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**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**



Reference

REN/AERO-00007-1

Keywords

aeronautical, digital, radio, testing, VHF

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Foreword

This European Standard (Telecommunications series) has been produced by ETSI Technical Committee Aeronautics (AERO).

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 [10] parts 1 to 5, covering the VHF air-ground Data Link (VDL) Mode 4 radio equipment; Technical characteristics and methods of measurement for ground-based equipment.

NOTE: Minimum Operational Performance Specifications (MOPS) are also being developed for VDL Mode 4. EUROCAE have previously published Interim MOPS for VDL Mode 4 [i.2] which are a sub set of EN 302 842-1, 2 [7], 3 [8] and 4 [11]. EN 302 842-1, 2 [7], 3 [8] and 4 [11] complies with the requirements of CEC Mandate M/318 [i.3].

National transposition dates	
Date of latest announcement of this EN (doa):	31 March 2011
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	30 September 2011
Date of withdrawal of any conflicting National Standard (dow):	30 September 2011

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 VDL SARPs [2].

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 applies to the following radio equipment types:

- 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 VDL SARPs [2].

The present technical document provides part 1 of the technical specifications.

The present document is designed to ensure that equipment certified to it will be compatible with the relevant ICAO VDL SARPs [2] and ICAO VDL4 Technical Manual [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 receiver(s) may cover any 25 kHz channel from 108,000 MHz to 117,975 MHz.

The present document applies to "aeronautical mobile (airborne and in some cases ground vehicles)" 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 [10].

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:

- ICAO VDL4 Technical Manual [1] and ICAO VDL SARPs [2] produced under the auspices of the International Civil Aviation Organization (ICAO).
- 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:

- clause 2 provides references to relevant documents;
- clause 3 provides general definitions, abbreviations and symbols used;
- 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 VDL Mode 4 equipment requirements;
- clause 7 provides general design requirements;
- clause 8 provides environmental test requirements;
- clause 9 provides detailed test procedures for the physical layer;
- clause 10 provides installed equipment requirements;
- annex A provides a detailed cross-reference to the relevant requirements contained in reference [1];
- annex B provides an assessment of VDL Mode 4 Link Budget;
- annex C provides a Bibliography;
- a document history.

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

NOTE: Flight tests are defined in EN 302 842-2 [7].

Mandating and recommendation phrases

- a) "Shall"
 - The use of the word "Shall" indicates a mandated criterion; e.g. 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

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

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

NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are necessary for the application of the present document.

- [1] ICAO Doc 9816 (First Edition 2004): "Manual on VHF Digital Link (VDL) Mode 4, Part 2: Detailed Technical Specifications".
- [2] ICAO Annex 10 to the Convention on International Civil Aviation: "Aeronautical Telecommunications, Volume III: Communication Systems, Part I: Digital Data Communication Systems, chapter 6".
- [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] EUROCAE ED-12B/RTCA DO-178B: "Software Considerations in Airborne Systems and Equipment Certification".
- [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 (V1.3.1): "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 302 842-3 (V1.3.1): "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 3: Additional broadcast aspects".
- [9] Void.
- [10] ETSI EN 301 842: "VHF air-ground Digital Link (VDL) Mode 4 radio equipment; Technical characteristics and methods of measurement for ground-based equipment".
- [11] ETSI EN 302 842-4 (V1.2.2): "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 4: Point-to-point functions".

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

- [i.1] ETSI EN 300 113-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Land mobile service; Radio equipment intended for the transmission of data (and/or speech) using constant or non-constant envelope modulation and having an antenna connector; Part 1: Technical characteristics and methods of measurement".
- [i.2] EUROCAE ED-108A: "MOPS for VDL Mode 4 Aircraft Transceiver for ADS-B".
- [i.3] CEC Mandate M/318: "Mandate to CEN/CENELEC/ETSI for standardisation in the field of air traffic management systems and Galileo local components".
- [i.4] EASA CS-25: "Large Aeroplanes" Appendix F (previously Joint Airworthiness Requirements (JAR), Part 25).

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 Telecommunication 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 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): ratio between the number of erroneous bits received and the total number of bits transmitted

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

Co-Channel Interference (CCI): 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 Telecommunication 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 should 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 (MAC): 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 (OSI) 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 CTRL and UCTRL DLPDUs and that are unique to the VHF digital link environment

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

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

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

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 μ s

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 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 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: sequence of source address, burst ID, information, slot reservation, and Cyclic Redundancy Check (CRC) fields, bracketed by opening and closing flag sequences

NOTE: The start of a burst may occur only at the start of a VDL Mode 4 time slot, 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

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 station address: 27-bit identifier used to uniquely identify a VDL Mode 4 station, which may be unique or locally unique. A combination of the 24 bit ICAO aircraft address plus 3 additional bits to discriminate between unique/non-unique and ground/mobile addresses

VDL station: 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 messages over the air-air and air-ground interface and comprises, at a minimum: a physical layer, a media access control sublayer, and a unique station address.

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.

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.

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 Power
ACR	Adjacent Channel Rejection
ADS-B	Automatic Dependent Surveillance Broadcast
AMS	Aeronautical Mobile Service
ANC	Air Navigation Commission
ATN	Aeronautical Telecommunication Network
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BITE	Built In Test Equipment
BT	Bandwith Time
CCI	Co-Channel Interference
CRC	Cyclic Redundancy Check

CTRL	ConTRoL (DLPDU)
CW	Continuous Wave
dB	deciBel
dBm	deciBels with respect to 1mW
DLE	Data Link Entity
DLPDU	Data Link Protocol Data Unit
DLS	Data Link Service
EIRP	Equivalent Isotropically Radiated Power
FCS	Frame Check Sequence
FIS-B	Flight Information Service - Broadcast
FM	Frequency Modulation
GFSK	Gaussian Filtered Frequency Shift Keying
GNSS	Global Navigation Satellite System
GSC	Global Signalling Channel
ICAO	International Civil Aviation Organization
ID	IDentity
IF	Intermediate Frequency
ISO	International Organization for Standardization
LME	Link Management Entity
MAC	Media Access Control
MASPS	Minimum Aviation System Performance Standards
MER	Message Error Rate
MOPS	Minimum Operational Performance Specifications
NENV	Environmental Noise
NM	Nautical Mile
NRZI	Non-Return to Zero Inverted
ns	nanoseconds
OSI	Open Systems Interconnection
PC	Personal Computer
ppm	parts per million
rcvr	receiver control field
RF	Radio Frequency
SARPs	Standards And Recommended Practices
STDMA	Self-organizing Time Division Multiple Access
TDMA	Time Division Multiple Access
TIS-B	Traffic Information Service - Broadcast
UCTRL	Unacknowledged ConTRoL data broadcast (DLPDU)
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

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 or duplex mode.

NOTE: The following requirement is contained in ICAO VDL SARPs [2]: "Mobile and ground VDL Mode 4 stations should access the physical medium operating in simplex mode". This requirement is overly restrictive, as there are circumstances in which a mobile may satisfactorily operate in duplex mode (e.g. when there is a sufficient frequency separation between the transmit and receive frequencies).

5.1.1 Functions

The tasks of the physical layer shall 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 physical layer shall appropriately decode received RF input signals and forward them to the higher layers for processing.

5.1.3 Data transmission

The 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 (e.g. NRZI encoding). The training sequence shall be the 24 bit sequence 0101 0101 0101 0101 0101 transmitted from left to right. Binary *ones* and binary *zeros* shall be generated with a modulation index of 0,25 plus or minus 0,03 and a BT product of 0,28 plus or minus 0,03.

6 VDL Mode 4 equipment requirements

Unless otherwise stated, all specifications shall be met under room conditions, and under environmental conditions as 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

6.1.1 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 ICAO VDL SARPs [2].

NOTE: Manufacturers should note that in future the tuning range for the receiver(s) may cover any 25 kHz channel from 108,000 MHz to 117,975 MHz.

6.1.2 BER requirement

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: This requirement is derived from the assumed performance for VDL Mode 4 inferred from ICAO VDL SARPs [2].

NOTE 2: 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 3: 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).

NOTE 4: The following requirement is contained in ICAO VDL SARPs [2]: "A receiver should be capable of demodulating a transmission of minimum length 19 200 bits without degradation of BER". However compliance with such a requirement does not on its own provide sufficient assurance of the BER/MER. As stated in the test for BER in clause 9.2.1, BER test statistics should be generated from a sample size large enough to enable an average BER to be calculated within a reasonable error range.

6.1.3 Reference signal level

The reference signal level applied at the receiver input for all receiver requirements, unless otherwise stated, shall be minus 87 dBm in the frequency range 118,000 MHz to 136,975 MHz.

NOTE: This reference level is derived as follows. ICAO VDL SARPs [2] clause 6.9.5.1.1.1 defines the signal-in-space power received at the antenna at the edge of the service volume to be -87,8 dBm. Assuming a 4 dB antenna loss plus a 2 dB cable loss in the aircraft (as determined in annex A of the present document), the minimum signal level expected at the receiver input is minus 93,8 dBm. European practice is to set the reference signal level at some figure higher than the minimum signal level. Therefore, the appropriate reference signal level for test purposes is chosen to be minus 87 dBm.

6.1.4 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 6.1.2 in the frequency range 118,000 MHz to 136,975 MHz.

NOTE 1: This requirement is based on the minimum power level to achieve a BER of 10^{-4} or better at an air-air operating range of 120 NM for Class A transmitters and 60 NM for Class B transmitters, assuming antenna/cable losses in the aircraft and noise figures in accordance with the assumptions made in annex A.

NOTE 2: Manufacturers should note that in future the tuning range for the receiver(s) may also cover any 25 kHz channel from 108,000 MHz to 117,975 MHz. Where a receiver is required to support operational requirements in the frequency range 108,000 to 117,975 MHz, an appropriate sensitivity level would need to be determined.

