dBi*	-4,0	-4,0	-4,0	-4,0	-4,0
Receiver cable loss	*dB*	3,0	3,0	3,0	3,0	3,0
Power at receiver input terminal (C)	*dBm*	-71,6	-77,6	-81,1	-83,6	-85,6
Noise at receiver terminal (Mobile)						
Receiver noise figure	*dB*	14,0	14,0	14,0	14,0	14,0
External noise figure	*dB*	8,0	8,0	8,0	5,0	5,0
Receiver noise floor (kTo)	*dBm/Hz*	-174,0	-174,0	-174,0	-174,0	-174,0
System noise power density (No)	*dBm/Hz*	-159,56	-159,56	-159,56	-159,82	-159,82
System Margin						
C/No	*dBHz*	87,98	81,96	78,44	76,20	74,26
Baud rate	*dBHz*	42,83	42,83	42,83	42,83	42,83
Available Es/No	*dB*	45,15	39,13	35,61	33,37	31,43
Theoretical Es/No	*dB*	18,0	18,0	18,0	18,0	18,0
Transmitter Implementation loss	*dB*	1,0	1,0	1,0	1,0	1,0
Receiver Implementation loss	*dB*	1,2	1,2	1,2	1,2	1,2
Required Es/No	*dB*	20,2	20,2	20,2	20,2	20,2
Residual System Margin	*dB*	25,0	18,9	15,4	13,2	11,2

Table A.4b: VDL MODE 4 UPLINK LINK BUDGET FOR CLASS B EQUIPMENT

Frequency (MHz)		Range (NM)			
137,000		40,0	80,0	120,0	160,0
Transmitter output power (Ground)					
Power emitted at Transmitter terminal	*W*	25,0	25,0	25,0	25,0
	dBm	44,0	44,0	44,0	44,0
Transmitter feeder line loss	*dB*	2,0	2,0	2,0	2,0
Transmitter Antenna Gain	*dBi*	6,0	6,0	6,0	6,0
SARPs Signal-in-Space					
EIRP emitted at transmitter	*dBm*	48,0	48,0	48,0	48,0
Standard free path loss	*dB*	112,6	118,6	122,1	124,6
Excess path loss	*dB*	0,0	0,0	0,0	0,0
EIRP at receiver antenna	*dBm*	-64,6	-70,6	-74,1	-76,6
Signal power at receiver terminal (Mobile)					
Receiver antenna gain	*dBi*	-4,0	-4,0	-4,0	-4,0
Receiver cable loss	*dB*	3,0	3,0	3,0	3,0
Power at receiver input terminal (C)	*dBm*	-71,6	-77,6	-81,1	-83,6
Noise at receiver terminal (Mobile)					
Receiver noise figure	*dB*	14,0	14,0	14,0	14,0
External noise figure	*dB*	8,0	8,0	8,0	5,0
Receiver noise floor (kTo)	*dBm/Hz*	-174,0	-174,0	-174,0	-174,0
System noise power density (No)	*dBm/Hz*	-159,56	-159,56	-159,56	-159,82
System Margin					
C/No	*dBHz*	87,98	81,96	78,44	76,20
Baud rate	*dBHz*	42,83	42,83	42,83	42,83
Available Es/No	*dB*	45,15	39,13	35,61	33,37
Theoretical Es/No	*dB*	18,0	18,0	18,0	18,0
Transmitter Implementation loss	*dB*	1,0	1,0	1,0	1,0
Receiver Implementation loss	*dB*	1,2	1,2	1,2	1,2
Required Es/No	*dB*	20,2	20,2	20,2	20,2
Residual System Margin	*dB*	25,0	18,9	15,4	13,2

Table A.5a: UPLINK MARGIN (class a) considering excess path loss

	Range (NM)				
Altitude (FT)	**40**	**80**	**120**	**160**	**200**
5 000	25,3	3,7	-	-	-
18 000	25,9	19,1	13,7	-4,4	-
33 000	25,9	19,9	16,1	10,6	0,7
45 000	25,9	19,9	16,3	12,8	6,9
NOTE: Dashed entries indicate beyond line of sight. All values in dB.					

Table A.5b: UPLINK MARGIN (class B) considering excess path loss

	Range (NM)			
Altitude (FT)	**40**	**80**	**120**	**160**
5 000	24,4	2,7	-	-
18 000	25,0	18,1	12,7	-5,8
33 000	25,0	18,9	15,1	9,2
45 000	25,0	18,9	15,3	11,4
NOTE: Dashed entries indicate beyond line of sight. All values in dB.				

The equivalent link budgets for the air-to-air case are given in tables A.6a and A.6b.

