



**VHF air-ground Digital Link (VDL) Mode 2;
Technical characteristics and
methods of measurement
for ground-based equipment;
Part 1: Physical layer and MAC sub-layer**

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Foreword

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

The present document is part 1 of a multi-part deliverable covering VHF air-ground Digital Link (VDL) Mode 2; Technical characteristics and methods of measurement for ground-based equipment, as identified below:

Part 1: "Physical layer and MAC sub-layer";

Part 2: "Upper layers";

Part 3: "Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive".

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Modal verbs terminology

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Introduction

The present document states the technical specifications for ground-based equipment implementing Very High Frequency (VHF) Digital Link (VDL) Mode 2 air interface, operating in the VHF band (117,975 MHz to 137,000 MHz) with 25 kHz channel spacing.

Manufacturers should note that in the future, all or part of the frequency band 108,000 MHz to 117,975 MHz may become available for aeronautical communications.

The VDL Mode 2 system is designed to be a Ground/Air sub-system of the Aeronautical Telecommunication Network (ATN) using the AM(R)S band and it is organized according to the Open Systems Interconnection (OSI) model (defined by ISO). It will provide reliable subnetwork services to the ATN system.

The present document may be used to produce tests for the assessment of the performance of the equipment.

1 Scope

The present document applies to VDL Mode 2 ground-air digital communications using Differential Eight Phase Shift Keying (D8PSK), intended for channel increments of 25 kHz. The VDL Mode 2 system provides data communication exchanges between aircraft and ground-based systems. The scope of the present document is limited to ground-based stations.

The present document provides functional specifications for ground-based radio equipment intended to be used for ground-air data communications. The present document is derived from the following documents:

- Annex 10 of the ICAO Convention on International Civil Aviation [1].
- ED 92B [i.2]: "MOPS for an Airborne VDL Mode-2 Transceiver Operating in the frequency range 118-136.975 MHz" (2012), which specifies the airborne transceiver.

The present document consists of two parts:

- the first part provides functional specifications and test procedures for physical layer and MAC sub-layer;
- the second part provides functional specifications and test procedures for link and sub-network access layers.

2 References

2.1 Normative 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.

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

- [1] ICAO Convention on International Civil Aviation: "Annex 10 - Aeronautical Telecommunications, Volume III - Communication Systems, Part I - Digital Data Communication Systems, Second Edition, July 2007, incorporating Amendments up to 88A (applicable 14/11/13). Chapter 6 - VHF Air-ground Digital Link (VDL)".
- [2] ICAO Convention on International Civil Aviation: "Annex 10 - Aeronautical Telecommunications, Volume V - Aeronautical Radio Frequency Spectrum Utilization", Third Edition, July 2013 incorporating Amendments up to 88A.
- [3] 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".
- [4] ICAO Document 9776/AN970 (first edition, 2001): "Manual on VHF Digital Link (VDL) mode 2".

2.2 Informative references

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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 301 841-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); VHF air-ground Digital Link (VDL) Mode 2; Technical characteristics and methods of measurement for ground-based equipment; Part 2: Upper layers".
- [i.2] EUROCAE ED 92B: "MOPS for an Airborne VDL Mode-2 Transceiver operating in the frequency range 118-136.975 MHz".
- [i.3] ISO/IEC 13239: "Information technology - Telecommunications and information exchange between systems - High-level data link control (HDLC) procedures".
- [i.4] ISO/IEC 8208: "Information technology - Data communications - X.25 Packet Layer Protocol for Data Terminal Equipment".
- [i.5] ISO/IEC 7498-1: "Information technology - Open Systems Interconnection - Basic Reference Model: The Basic Model".
- [i.6] ISO/IEC 10731: "Information technology - Open Systems Interconnection - Basic Reference Model - Conventions for the definition of OSI services".
- [i.7] ITU Radio Regulations (2012).

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 [i.5]:

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

3.1.2 Service conventions definitions

For the purposes of the present document, the terms and definitions given in ISO/IEC 10731 [i.6] apply:

- 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 transmitted outside of the assigned channel

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

adjacent channel rejection: receiver's ability to demodulate the desired signal and meet the uncorrected 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 uncorrected BER, is the adjacent channel rejection (ACR) ratio.

aeronautical mobile service: mobile service between aeronautical stations and aircraft stations, or between aircraft stations, in which survival craft stations may participate

average transmitter output power: average power supplied to the antenna transmission line by a transmitter during an interval of time sufficiently long, compared with the lowest frequency encountered in the modulation, taken under normal operating conditions

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

NOTE: The uncorrected BER represents the BER without the benefit of Forward Error Correction (FEC).

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 channel

NOTE: The ratio (in dB) between the wanted signal level and the unwanted signal level is the co-channel interference ratio.