6.1.5 Adjacent channel rejection

The minimum Adjacent Channel Rejection (ACR) shall be determined in the presence of the reference signal level (clause 6.1.3).

The ACR required to achieve the BER (clause 6.1.2) shall be equal to, or greater than 32 dB, when tested using DSB-AM, VDL Mode 2 and VDL Mode 4 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 6.1.2) shall be equal to, or greater than 60 dB, when tested using DSB-AM, VDL Mode 2 and VDL Mode 4 undesired signals on each side of the wanted signal and at a nominal channel separation of 100 kHz from it.

NOTE 1: This requirement is derived from ICAO VDL SARPs [2].

NOTE 2: 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.

6.1.6 Receiver performance in the presence of strong signals inside the VHF aeronautical band

The BER requirement (clause 6.1.2) 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.

6.1.7 Receiver performance in the presence of strong signals outside the VHF aeronautical band

The BER requirement (clause 6.1.2) shall be achieved when one of the unwanted signals specified below is applied in turn and in addition to the reference signal level (clause 6.1.3).

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: 108,000 MHz to 156,000 MHz (excluding 117,975 MHz to 137,025 MHz)

NOTE 2: There is no equivalent ICAO VDL SARPs [2] requirement.

Unwanted signal B:

Level: minus 7 dBm.
 Modulation: none.
 Frequency range: 50 kHz to 1 215,000 MHz (excluding the range 87,500 MHz to 156,000 MHz)

NOTE 3: There is no equivalent ICAO VDL SARPs [2] requirement. These requirements are based on EUROCAE ED-23B.

NOTE 4: 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: 87,500 MHz to 107,900 MHz

6.1.8 Desired signal dynamic range

The receiver shall continue to achieve the BER requirement (clause 6.1.2) when the reference signal level is increased to a level of minus 7 dBm.

NOTE: There is no equivalent ICAO VDL SARPs [2] requirement. The requirement is derived from EUROCAE ED-23B.

6.1.9 Symbol rate capture range

The BER requirement (clause 6.1.2) shall be achieved when the reference signal level is subject to a symbol rate offset of plus/minus 50 parts per million.

NOTE: This requirement is derived from the transmitter symbol rate stability standard specified in ICAO VDL SARPs [2].

6.1.10 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 6.1.2) shall be achieved when the reference signal level is subject to a frequency offset of plus/minus 967 Hz.

NOTE 1: This value is composed of the maximum transmitter frequency error at 136,975 MHz (plus or minus 685 Hz) and the maximum Doppler shift (plus or minus 282 Hz).

NOTE 2: This requirement is derived from the transmitter frequency stability standard specified in ICAO VDL SARPs [2].

6.1.11 Doppler rate

The BER requirement (clause 6.1.2) shall be achieved when the reference signal level, at the maximum limit of frequency capture range specified clause 6.1.10, is additionally subject to a carrier frequency change rate of plus/minus 300 Hz/s.

6.1.12 Co-channel interference

The BER requirement (clause 6.1.2) shall be achieved when a VDL Mode 4 interfering signal 12 dB below the reference signal is applied in addition to the reference signal level.

6.1.13 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 minus 57 dBm over the frequency range of 50 kHz to 1 215 MHz and shall not exceed minus 64 dBm over the frequency range 108,000 MHz to 137,000 MHz.

NOTE: There is no equivalent direct ICAO VDL SARPs [2] requirement - just a general requirement (clause 6.3.3.1 for mobiles and clause 6.2.3.1 for ground stations) to keep to a minimum. The requirements are based on EUROCAE ED-23B. Note also that Appendix 8 to the Radio Regulations (Radio Regulation 304) provides further information on this topic.

6.1.14 FM broadcast intermodulation

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

The BER requirement (clause 6.1.2) shall be achieved in the presence of two unmodulated interfering signals within the frequency range of 87,500 MHz to 107,900 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.

6.1.15 In-band intermodulation

The BER requirement (clause 6.1.2) 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 plus or minus 1 MHz.

Unwanted signal B:

Level: minus 32 dBm.
Modulation: VDL Mode 4 modulation as defined in clause 5.2.
Frequency: test frequency plus or minus 2 MHz.

NOTE: Manufacturers should consider improving on the above values.

6.2 Transmitter requirements

Two classes of transmitter equipment are defined: Class A and Class B (see clause 6.2.3). All transmitter requirements shall apply to Class A and Class B transmitters unless otherwise stated.

NOTE 1: All transmitter measurements should 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 milliseconds (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 milliseconds (for 202 NM guard range) which will therefore be taken as the minimum "off" period.

The maximum duty cycle is therefore 25,4 milliseconds in "transmit" mode followed by 1,25 milliseconds "off".

It should be noted that a duty cycle based on a longer message than 2 slots should be used in the case of a system supporting more than the minimum core functionality (e.g. a system supporting point-to-point functionality).

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

6.2.1 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 ICAO VDL SARPs [2].

NOTE: 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.

6.2.2 Channel bit rate

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

6.2.3 Manufacturer's declared output power

Class A: The transmitter mean output power, measured at the output of the transmitter, shall be 15 watts plus or minus 1,5 dB (e.g. 10,6 watts to 21,2 watts) 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.

Class B: The transmitter mean output power, measured at the output of the transmitter, shall be 4 watts plus or minus 1,5 dB (e.g. 2,8 watts to 5,6 watts) 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.

NOTE 1: The difference between Class A and Class B is 6 dB. This gives Class A about twice the nominal range of Class 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 power stabilization segment shall have a duration of 832 microseconds. The transmitter power level at the end of the transmitter power stabilization segment shall be no less than 90 % of the mean output power level measured during signal transmission (steady state power level).

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 minus 90 dB below the manufacturer declared output power level 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.

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 manufacturer's declared output power (e.g. 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 minus 60 dBc.

When the transmitter is "idle" (e.g. 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 nanowatt (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.

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.

NOTE 1: Based on ICAO VDL SARPs [2].

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

NOTE 2: Based on ICAO VDL SARPs [2].

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.

NOTE 3: Based on ICAO VDL SARPs [2].

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.

NOTE 4: Based on ICAO VDL SARPs [2].

NOTE 5: Regarding transceiver equipment manufactured to comply with Amendment 72 of the ICAO VDL SARPs [2], manufacturers are reminded that the ICAO Air Navigation Commission (ANC) has determined that these equipments may not be installed after 1/1/2002 and may not be operated, in any aircraft after 1/1/2005.

6.2.8 Wide-band noise

Beyond the fourth adjacent channel, the RF power measured in a 25 kHz channel bandwidth shall decrease at a rate of no less than 5 dB per octave of channel offset (for example, minus 43 dBm at the eighth adjacent channel, minus 48 dBm at the sixteenth adjacent channel, and minus 53 dBm at the thirty-second adjacent channel) to minus 53 dBm or less under all operating conditions (including transmitter attack and delay).

NOTE 1: Based on ICAO VDL SARPs [2].

NOTE 2: Regarding transceiver equipment manufactured to comply with Amendment 72 of the ICAO VDL SARPs [2], manufacturers are reminded that the ICAO Air Navigation Commission (ANC) has determined that these equipments may not be installed after 1/1/2002 and may not be operated, in any aircraft after 1/1/2005.

6.2.9 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 minus 3 dB of the manufacturer's declared value (see clause 6.2.3).

6.2.10 Adjacent channel transient power

The transient power in the adjacent channels shall not exceed a value of 60 dB below the carrier power (conducted) of the transmitter in decibels relative to the carrier power (dBc), without the need to be below 2 microwatts (minus 27 dBm).

NOTE 1: Transient power is the power falling into adjacent (or other) spectrum due to the switching on or off of a transmitter.

NOTE 2: This requirement is based on a similar requirement in EN 300 113-1 [i.1], clause 5.1.9.2.1.

6.2.11 Frequency tolerance

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

6.2.12 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.

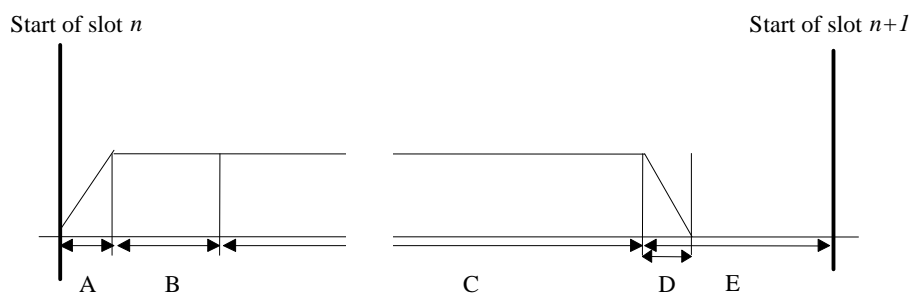
NOTE: The nominal start of transmission always coincides with the time of the start of a slot.

6.2.13 Structure of bursts

The start of a burst shall be aligned with the start of a UTC-second (e.g. with the start of a slot).

NOTE 1: A VDL Mode 4 burst consists of:

- transmitter power stabilization (A);
- synchronization and ambiguity resolution (B);
- data (C);
- transmitter decay (D);
- and propagation guard time (E).



A burst shall contain one or multiple frames in the "data" portion of the burst, with n frames separated by $n + 1$ flags.

NOTE 2: For example, a burst containing two frames, would require three flags, with the middle flag separating the two frames.

Each frame shall conform to the burst structure as specified in the ICAO VDL4 Technical Manual [1], clause 1.3.2.