Table A.6a: VDL Mode 4 air to air link budget (CLASS A)

Frequency (MHz)		Range (NM)				
137,000		40,0	60,0	80,0	100,0	120,0
Transmitter output power (Mobile)						
Power emitted at Transmitter	*W*	15,0	15,0	15,0	15,0	15,0
terminal	*dBm*	41,8	41,8	41,8	41,8	41,8
Transmitter feeder line loss	*dB*	3,0	3,0	3,0	3,0	3,0
Transmitter Antenna Gain	*dBi*	-4,0	-4,0	-4,0	-4,0	-4,0
SARPs Signal-in-Space						
EIRP emitted at transmitter	*dBm*	34,8	34,8	34,8	34,8	34,8
Standard free path loss	*dB*	112,6	116,1	118,6	120,5	122,1
Excess path loss	*dB*	0,0	0,0	0,0	0,0	0,0
EIRP at receiver antenna	*dBm*	-77,8	-81,3	-83,8	-85,8	-87,3
Signal power at receiver terminal (Mobile)						
Receiver antenna gain	*dBi*	-4,0	-4,0	-4,0	-4,0	-4,0
Receiver cable loss	*dB*	3,0	3,0	3,0	3,0	3,0
Power at receiver input terminal (C)	*dBm*	-84,8	-88,3	-90,8	-92,8	-94,3
Noise at receiver terminal (Mobile)						
Receiver noise figure	*dB*	14,0	14,0	14,0	14,0	14,0
External noise figure	*dB*	5,0	5,0	5,0	5,0	5,0
Receiver noise floor (kTo)	*dBm/Hz*	-174,0	-174,0	-174,0	-174,0	-174,0
System noise power density (No)	*dBm/Hz*	-159,82	-159,82	-159,82	-159,82	-159,82
System Margin						
C/No	*dBHz*	75,02	71,50	69,00	67,06	65,48
Baud rate	*dBHz*	42,83	42,83	42,83	42,83	42,83
Available Es/No	*dB*	32,19	28,67	26,17	24,23	22,65
Theoretical Es/No	*dB*	18,0	18,0	18,0	18,0	18,0
Transmitter Implementation loss	*dB*	1,0	1,0	1,0	1,0	1,0
Receiver Implementation loss	*dB*	1,2	1,2	1,2	1,2	1,2
Required Es/No	*dB*	20,2	20,2	20,2	20,2	20,2
Residual System Margin	*dB*	12,0	8,5	6,0	4,0	2,4

Table A.6b: VDL Mode 4 air to air link budget (CLASS B)

Frequency (MHz)		Range (NM)				
137,000		10,0	20,0	40,0	60,0	80,0
Transmitter output power (Mobile)						
Power emitted at	*W*	4,0	4,0	4,0	4,0	4,0
Transmitter terminal	*dBm*	36,0	36,0	36,0	36,0	36,0
Transmitter feeder line loss	*dB*	3,0	3,0	3,0	3,0	3,0
Transmitter Antenna Gain	*dBi*	-4,0	-4,0	-4,0	-4,0	-4,0
SARPs Signal-in-Space						
EIRP emitted at transmitter	*dBm*	29,0	29,0	29,0	29,0	29,0
Standard free path loss	*dB*	100,5	106,5	112,6	116,1	118,6
Excess path loss	*dB*	0,0	0,0	0,0	0,0	0,0
EIRP at receiver antenna	*dBm*	-71,5	-77,5	-83,5	-87,1	-89,6
Signal power at receiver terminal (Mobile)						
Receiver antenna gain	*dBi*	-4,0	-4,0	-4,0	-4,0	-4,0
Receiver cable loss	*dB*	3,0	3,0	3,0	3,0	3,0
Power at receiver input terminal (C)	*dBm*	-78,5	-84,5	-90,5	-94,1	-96,6
Noise at receiver terminal (Mobile)						
Receiver noise figure	*dB*	14,0	14,0	14,0	14,0	14,0
External noise figure	*dB*	5,0	5,0	5,0	5,0	5,0
Receiver noise floor (kTo)	*dBm/Hz*	-174,0	-174,0	-174,0	-174,0	-174,0
System noise power density (No)	*dBm/Hz*	-159,82	-159,82	-159,82	-159,82	-159,82
System Margin						
C/No	*dBHz*	81,32	75,30	69,28	65,76	63,26
Baud rate	*dBHz*	42,83	42,83	42,83	42,83	42,83
Available Es/No	*dB*	38,49	32,47	26,45	22,93	20,43
Theoretical Es/No	*dB*	18,0	18,0	18,0	18,0	18,0
Transmitter Implementation loss	*dB*	1,0	1,0	1,0	1,0	1,0
Receiver Implementation loss	*dB*	1,2	1,2	1,2	1,2	1,2
Required Es/No	*dB*	20,2	20,2	20,2	20,2	20,2
Residual System Margin	*dB*	18,3	12,3	6,2	2,7	0,2

Annex B (informative): Bibliography

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