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

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

spurious emissions: 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

NOTE: Spurious emissions include parasitic emissions, intermodulation products and frequency conversion products.

X 25: ITU-T standard for the protocols and message formats that define the interface between a terminal and a packet switching network

3.2 Abbreviations

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

| | |
|--------------|---|
| AC | Alternating Current |
| ACP | Adjacent Channel Protection |
| ACR | Adjacent Channel Rejection |
| AGC | Automatic Gain Control |
| AM(R)S | Aeronautical Mobile (Route) Service |
| ATN | Aeronautical Telecommunication Network |
| AVL | Aviation VHF Link |
| AVLC | Aviation VHF Link Control |
| AVLC_LI | Aviation VHF Link Control Length Indicator |
| AVPL | Aviation VHF Physical Layer |
| AVPL-Header | AVPL Header and training sequence |
| AVPL-TBS | AVPL Transmitted Bit Scrambled sequence |
| AVPL-THeader | AVPL Transmission Header sequence |
| AVPL-THI | AVPL Transmitted Header appended and Interleaved sequence |
| AVPL-TIRS | AVPL Transmitted Interleaved RS encoded sequence |

| | |
|-------------|---|
| AVPL-TTS | AVPL Transmitted Ternary Symbol sequence |
| AWG | Arbitrary Waveform Generator |
| BER | Bit Error Rate |
| CCI | Co Channel Interference |
| CRC | Cyclic Redundancy Check |
| CSMA | Carrier Sense Multiple Access |
| CW | Continuous Wave |
| D8PSK | Differentially encoded 8 Phase Shift Keying |
| dBc | Decibels relative to the carrier |
| dBm | Decibels relative to 1 milliwatt |
| DLS | Data Link Service |
| ED | Eurocae Document |
| EVM | Error Vector Magnitude |
| FCS | Frame Check Sequence |
| FEC | Forward Error Correction |
| FM | Frequency Modulation |
| HDLC | High-level Data Link Control |
| ICAO | International Civil Aviation Organization |
| IF | Intermediate Frequency |
| ISO | International Organization for Standardization |
| LME | Link Management Entity |
| MAC | Media Access Control |
| MOPS | Minimum Operational Performance Specification |
| OSI | Open Systems Interconnection |
| PC | Personal Computer |
| ppm | parts per million |
| RF | Radio Frequency |
| RMS | Root Mean Square |
| RS | Reed-Solomon |
| RSSI | Received Signal Strength Indicator |
| SAP | Service Access Point |
| SARPS | Standards And Recommended Practices (ICAO) |
| SNAcP | SubNetwork Access Protocol |
| SQP | Signal Quality Parameter |
| TIRS matrix | Transmission Interleaver and RS encoding matrix |
| VDL | VHF Digital Link |
| VHF | Very High Frequency |
| VME | VDL Management Entity |
| VSA | Vector Signal Analyser |
| VSWR | Voltage Standing Wave Ratio |

4 General architecture of VDL Mode 2

The general architecture of the VHF radio equipment operating in VDL Mode 2 is depicted in figure 1. This figure presents the different functional parts of the VDL Mode 2 equipment.

The VDL system is related to the three lower layers of the OSI model providing services described as follows:

Layer 1 (Physical layer): provides transceiver frequency control, bit exchanges over the radio media, and notification functions. These functions are often known as radio and modulation functions. The physical layer handles information exchanges at the lowest level and manipulates bits. The physical layer handles modulation, data encoding and includes a forward error correction mechanism based on interleaving and Reed Solomon coding.

Layer 2 (Link Layer): is split into two sublayers and a link management entity:

- The MAC sublayer provides access to the Physical layer by a CSMA algorithm in charge of channel access. The MAC layer controls channel access and sharing.
- The DLS sublayer is composed of the AVLC derived from the HDLC protocol (ISO/IEC 13239 [i.3]) whose main functions are frame exchanges, frame processing, and error detection.
- The LME controls the link establishment and maintenance between DLS sublayers.

Layer 3: Only the lowest network sublayer of layer 3 (SNAcP) will be described in ETSI EN 301 841-2 [i.1]. It is compliant with the subnetwork sublayer requirements defined in the ATN SARPs and conforms with the ISO/IEC 8208 [i.4] (or network layer of X.25). It provides packet exchanges over a virtual circuit, error recovery, connection flow control, packet fragmentation, and subnetwork connection management functions.

The DLS and LME part of the Layer 2 and Layer 3 are specified in ETSI EN 301 841-2 [i.1].