NOTE 3: The above requirement implicitly requires that the bit position with respect to the start of an octet is maintained between the frame's initial flag and the message ID, and between the reservation field and the final flag. Within the information field, whether or not bit position is maintained with respect to the start of an octet is dependent on the application.

NOTE 4: The information field within a frame may contain multiple messages, depending on the application requirements, with each message identified by a message identifier field. The procedure by which one message may follow another message within the information field of a frame is dependent on the application. In EN 302 842-3 [8], this procedure has been defined for the applications specified.

6.3 Transceiver requirements

6.3.1 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 1 second. Reset to an operational mode for the affected amplifier shall require a manual operation.

6.3.2 Tuning time

The transmitter shall be capable of tuning to and operating on any 25 kHz channel in its operating range within 13 milliseconds 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 should be capable of operating on that new channel in slot N + 2.

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 should 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 millisecond after completing a transmission.

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

6.3.5 Short power interrupt

The VDL Mode 4 transceiver shall continue to operate all functions with the exception of the transmitter, throughout a short power interruption, according to the requirements of the appropriate equipment category in ED-14D/ DO-160D [6].

NOTE: The test for this requirement is a protocol test and is therefore contained in EN 302 842-2 [7].

6.3.6 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.

6.3.7 System timing requirements

A VDL mode 4 station which is unable to maintain either primary or secondary time, shall not transmit.

6.3.8 Reservation table stored in memory

A VDL Mode 4 transceiver shall always have an up-to-date copy of its reservation table stored in memory, that shall be stored for at least 10 seconds following power failure.

NOTE: This is to minimize the impact of power failure, allowing the equipment to continue operation if the m2 filter permits.

6.3.9 Failure of associated equipment

In the event of any failure of associated equipment providing position and/or timing information, the transceiver shall ignore data received from such associated equipment while the failure indication exists, and shall take any other appropriate action as defined by the ICAO VDL4 Technical Manual [1] (e.g. this may include issue of a General failure burst). Data derived from associated equipment under failure conditions shall not be transmitted.

In the event of unavailability of application data, the transceiver shall provide an indication that the data is not available, in accordance with the applicable application standard.

NOTE: Application standards may specify a flag to indicate invalidity or unavailability of data, or else a reserved value.

6.3.10 Simultaneous reception

A VDL Mode 4 station shall be capable of receiving two channels simultaneously.

NOTE: The test for this requirement is a protocol test and is therefore contained in EN 302 842-2 [7].

Recommendation:

A VDL Mode 4 station should be capable of receiving additional channels simultaneously as required by operational services.

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 seconds and shall meet the requirements of the present document within a further 60 seconds under normal conditions.

NOTE: For testing purposes, a primary time source should 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) [i.4].

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 Failure of VDL Mode 4 equipment

Failure of the VDL Mode 4 equipment shall not degrade the operation of other airborne equipment.

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 [5]. The RTCA equivalent document DO-178B, or later editions of ED-12B/DO-178B [5], 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 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 e.g. simplex/dual, and availability of cross-links between transceivers;
- f) channel frequency selection.

7.14 Provision for multiple redundant VDL4 transceivers

Recommendation:

If it is required to meet operational availability requirements, provision should be made for multiple redundant VDL Mode 4 Transceivers (e.g. a "hot" standby unit) with cross-links between them which may provide for:

- a) Exchange of reservation information on all channels monitored by each transceiver, so as to enable either transceiver to continue to operate on a channel previously monitored by the other transceiver in the event of an equipment failure, without a need to perform net-entry.
- b) Co-ordination of the channels monitored and applications supported by each transceiver in normal operation.
- c) Monitoring operation of individual transceivers, to allow timely response to an equipment failure. In the event of such failure, cross-links allow the system to adjust its operation so as to maintain operation of the most critical applications.

NOTE: Requirements and tests for cross-links are outside the scope of the present document.

7.15 Reception capability

The minimum reception capability shall be for two receivers.

NOTE: Depending on the applications and the traffic densities to be supported, additional receivers will be required.

7.16 Transmission capability

The minimum transmission capability shall be for one transmitter.

NOTE 1: Depending on the applications and the traffic densities to be supported, additional transmitters may be required.

A station shall be capable of transmitting in 120 slots per minute.

NOTE 2: This takes into account the minimum requirement to operate on two global signalling channels. This also permits additional channels to be monitored with a receive function only.

NOTE 3: It should be noted that additional transmission capability may be required for point-to-point operation.

7.17 Monitoring of proper operation

The VDL Mode 4 transceiver shall contain Built-In Test Equipment (BITE) which shall be capable of detecting and annunciating failures of the transceiver system.

Automatic monitoring of correct operation of the VDL Mode 4 equipment shall take place continuously during operation, taking into account any impaired functionality detected in associated equipment (e.g. loss or reported failure of sources of position and time).

The BITE shall display the system condition and indicate any failures upon activation of the power-up self test. The BITE shall operate during the time the transceiver is being powered up and at other times when commanded manually by an operator.

No failure occurring within the BITE subsystem shall interfere with the normal operation of the transponder.

The VDL Mode 4 equipment shall be capable of providing an indication to the crew of any detected failure.

The BITE history of malfunction events shall be stored for later retrieval.

NOTE: An acceptable means of compliance would be to provide system status monitor(s) and built-in test functions which would detect and indicate to the flight crew a failure of the VDL Mode 4 system due to any of the following:

- a) loss of system electrical power to the VDL Mode 4 equipment;
- b) failure of digital interfaces;
- c) input data flagged as failed by source equipment, or else fails to pass a credibility check;
- d) failure of the equipment to perform intended functions;
- e) removal of the equipment from the aircraft.

7.18 Power-up self test

The VDL Mode 4 transceiver shall automatically perform a power-up self test when it is turned on. The power-up self test shall not be initiated in the event of short duration power interrupts as defined in clause 6.3.5. The transceiver shall provide an operator-initiated manual self-test capability for troubleshooting and installation verification. The operator shall be provided with the results of the self-test.

8 Environmental test requirements

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 ED-14D/DO-160D [6].

The tests in tables 8.1 and 8.2 shall be conducted at the frequencies specified in clause 5.1.1.7.

8.2 Receiver

Table 8.1: Receiver environmental test conditions matrix

Receiver subsystem		EN requirement clauses							Notes
ED-14D/DO-160D [6] clauses	Function	6.3.4 Transmitter to receiver turnaround time	6.1.4 Sensitivity	6.1.5 Adjacent Channel Rejection	6.1.6 Receiver performance in the presence of strong signals inside the VHF aeronautical band	6.1.7 Receiver performance in the presence of strong signals outside the VHF aeronautical band	6.1.8 Desired signal dynamic range	6.1.9 Symbol rate capture range	
4.5.1	Low Temperature	X	X	X	X	X	X	X	5
4.5.2, 4.5.4	High Temperature	X	X						5
4.5.3	High Temperature	X	X	X	X	X		X	
4.6.1	Altitude		X	X					
4.6.2	Decompression (if required)		X	X					5
4.6.3	Overpressure (if required)		X	X					5
5.0	Temperature Variation		X	X					
6.0	Humidity		X	X					5
7.0	Shock		X	X					1
8.0	Vibration		X	X					
9.0	Explosion proofing (if required)								2, 3
10.0	Waterproofing (if required)		X	X					
11.0	Fluids Susceptibility (if required)		X	X					
12.0	Sand and Dust (if required)		X	X					
13.0	Fungus Resistance (if required)		X	X					
14.0	Salt Spray (if required)		X	X					
15.0	Magnetic Effect								3
16.5.1, 16.5.2	Power Input (Normal Operating Conditions)		X	X					

Receiver subsystem		EN requirement clauses							Notes
ED-14D/DO-160D [6] clauses	Function	6.3.4 Transmitter to receiver turnaround time	6.1.4 Sensitivity	6.1.5 Adjacent Channel Rejection	6.1.6 Receiver performance in the presence of strong signals inside the VHF aeronautical band	6.1.7 Receiver performance in the presence of strong signals outside the VHF aeronautical band	6.1.8 Desired signal dynamic range	6.1.9 Symbol rate capture range	
16.5.3, 16.5.4	Power Input (Abnormal Operating Conditions)		X						
17.0	Voltage Spike		X	X					
18.0	Audio Frequency Conducted Susceptibility - Power Inputs		X	X					
19.0	Induced Signal Susceptibility		X	X					
20.0	Radio Frequency Susceptibility (Radiated and Conducted)		X	X					4
21.0	Emission of Radio Frequency Energy								3
22.0	Lightning Induced Transient Susceptibility (if required)	X	X	X	X	X	X	X	
23.0	Lightning Direct Effects (if required)	X	X	X	X	X	X	X	
24.0	Icing (if required)		X	X					
25.0	Electrostatic Discharge (ESD) (if required)	X	X	X	X	X	X	X	

NOTE 1: The application of this test may result in damage to the equipment. It may, therefore, be conducted after the other tests. Furthermore, clause 2.7 of ED-14D/DO-160D [6] -"Effects of Tests" - does not apply following crash safety shocks.

NOTE 2: The application of this test may result in damage to the equipment. It may, therefore, be conducted after the other tests. Furthermore, clause 2.7 of ED-14D/DO-160D [6] -"Effects of Tests" - does not apply.

NOTE 3: Equipment performance requirements for this function of the unit under test are defined within ED-14D/ DO-160D [6].

NOTE 4: The radiated and conducted RF test signal should exclude the frequency to which the receiver is tuned and the response within its resonant passbands.

NOTE 5: All mechanical devices shall perform their intended functions.

8.3 Transmitter

Table 8.2: Transmitter environmental test conditions matrix

Transmitter subsystem		EN Requirement clauses									Notes
ED-14D/DO-160D [6] clauses	Function	6.3.3 Receiver to transmitter turnaround time	6.2.2 Channel Bit Rate	6.2.3 Manufacturer's declared output power	6.2.4 RF power rise time	6.2.5 RF power release time	6.2.6 Spurious missions	6.2.7 Adjacent channel power	6.2.8 Wide-band noise	6.2.9 Frequency tolerance	
4.5.1	Low Temperature	X	X	X	X	X	X	X			9
4.5.2, 4.5.4	High Temperature			X				X	X		1, 9
4.5.3	High Temperature	X	X	X	X	X	X	X			
4.6.1	Altitude			X				X			2
4.6.2	Decompression (if required)			X				X			3, 9
4.6.3	Overpressure (if required)			X				X			9
5.0	Temperature Variation			X				X			
6.0	Humidity			X				X			9
7.0	Shock			X				X			4
8.0	Vibration			X				X		X	
9.0	Explosion proofing (if required)										5, 6
10.0	Waterproofing (if required)			X				X			
11.0	Fluids Susceptibility (if required)			X				X			
12.0	Sand and Dust (if required)			X				X			
13.0	Fungus Resistance (if required)			X				X			
14.0	Salt Spray (if required)			X				X			
15.0	Magnetic Effect										6
16.5.1, 16.5.2	Power Input (Normal Operating Conditions)			X				X		X	7
16.5.3, 16.5.4	Power Input (Abnormal Operating Conditions)			X							8
17.0	Voltage Spike			X				X			
18.0	Audio Frequency Conducted Susceptibility - Power Inputs			X				X		X	
19.0	Induced Signal Susceptibility			X				X		X	

Transmitter subsystem		EN Requirement clauses									
ED-14D/DO-160D [6] clauses	Function	6.3.3 Receiver to transmitter turnaround time	6.2.2 Channel Bit Rate	6.2.3 Manufacturer's declared output power	6.2.4 RF power rise time	6.2.5 RF power release time	6.2.6 Spurious missions	6.2.7 Adjacent channel power	6.2.8 Wide-band noise	6.2.9 Frequency tolerance	Notes
20.0	Radio Frequency Susceptibility (Radiated and Conducted)			X				X			
21.0	Emission of Radio Frequency Energy										6
22.0	Lightning Induced Transient Susceptibility (if required)			X							
23.0	Lightning Direct Effects (if required)	X	X	X	X	X	X				
24.0	Icing (if required)			X				X			
25.0	Electrostatic Discharge (ESD) (if required)	X	X	X	X	X	X				
NOTE 1: Under the conditions of these tests, the specified output power of clause 6.2.3 of the present document may be degraded by up to 6 dB. There shall be no evidence of materials exuding or dripping from the equipment components.											
NOTE 2: Ensure that there is no evidence of corona or arcing without modulation and with modulation.											
NOTE 3: Under the conditions of these tests, the specified output power of clause 6.2.3 of the present document may be degraded by up to 1,5 dB.											
NOTE 4: The application of this test may result in damage to the equipment. It may therefore, be conducted after the other tests. Furthermore, clause 2.7 of ED-14D/DO-160D [6] - "Effects of Tests" - does not apply following crash safety shocks.											
NOTE 5: The application of this test may result in damage to the equipment. It may, therefore, be conducted after the other tests. Furthermore, clause 2.7 of ED-14D/DO-160D [6] - "Effects of Tests" - does not apply.											
NOTE 6: Equipment performance requirements for this function of the unit under test are defined within ED-14D/ DO-160D [6].											
NOTE 7: In respect to Sections 16.5.2.3 and 16.5.2.4 (Momentary power interruptions), the tests may be carried out following the power interruptions.											
NOTE 8: Under the conditions of these tests, the specified output power of clause 6.2.3 of the present document may be degraded by up to 3 dB. For equipment operating on DC power, the gradual reduction to zero of the primary power voltage(s) should produce no detrimental effects (see clause 2.7 of ED-14D/DO-160D [6] - "Effects of Tests").											
NOTE 9: All mechanical devices shall perform their intended functions.											

NOTE: Some of the performance requirements in clause 6 of the present document are not required to be tested to all of the conditions contained in ED-14D/DO-160D [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 of the present document will not be measurably degraded by exposure to these conditions.

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. Prior to testing the equipment shall be switched on for not less than 5 minutes. 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 (see clauses 9.2 to 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 = $100 \times [1 - (\text{probability of message success})]$
 = $100 \times [1 - (1 - \text{BER})^{(\text{number of bits in message})}]$.

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 6.1.2).

- 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 VDL 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 , statistics shall be generated from a series of transmissions which provide at least 1×10^5 bits.

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:

- a) VDL Mode 4 waveform (GFSK, symbol rate 19,200 Hz, 1 bit per symbol, frequency deviation 2 400 Hz, Gaussian filter, modulation index = 0,25 plus or minus 0,03 and BT = 0,28 plus or minus 0,03).
- b) VDL Mode 2 waveform (narrow band FM, maximum deviation of plus/minus 5,25 kHz, 400 Hz sine wave modulation).
- c) Unmodulated.
- d) DSB-AM waveform (1 kHz modulated signal with 30 % modulation depth).

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.

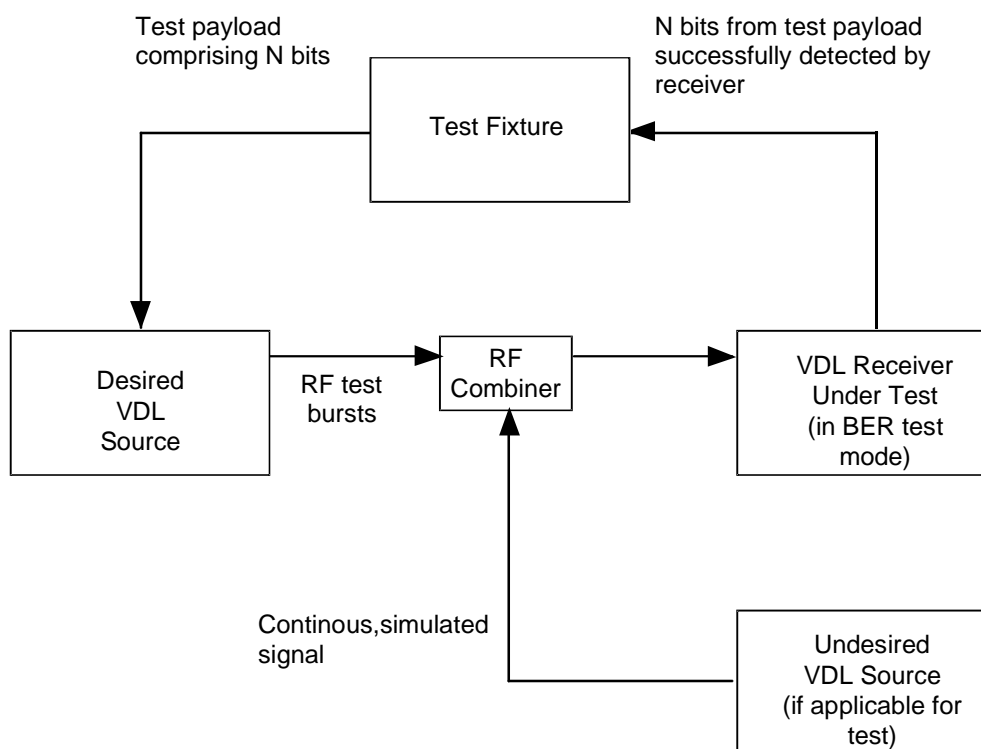


Figure 9.1: Receiver BER measurement

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 6.1.4) 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 that the Sensitivity requirement (see clause 6.1.4) is achieved at all of the three test frequencies (see clause 9.1.7).

9.2.3 Adjacent Channel Rejection (ACR)

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 6.1.3) 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 9.2.1).
- 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 or DSB-AM interfering signal (see clause 9.2.1 - the test should be repeated for each of these three interfering waveforms). 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 6.1.2). Record the interfering signal level at the receiver input terminals.
- Step 7: Repeat steps 5 and 6 for the lower adjacent channel.
- Step 8: Determine the ratio between the Desired and Interfering 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).
- Step 10: Check that the ACR requirement (defined in clause 6.1.5) is achieved in all cases.

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

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 fixture. Adjust signal generator A to provide the reference signal level (see clause 6.1.3) 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 6.1.6. Adjust the level of the signal generator B to the unmodulated interfering signal power value (also defined in clause 6.1.6) 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 steps 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 6.1.2) is achieved in all cases.

NOTE: The noise sidebands of the interfering signal should not interfere with the desired signal in the receiver passband. The isolation offered by the RF combiner should 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 6.1.3) 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 a low-band frequency for one of the frequency bands defined for unwanted signal A defined in clause 6.1.7. Adjust the level of generator B to provide the interfering signal level also defined in clause 6.1.7 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 steps 5 and 6 by tuning generator B to a mid-band test frequency for each of the bands defined for unwanted signal A in clause 6.1.7.
- Step 8: Repeat steps 5 and 6 by tuning generator B to an upper band test frequency for each of the bands defined for unwanted signal A in clause 6.1.7.
- Step 9: Repeat steps 4 to 8 for the bands defined for unwanted signals B and C in clause 6.1.7.
- Step 10: Repeat steps 4 to 9 at the remaining two test frequencies (clause 9.1.7).
- Step 11: Check that the BER requirement (see clause 6.1.2) is achieved in all cases.