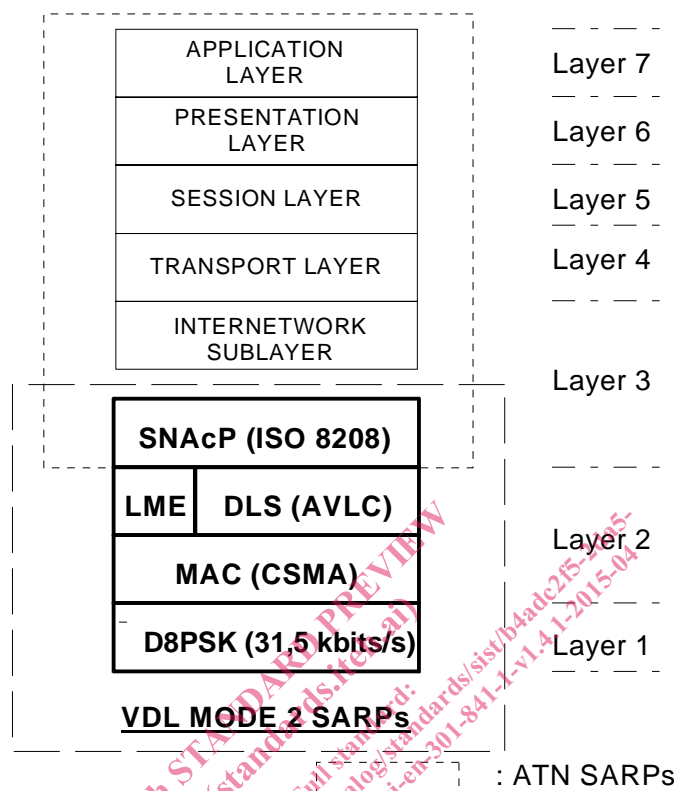


Figure 1: VDL SARPs [1] in the ATN/OSI Organization

5 Physical layer protocols and services functional specifications

5.1 Overview

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

5.1.1 Functions

The tasks of the physical layer include the following:

- to modulate and demodulate radio carriers with a bit stream of a defined instantaneous rate to create an rf link;
- to acquire and maintain bit and burst synchronization between Transmitters and Receivers;
- to transmit or receive a defined number of bits at a requested time (packet mode) and on a particular carrier frequency;
- to add and remove a training sequence;
- to encode and decode the Forward Error Correction scheme;
- to measure received signal strength;
- to decide whether a channel is idle or busy, for the purposes of managing channel access attempts;

- to offer a notification service about the quality of link.

5.1.2 Data reception by the receiver

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

5.1.3 Data transmission

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

5.2 Transmission procedure

To transmit a sequence of frames, a station shall insert the bit numbers and, compute the FEC, interleave, insert the training sequence, carry out bit scrambling, and finally encode and modulate the rf signal. See figure 2.