NOTE 1: The noise sidebands of the interfering signal should not interfere with the desired signal in the receiver pass band. The isolation offered by the RF combiner should 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 6.1.8) 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 6.1.2) 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 6.1.3) 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 6.1.9.
- 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 6.1.9.
- 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 6.1.2) 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 6.1.10 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 6.1.3) 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 6.1.10).
- Step 6: Repeat steps 3 to 5 at the two remaining test frequencies (clause 9.1.7).
- Step 7: Check that the BER requirement (clause 6.1.2) 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 6.1.3) 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 6.1.11. 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 6.1.2) 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 6.1.3) 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 interfering signal as specified in clause 6.1.12, with signal level 12 dB below the reference signal level (clause 6.1.3) at the receiver input terminals.
- Step 6: Apply the desired signal and the VDL Mode 4 interfering 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 6.1.2) 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 6.1.13.

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 transceiver 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 6.1.13.
- Step 4: Record the frequency and power level of all signals which exceed the limit specified in clause 6.1.13.
- 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 6.1.13 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 6.1.3) 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 6.1.14 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 6.1.2) is achieved in all cases.

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

NOTE 2: Third order intermodulation frequencies are defined as:

$$F_A = 2F_B \pm F_C \text{ or } F_B \pm 2F_C$$

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.

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	95,8	120,0	-5,0
107,9	87,5	128,3	-5,0

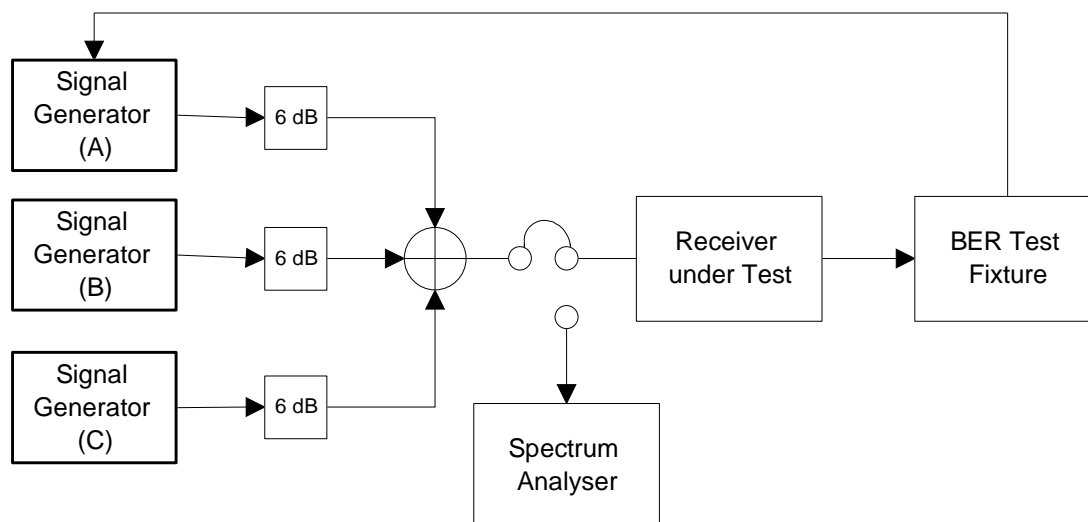


Figure 9.2: Intermodulation measurement

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 6.1.2) is achieved in all cases.

NOTE: In the absence of the desired signal (e.g. Generator A switched "off"), the intermodulation products produced by any interaction between the interfering signal generators B and C, should 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

NOTE: The following tests may require the use of a vector signal analyser. A vector signal analyser integrates frequency-domain and time domain analysis to provide advanced measurements of complex signals. These analysers offer complex signal analysis such as digital modulation (e.g. GFSK for VDL-Mode 4) plus AM/FM/PM demodulation, vector spectrum analysis and time-gated spectrum analysis.

9.3.1 Channel bit rate

This requirement (clause 6.2.2) may be satisfied by written evidence.

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

NOTE: The evidence should demonstrate that consideration has been given to the temperature variation which the equipment will be subjected (see clause 8) 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 or vector signal analyser.

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 VDL Mode 4 messages from the transmission generator.
- Step 4: Set the power meter (or vector signal analyser) to capture the VDL Mode 4 transmitted signal and determine the average 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 Class 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 should be measured during signal transmission (steady state power level) and should not be averaged over the time intervals between signal transmissions.

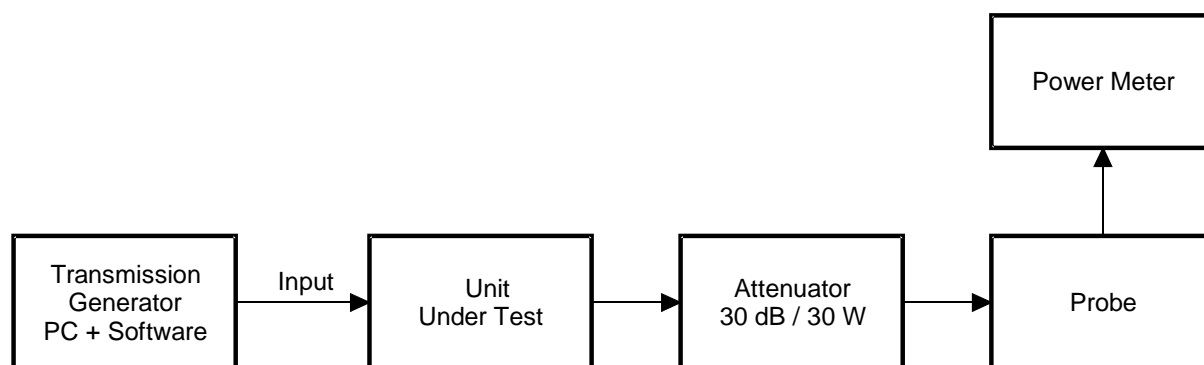


Figure 9.3: Output power measurement

9.3.3 RF power rise time

Equipment required:

- Transmission generator, PC with suitable software.
- Attenuator 30 dB, 30 W.
- Vector signal analyser.

Measurement procedure:

- Step 1: Connect the equipment as shown in figure 9.4.
- Step 2: Configure the vector analyser to display both constellation diagram and power versus time charts.
- Step 3: Use the transmission generator to produce a minimum length VDL Mode 4 message and capture the start of this message.
- Step 4: Using both constellation and power versus time display, identify the first symbol of the synchronization sequence.
- Step 5: Record the RF power level at the moment when the first synchronization symbol (defined in clause 6.2.4) occurs.
- Step 6: Check that the RF power rise time defined in clause 6.2.4 is achieved.

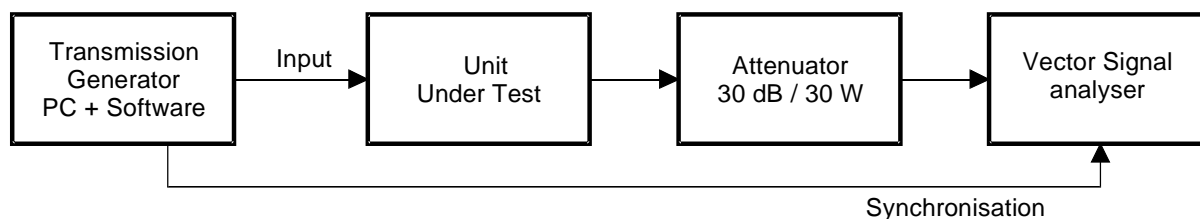


Figure 9.4: RF power rise and release time measurement

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: Configure the vector signal analyser in digital demodulation mode, to display log magnitude of I & Q vectors, with normalization disabled. Set the Y axis to read "dBm". The symbol times are displayed on the resultant profile of power versus time. Use of the trigger hold off function will aid signal acquisition.
- Step 3: Using the transmission generator to produce a minimum length VDL Mode 4 message, capture the end of this message on the vector signal analyser.
- Step 4: Use the power versus time display to determine the corresponding profile for each symbol of the "power down" ramp.
- Step 5: 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 (clause 9.1.7).
- 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 VDL 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 9: Check that the results do not exceed the limits specified in clause 6.2.6.

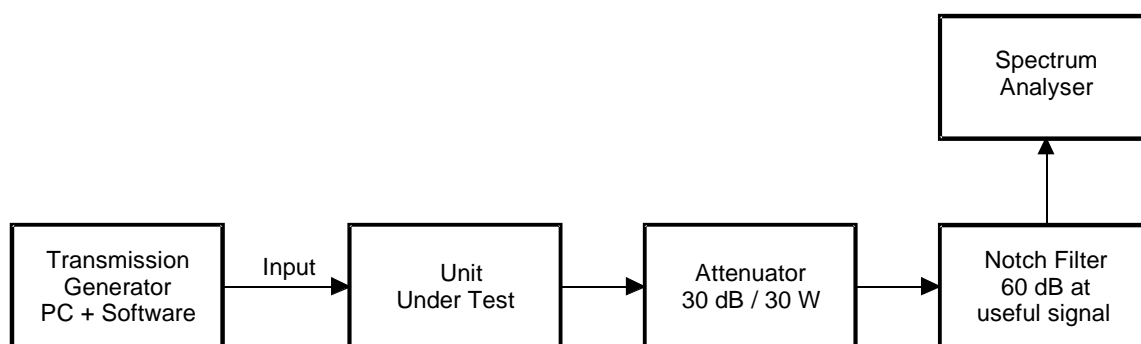


Figure 9.5: Spurious emissions measurement

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 VDL 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 a 100 kHz span, display the VDL 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 and then in a 25 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 (see Bibliography), 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.

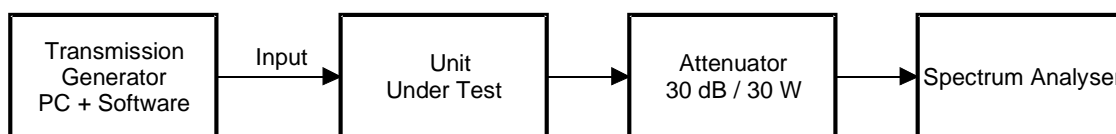


Figure 9.6: First adjacent channel power measurement

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 plus/minus 50 kHz.
- Spectrum analyser with power band marker function.

Measurement procedure:

Important: To protect the analyser, 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.

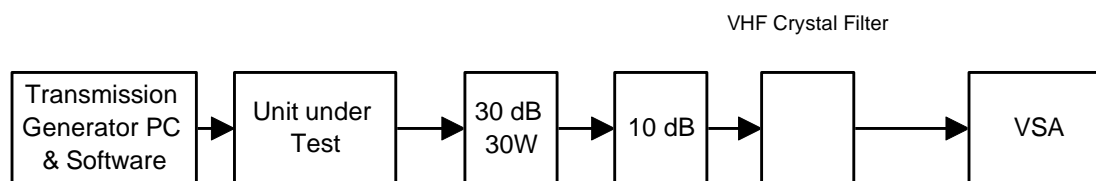


Figure 9.7: Second and fourth adjacent channel power measurement

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 plus/minus 50 kHz.
- Spectrum analyser with power band marker function.

Measurement procedure:

- 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 100 kHz above the VHF crystal filter centre frequency. Key the transmitter under test "on". Use the transmission generator to produce continuous maximum length VDL 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 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 6.2.7.
- 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 (B_r) much narrower than the channel bandwidth and the video bandwidth (B_v) equal to ten times B_r 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 minus 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:

$$P_i = \frac{10^{\frac{P_{idBm}}{10}}}{B_n}$$

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

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

P_i = Spectral power densities (mW/Hz).

NOTE: $B_n = k \times B_r$, 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 VDL 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).

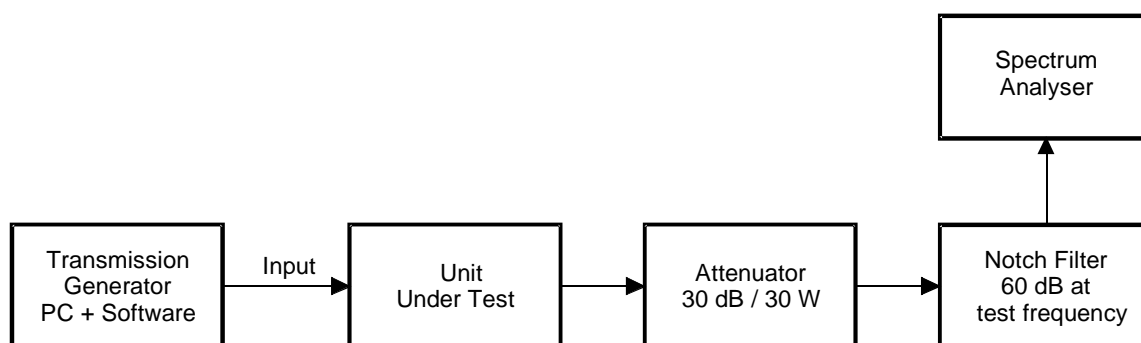


Figure 9.8: Wideband noise measurement

9.3.8 Load VSWR capability

Equipment required:

- Transmission generator, PC with suitable software.
- 30 dB directional coupler.
- Adjustable delay line.
- 2:1 VSWR Resistive load.
- Vector signal analyser with power band marker function.

Measurement procedure:

- Step 1: Connect the equipment as shown in figure 9.9.
- Step 2: Tune the transmitter to one of the test frequencies (clause 9.1.7).
- Step 3: Key the transmitter under test with the transmission generator with repetitive maximum length VDL 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 6.2.9.
- Step 6: Repeat steps 2 to 5 at the two remaining test frequencies.

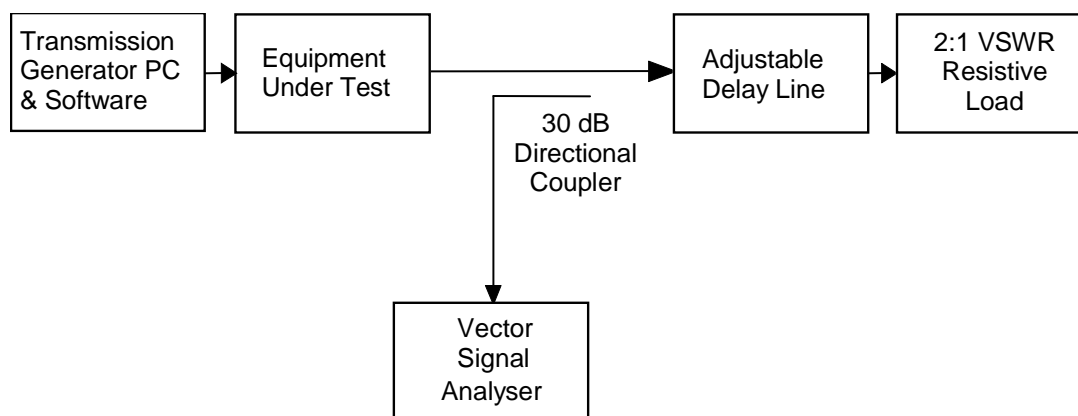


Figure 9.9: Load VSWR capability

9.3.9 Adjacent channel transient power

Equipment required:

- Mixer: 50 W balanced diode mixer; with an appropriate local oscillator level, for example +7 dBm.
- Adjacent channel filter: matched to 50 W.
- Spectrum analyser: 100 kHz bandwidth, peak detection, or power/time measurement provision.

Measurement procedure:

- Step 1: Connect the equipment as shown in figure 9.10.
- Step 2: The transmitter shall be operated at the maximum rated carrier power level, under normal test conditions.
- Step 3: The tuning of the "transient power measuring device" shall be adjusted so that a maximum response is obtained. This is the 0 dBc reference level.
- Step 4: The transmitter shall then be switched off.
- Step 5: The tuning of the "transient power measuring device" shall be adjusted away from the carrier so that its minus 6 dB response nearest to the transmitter carrier frequency is located at a displacement from the nominal carrier frequency as given in the table below.

Channel separation (kHz)	Displacement (kHz)
25	17

- Step 6: The transmitter shall then be switched on.
- Step 7: The spectrum analyser shall be used to record the envelope of the transient power as a function of time (approximately 50 milliseconds duration). The peak envelope transient power shall be noted in dBc.
- Step 8: The transmitter shall be switched off.
- Step 9: The spectrum analyser shall be used to record the envelope of the transient power as a function of time (approximately 50 milliseconds duration). The peak envelope transient power shall be noted in dBc.
- Step 10: Steps 6 to 9 shall be repeated five times and the highest response during "switch-on" and "switch-off" conditions shall be recorded.
- Step 11: Steps 5 to 10 shall be repeated with the "transient power measuring device" tuned to the other side of the carrier.
- Step 12: The adjacent channel transient power during the attack and release times is the dBc value corresponding to the highest of the values recorded in step 10).
- Step 13: This value shall be recorded.

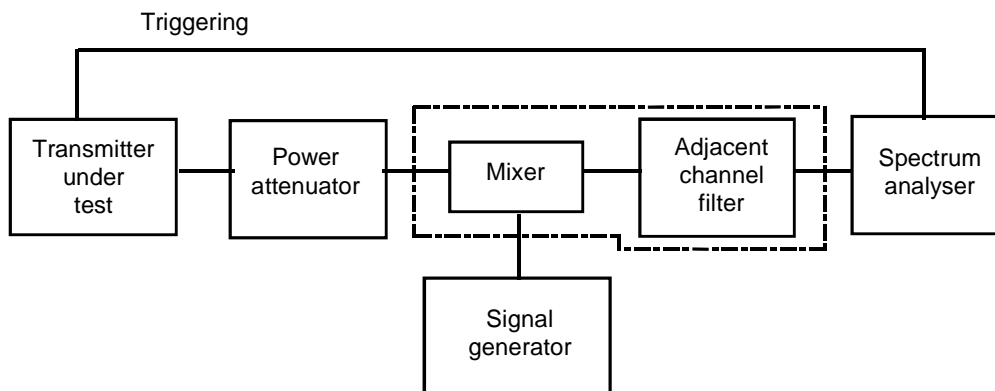


Figure 9.10: Adjacent channel transient power

9.3.10 Frequency tolerance

This requirement may be satisfied by written evidence.

NOTE: In this case, the manufacturer should declare crystal stability, aging and temperature coefficients, and provide evidence that the design supports the requirements. The evidence should demonstrate that consideration has been given to the temperature variation to which the equipment will be subjected (see clause 8) and the frequency range for which the equipment is designed to operate.

9.4 Transceiver

9.4.1 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 milliseconds.
- 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 EN 302 842-2 [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 milliseconds after receipt of the command to change channel.
 - Step 5: Repeat the test starting at each of the remaining two test frequencies.

9.4.2 Receiver to transmitter turn-around time

Measurement procedure:

- Step 1: Limit the periodic dither range of the periodic streams from the equipment to plus or minus 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 that used by the system under test's periodic stream.
- Step 4: Ensure that the timing of the bursts from the test equipment result in termination of the bursts 16 microseconds 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 EN 302 842-2 [7] (test case Physical_SysParams).

9.4.3 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 plus or minus 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 millisecond 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 EN 302 842-2 [7] (test case Physical_SysParams).

10 Installed equipment requirements

10.1 Introduction

This clause specifies the minimum acceptable level of performance, and test procedures for verifying that performance, for the equipment when installed in an aircraft.

10.2 Equipment installation

10.2.1 Aircraft environment

Equipment shall be compatible with the environmental conditions present in the specific location in the aircraft where the equipment is installed.

10.2.2 Failure protection

Any foreseeable failure of the VDL Mode 4 Transceiver function shall not degrade the normal operation of any other systems connected to it.