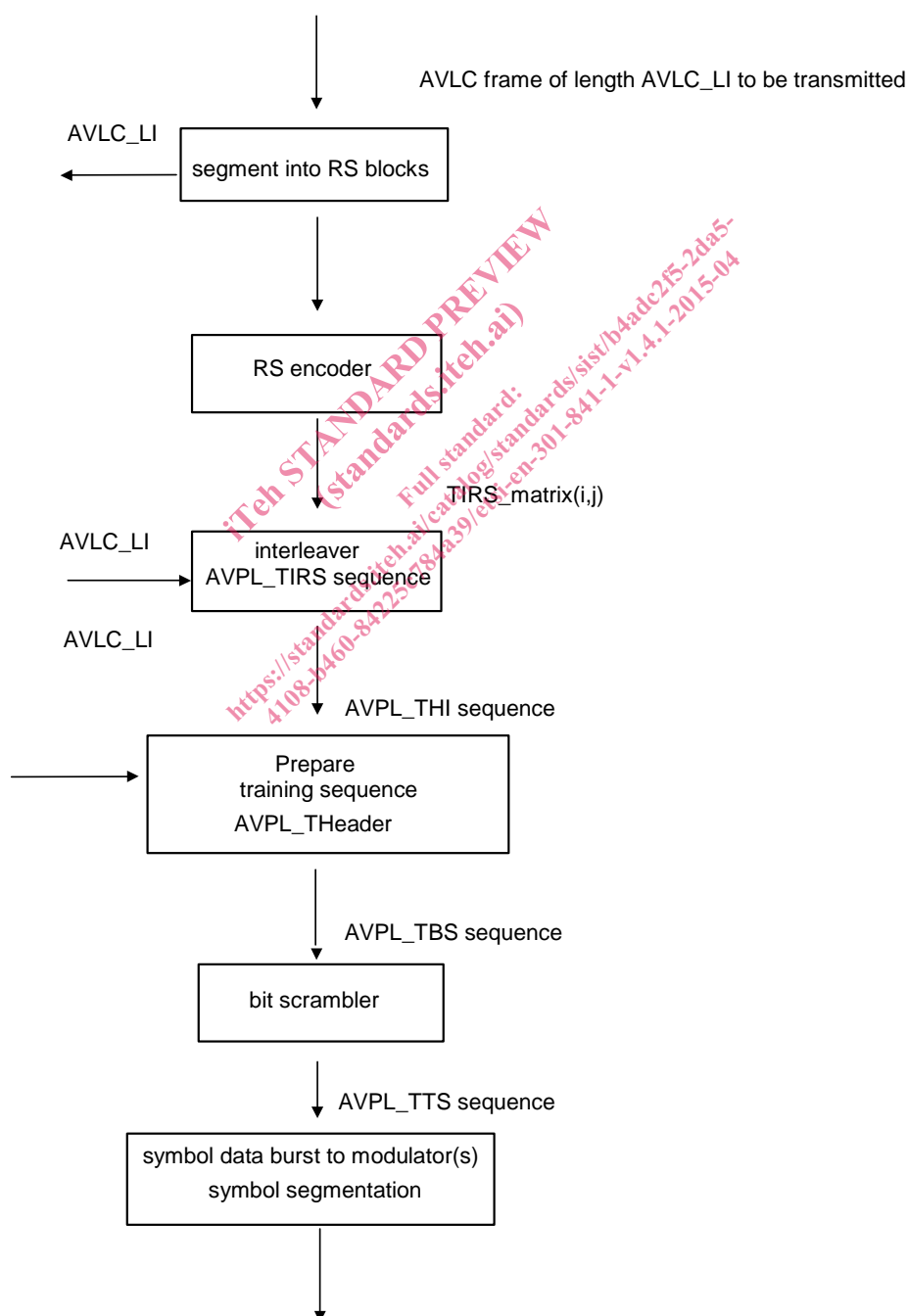


Figure 2: Data burst formatting procedure

5.3 Modulation scheme

Mode 2 shall use D8PSK, using a raised cosine filter with $\alpha = 0,6$ (nominal value). The information to be transmitted shall be differentially encoded with 3 bits per symbol transmitted as changes in phase rather than absolute phase. The data stream to be transmitted shall be divided into groups of 3 consecutive data bits, with the least significant bit first. Zeros shall be padded to the end of the transmissions if needed for the final channel symbol.

5.4 Training sequence

Data transmission shall begin with a demodulator training sequence consisting of five segments:

- transmitter ramp up and power stabilization (5 symbols);
- synchronization and ambiguity resolution (16 symbols - the "unique word");
- reserved symbol (1 symbol);
- transmission length (a single 17 bit word);
- header FEC (5 bits).

NOTE: Immediately after these segments there is an AVLC frame. See also figure 3 below.

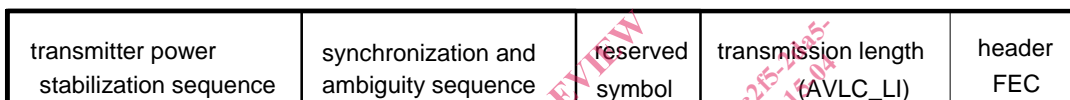
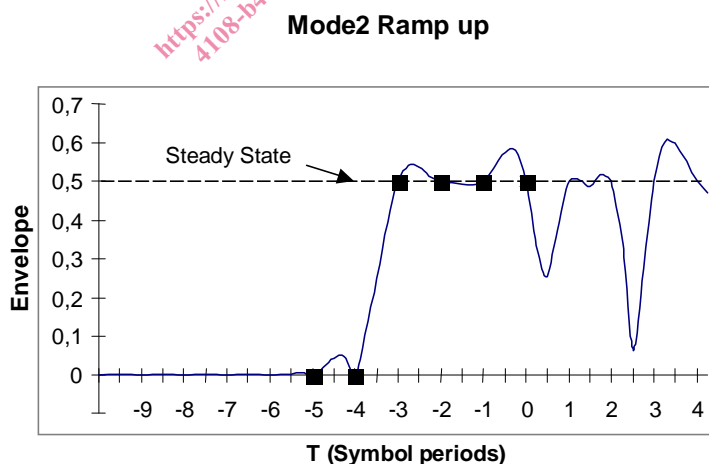


Figure 3: AVPL-header training sequence structure

5.4.1 RF power rise time definition

The purpose of the first segment of the training sequence, called the ramp-up, is to provide for transmitter power stabilization and receiver AGC settling and it shall immediately precede the first symbol of the unique word. The first segment also provides AGC settling time for the intended receiver. The time reference point (T), for the following specification is the centre of the first unique word symbol, a point that occurs 1/2 a symbol period after the end of the first segment. The start of the first segment is therefore defined at time $T = -5,5$ symbol periods.



Key: ■ Symbol increment

Figure 4: Transmitter Power Stabilization