10.2.3 Aircraft power source

The voltage and frequency tolerance characteristics of the equipment shall be compatible with the aircraft power source of appropriate category as specified in ED-14D/DO-160D [6].

10.3 Installed equipment performance requirements

The installed equipment shall have been shown to have met the requirements of clauses 5 to 9 as a result of bench tests.

Additionally, all sources of application data, and the interfaces to them, shall be capable of providing data of the appropriate accuracy, integrity and update rate to meet the requirements of the application.

Further installed equipment requirements are set out in the following clauses.

10.3.1 Dynamic response

Operation of the equipment shall not be adversely affected by aircraft ground operations, manoeuvring, or changes in attitude encountered in normal flight operations.

10.3.2 Interference effects

The equipment shall not be the source of harmful conducted or radiated interference, nor be adversely affected by conducted or radiated interference from other equipment or systems installed in the aircraft.

NOTE: Interference problems noted upon installation of this equipment may result from such factors as the design characteristics of previously installed systems or equipment and the physical installation itself. It is not intended that the equipment manufacturer designs for all installation environments. The installing facility will be responsible for resolving any incompatibility between this equipment and previously installed equipment in the aircraft.

10.3.3 Regular maintenance

The manufacturer should prescribe tests documented in the maintenance manual to ensure continued airworthiness. These tests should be based at minimum on a biannual inspection. The transceiver tests are to be defined by the manufacturer and described in the maintenance manual.

10.4 Conditions of test

Clauses 10.4.1 to 10.4.3 define conditions under which tests, specified in clause 10.5, shall be conducted.

10.4.1 Power input

Unless otherwise specified, tests shall be conducted with the equipment powered by the aircraft's electrical power generating system.

10.4.2 Associated equipment or systems

Unless otherwise specified, all aircraft electrically operated equipment and systems shall be turned on, and where possible operating, before conducting interference tests.

10.4.3 Environment

During the tests, the equipment shall not be subjected to environmental conditions that exceed those in ED-14D/DO-160D [6] as specified by the equipment manufacturer.

Where application data, and/or primary timing is provided by means of GNSS, the test shall be conducted under conditions of adequate GNSS reception.

10.5 Test procedures for installed equipment performance

The following test procedures provide one means of determining installed equipment performance.

Although specific test procedures are prescribed, it is recognized that other methods may be preferred by the installer/manufacture. Such alternative procedures may be used if they provide at least equivalent information, in which case, the procedures described in this clause should be used as one criterion in evaluating the acceptability of the alternative procedures.

10.5.1 Ground test procedures

10.5.1.1 Conformity inspection

- a) Visually inspect the installed equipment to determine the use of acceptable workmanship and engineering practices.
- b) Verify that proper mechanical and electrical connections have been made and that the equipment has been located and installed in accordance with the manufacturer's recommendations.

10.5.1.2 Interference tests

- a) With all equipment energized, individually operate each of the other electrically operated aircraft equipment and systems to determine that no significant levels of conducted or radiated interference exist.
- b) Evaluate all combinations of control settings and operating modes.
- c) Operate communication and navigation equipment on the lowest, highest and at least one but preferably four mid-band frequencies.
- d) Make note of systems or modes of operation that should also be evaluated during flight.
- e) If appropriate, repeat the tests using emergency power with the aircraft's batteries alone and the inverters operating.

10.5.1.3 Power supply fluctuation test

- a) With the equipment operating, cycle the aircraft engine(s) through all normal power settings, and verify the proper operation of the equipment as specified by the equipment manufacturer.
- b) Operate any aircraft control and system which may cause power fluctuations. Verify that the equipment continues to operate without re-initialization.

10.5.1.4 Reception

The reception of VHF communications signals shall be verified using another nearby VDL Mode 4 station to transmit data which makes reservations in specific future slots. It can then be shown that the installed equipment recognizes those slots as reserved by not transmitting in them for the expected period of time.

NOTE: This test can be performed by using a portable VDL Mode 4 station to transmit data.

10.5.1.5 Transmission

The transmission of VHF communications signals shall be verified using another VDL Mode 4 station and confirming receipt at that station of correctly formatted bursts from the installed equipment.

NOTE: This test can be performed by using a portable VDL Mode 4 station to monitor the RF performance of the transceiver under test.

10.5.1.6 Functional behaviour tests

NOTE 1: These tests can be performed by using a portable VDL Mode 4 station to monitor the RF performance of the transceiver under test.

- a) Verify that following power-up, VDL Mode 4 autonomous synchronization bursts are transmitted on both GSCs at the default rate.
- b) Verify that the time figure of merit corresponds to primary or primary certified time synchronization (as required).
- c) Verify that the aircraft source address is correctly encoded.
- d) Direct the station to transmit sync bursts on an alternative channel to the GSC, and verify that the station transmits in accordance with the directed request.
- e) In the case of a dual redundant installation, direct the station to transmit and monitor on further local channels, in addition to the GSCs, so that all receivers in the installation are active. Send simulated application data on all channels, and verify that the intended results are presented to the flight deck crew. Remove power to one redundant unit, and verify that re-configuration of operation occurs in accordance with the applicable application standards.

NOTE 2: In the absence of specific application requirements for re-configuration of operation in the event of failure, it should be verified that when a directed request is sent with the receiver control field (rcvr) indicating that a channel is to be monitored, and the transceiver monitoring the channel is subsequently disabled, the monitoring is transferred to the other unit.

10.5.1.7 Interface conformance tests

The objective of these tests is to verify that all interfaces to the VDL Mode 4 Transceiver perform their intended functions and the equipment configuration is compatible with the specific installation.

NOTE: These tests can be performed by using a portable VDL Mode 4 station to monitor the RF performance of the transceiver under test.

- a) For each fixed field, provide, by simulation if necessary, realistic inputs to all systems contributing data to the field.
- b) Exercise each input, selecting a sufficient number of test points to ensure the correct operation of the installation.
- c) Verify at each test point that the data is being correctly reported.

10.5.2 Flight test procedures

10.5.2.1 Interference effects

- a) For aircraft equipment and systems that can be checked only in flight, determine that significant levels of conducted or radiated interference do not exist.
- b) Evaluate all combinations of control settings and operating modes.
- c) Operate communications and navigation equipment on the lowest, highest and at least one but preferably four mid-band frequencies.

10.5.2.2 System performance

After verification of the receiver and transmitter functions, a flight test shall be performed to verify that the system meets at least the minimum operational performance requirements. The performance of the system shall be verified by flying the aircraft at the limit of its operational range from a ground station and at an appropriate altitude, with the installed equipment transmitting default sync bursts on the GSCs. Verify that messages can be reliably sent and received, for 360 degrees of bearing from the nose of the aircraft to the ground station, and over all normal flight attitudes (it is not necessary to prove that the BER requirement is met in flight).

NOTE: This note offers examples of flight test procedures for demonstrating performance. Flight demonstration of installed performance may be required by the aircraft operator or by airworthiness inspection agencies.

Preparation of flight tests

Equipment should be made available for independent verification of the data provided by the VDL Mode 4 equipment under test. A test area should be selected such that line-of-sight signal propagation is ensured so that a test operator can confirm valid returns through normal flight attitudes.

Flight tests

When airborne, the tests should be conducted at typical altitude and attitude profiles of the aircraft, using a test ground station.

- a) Before take-off, ensure that the ground tests have been completed successfully.
- b) After take-off, determine whether successful operation at the maximum usable range is achieved when flying towards and away from the ground station. Ideally data from the test ground station only should be displayed.
- c) At the maximum operational range, execute orbits and level the aircraft every 10 degrees. Ensure valid transmissions are received by the test ground station.
- d) At the maximum operational range, establish that valid transmissions can be received by the test ground station when flying towards and away from the station:
 - at usual attitudes in normal climb and descent;
 - at alternating usual bank angles used in cruising flight.

The exact test parameters to be applied during the flight tests should be determined by the relevant certification authority.

Where the aircraft is unable to perform any of the above tests, suitable alternatives should be agreed with the relevant certification authority.

Annex A (informative): Cross reference matrix

Table A.1 outlines the mapping between the VDL Mode 4 mobile station requirements and the related test procedures.

In these tables:

- column 1 is a reference to the requirement in the present document;
- column 2 identifies clause titles taken from the present document;
- column 3 is a reference to testing requirements specified elsewhere in the present document. Several tests verify a whole group of requirements. They are only mentioned in the first row of such a group, usually a headline. The applicability of these tests to the subordinated requirements is indicated by ditto marks ("") in the rows following the first instance of a test case name. Amplification of individual entries is provided by the following notes.
- column 4 qualifies each test procedure to be:
 - Essential: meaning that it is included with the Essential Radio Test Suite and therefore the requirement should be demonstrated to be met in accordance with the referenced procedures;
 - Other: meaning that the test procedure is illustrative but other means of demonstrating compliance with the requirement are permitted;
 - eXcluded: meaning that there is no specific test for the requirement.

NOTE 1: The clause number in column 1 is a headline or an introduction to requirements that are detailed in subsequent clauses. No test can be applied.

NOTE 1a: The clause number in column 1 is a definition. No test can be applied.

NOTE 2: The requirement listed in column 1 does not allow definition of a satisfactory go/no go test, for example, because it would be technically infeasible, or economically unreasonable. There are circumstances where the implementer can provide reasoned argument or test evidence that the implementation under test does conform to the requirements in column 1. For each of these circumstances the implementer may be required to satisfy the authorities by separate technical evidence.

NOTE 3: The requirement listed in column 1 is applicable only to VDL Mode 4 Ground station equipment. No mobile equipment test is required.

NOTE 4: This topic is heavily dependent on the implementation or results from a recommendation. No particular test is therefore provided in the present document.

NOTE 5: The requirement listed in column 1 is reflected in a more specific EN requirement specified and tested elsewhere in the present document.

NOTE 6: All tests whether "E" or "O" are relevant to the requirements. Rows designated "E" collectively make up the Essential Radio Test Suite; those designated "O" make up the Other Test Suite; for those designated "X" there is no test specified corresponding to the requirement. All tests classified "E" should be performed as specified with satisfactory outcomes as a necessary condition for a presumption of conformity. Requirements associated with tests classified "O" or "X" should be complied with as a necessary condition for presumption of conformity, although conformance with the requirement may be claimed by an equivalent test or by manufacturer's assertion supported by appropriate entries in the technical construction file.

Table A.1: VDL Mode 4 requirements according to ICAO TM

Requirement reference	Title	Test Case	E/O/X
6.1	Receiver Requirements	See note 1	X
6.1.1	Receiver operating range	See note 1a	X
6.1.2	BER requirement	9.2.1	E
6.1.3	Reference signal level	See note 2	X
6.1.4	Sensitivity	9.2.2	E
6.1.5	Adjacent channel rejection	9.2.3	E
6.1.6	Receiver performance in the presence of strong signals inside the VHF Aeronautical band	9.2.4	E
6.1.7	Receiver performance in the presence of strong signals outside the VHF Aeronautical band	9.2.5	E
6.1.8	Desired signal dynamic range	9.2.6	E
6.1.9	Symbol rate capture range	9.2.7	E
6.1.10	Frequency capture range	9.2.8	E
6.1.11	Doppler rate	9.2.9	E
6.1.12	Co-channel interference	9.2.10	E
6.1.13	Conducted spurious emission	9.2.11	E
6.1.14	FM Broadcast Intermodulation	See note 1	X
6.1.14.1	Radio frequencies in the band 117,975 MHz to 137,0 MHz	9.2.12	E
6.1.15	In-band intermodulation	9.1.13	E
6.2	Transmitter requirements	See note 1a	X
6.2.1	Transmitter operating range	See note 1a	X
6.2.2	Channel bit rate	9.3.1	E
6.2.3	Manufacturer's declared output power	9.3.2	E
6.2.4	RF power rise time	9.3.3	E
6.2.5	RF power release time	9.2.4	E
6.2.6	Spurious emissions	9.3.5	E
6.2.7	Adjacent channel power	9.3.6	E
6.2.8	Wide-band noise	9.3.7	E
6.2.9	Load VSWR capability	9.3.8	E
6.2.10	Adjacent channel transient power	9.3.9	E
6.2.11	Frequency Tolerance	See note 4	O
6.2.12	Start of transmission	See note 4	O
6.2.13	Structure of bursts	See note 2	X
6.3	Transceiver requirements	See note 1	X
6.3.1	Automatic transmitter shutdown	See note 2	O
6.3.2	Tuning time	9.4.1	E
6.3.3	Receiver to transmitter turnaround time	9.4.2	E
6.3.4	Transmitter to receiver turnaround time	9.4.3	E
6.3.5	Short power interrupt	See note 5	X
6.3.6	Demodulator action	See note 4	O
6.3.7	System timing requirements	See note 2	O
6.3.8	Reservation table stored in memory	See note 4	O
6.3.9	Failure of associated equipment	See note 4	O
6.3.10	Simultaneous reception	See note 5	X
7	General design requirements	See note 1	X
7.1	Controls and indicators	See note 2	O
7.2	Class of emission and modulation characteristics	See note 2	O
7.3	Warm up	See note 2	O
7.4	Airworthiness	See note 2	O
7.5	Intended function	See note 4	O
7.6	International Telecommunications Union Regulations	See note 4	O
7.7	Fire protection	See note 4	O
7.8	Operation of controls	See note 2	O
7.9	Accessibility of controls	See note 4	O
7.10	Effects of tests	See note 4	O
7.11	Failure of VDL Mode 4 equipment	See note 4	O
7.12	Software management	See note 4	O

Requirement reference	Title	Test Case	E/O/X
7.13	Transceiver configuration	See note 4	O
7.14	Provision for multiple redundant VDL4 transceivers	See note 2	O
7.15	Reception capability	See note 2	O
7.16	Transmission capability	See note 2	O
7.17	Monitoring of proper operation	See note 4	O
7.18	Power-up self test	See note 4	O
10	Installed equipment requirements	See note 1	X
10.1	Introduction	See note 1a	X
10.2	Equipment installation	See note 1	X
10.2.1	Aircraft environment	See note 2	O
10.2.2	Failure protection	See note 2	O
10.2.3	Aircraft power source	See note 2	X
10.3	Installed equipment performance requirements	See note 1a	X
10.3.1	Dynamic response	See note 2	O
10.3.2	Interference effects	See note 2	O
10.3.3	Regular maintenance	See note 4	O
10.4	Conditions of test	See note 1a	X
10.4.1	Power input	See note 1a	X
10.4.2	Associated equipment or systems	See note 2	O
10.4.3	Environment	See note 4	O

Annex B (informative): VDL Mode 4 link budget

The physical layer parameters specified in the present document, are based on a link budget assessment for VDL Mode 4. This is summarized in this clause for normal power Class A transmitters and Class B transmitters.

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 $E_b/N_0 > 18$ dB using noncoherent detection and Viterbi algorithm for sequence estimation (e.g. to compensate for intersymbol interference).
- VDL Mode 4 is currently assigned to operate in the 117,975 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.
- ICAO VDL SARPs [2] indicate that transmit power should be managed so as to generate an RF field strength of at least 35 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 (e.g. 5 W).
- Airborne VHF antenna gain is generally observed to exceed minus 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 airborne 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 airborne 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 airborne stations.

Tables B.1a and B.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) equipment respectively.

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

Table B.1b: VDL Mode 4 downlink budget Class B equipment

Frequency (MHz)		Range (NM)			
137,000		40,0	80,0	120,0	160,0
Transmitter output power (Airborne)					
Power emitted at Transmitter terminal	<i>W</i> <i>dBm</i>	4,0 36,0	4,0 36,0	4,0 36,0	4,0 36,0
Transmitter feeder line loss	<i>dB</i>	3,0	3,0	3,0	3,0
Transmitter Antenna Gain	<i>dB</i>	-4,0	-4,0	-4,0	-4,0
SARPs Signal-in-Space					
EIRP emitted at transmitter	<i>dBm</i>	29,0	29,0	29,0	29,0
Standard free path loss	<i>dB</i>	112,6	118,6	122,1	124,6
Excess path loss	<i>dB</i>	0,0	0,0	0,0	0,0
EIRP at receiver antenna	<i>dBm</i>	-83,5	-89,6	-93,1	-95,6
Signal power at receiver terminal (Ground)					
Receiver antenna gain	<i>dB</i>	6,0	6,0	6,0	6,0
Receiver cable loss	<i>dB</i>	2,0	2,0	2,0	2,0
Power at receiver input terminal (C)	<i>dBm</i>	-79,5	-85,6	-89,1	-91,6
Noise at receiver terminal (Ground)					
Receiver noise figure	<i>dB</i>	10,0	10,0	10,0	10,0
External noise figure	<i>dB</i>	8,0	8,0	8,0	5,0
Receiver noise floor (kTo)	<i>dBm/Hz</i>	-174,0	-174,0	-174,0	-174,0
System noise power density (No)	<i>dBm/Hz</i>	-162,75	-162,75	-162,75	-163,44
System Margin					
C/No	<i>dBHz</i>	83,21	77,19	73,67	71,87
Baud rate	<i>dBHz</i>	42,83	42,83	42,83	42,83
Available Es/No	<i>dB</i>	40,38	34,36	30,84	29,04
Theoretical Es/No	<i>dB</i>	18,0	18,0	18,0	18,0
Transmitter Implementation loss	<i>dB</i>	1,0	1,0	1,0	1,0
Receiver Implementation loss	<i>dB</i>	1,2	1,2	1,2	1,2
Required Es/No	<i>dB</i>	20,2	20,2	20,2	20,2
Residual System Margin	<i>dB</i>	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 $52 - 29\log_{10}(f[\text{MHz}]) + \text{NENV}$, where NENV is 15 dB and 18 dB for rural and urban environments respectively (TSB-88-A, TIA/EIA, 1999.)

The link margins in tables B.1a and B.1.b 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 B.2. This model considers the dependence of the atmosphere's refractive index (and hence the direction of the ground reflected component) on aircraft altitude. tables B.3a and B.3b provide the link margins taking account of the excess path loss.

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

Altitude (ft)	Range (NM)				
	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 B.3a: Downlink margin (Class A) considering excess path loss

Altitude (ft)	Range (NM)				
	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 B.3b: Downlink Margin (Class B) considering excess path loss

Altitude (ft)	Range (NM)				
	40	80	120	160	200
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 minus 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 VDL 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 $kT_0 + \text{effective noise figure}$. From table B.1a this is given by $-173,98 + 20,94 = -150,04$ dBm/Hz. The appropriate reference signal would be minus 93,5 dBm (for Class A equipment).

The specifications for performance against interference (see clause 6) require an input power level at the receiving antenna of minus 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 minus 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 B.4a (Class A equipment) and table B.4b (Class B equipment).

Table B.4a: VDL Mode 4 uplink link budget for Class A equipment

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

Table B.4b: VDL Mode 4 uplink link budget for Class B equipment

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

Table B.5a: Uplink margin (Class A) considering excess path loss

Altitude (FT)	Range (NM)				
	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 B.5b: Uplink margin (Class B) considering excess path loss

Altitude (FT)	Range (NM)			
	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 B.6a and B.6b.

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

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

Annex C (informative): Bibliography

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