**Annex 3 – VDE-Terrestial specific**

Annex 3 shall contain the general information suitable for ITU-R M.VDES-0.

Overall document structure

Annex 1 VDES Operation

Annex 2 (ASM)

**Annex 3 (VDE-TER)**

Annex 4 (VDE-SAT-Downlink)

Annex 5 (VDE-SAT-Uplink)

Annex 6 TER-SAT sharing

Review/working group:

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Stefan Bober,

Mark Johnson,

Hans Haugli , - Synchronisation (Preamble, postamble? ) + Pysical Layer Header

Arunas (Exact Earch),-Link budget table

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Yoshi (JRC), -Input for link budget, Spectrum mask input

Giuanluigi DLR, - Review error correction coding, interleaver suggestion

Nader (ESA), - Interleaver input

Krysztof Bronk, - scrambling, Synchronisation (Preamble, postamble? ) + Pysical Layer Header

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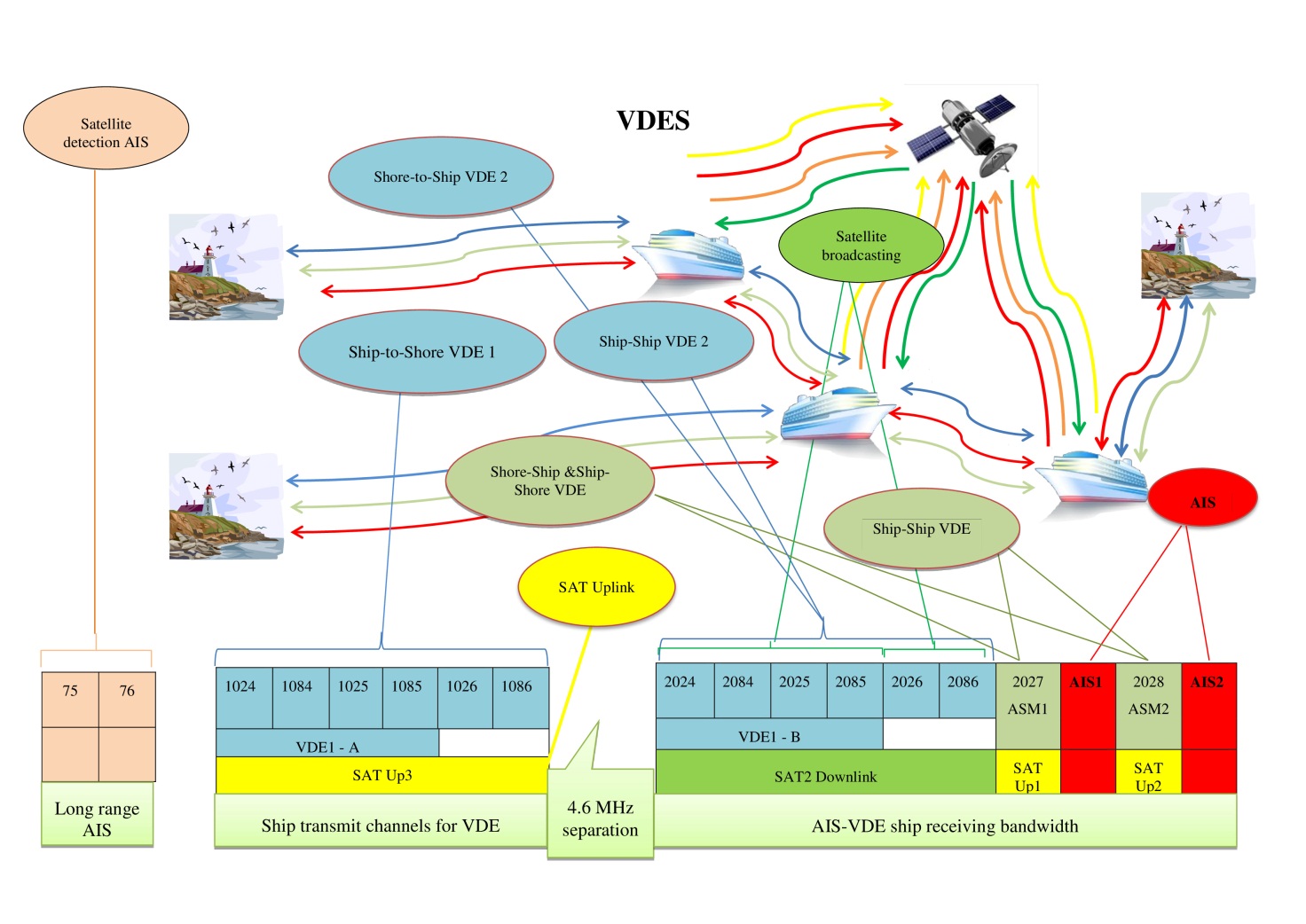
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Annex 3  
  
Technical characteristics of VDE-terrestrial  
in the maritime mobile band



## VHF data exchange system channel usage in accordance with RR Appendix 18

### 5.1.1 VHF data exchange system data exchange between terrestrial stations

− VDE1-A lower legs (channels 1024, 1084, 1025, 1085) are ship-to-shore VDE;

− VDE1-B upper legs (channels 2024, 2084, 2025, 2085) are shore-to-ship and ship-to-ship VDE.

# OSI Layer (from Annex 2)

The VDES architecture utilizes the open systems interconnection (OSI) model as illustrated in Figure 3.

The first four layers (physical, link, network and transport) are described with-in this recommendation. These layers for the VDE, ASM and AIS sub-systems need to be coordinated. AIS should have the highest priority in the VDES, and all other functions should be organized such that the AIS is not adversely affected.

Figure 4

|  |  |  |
| --- | --- | --- |
| Application Layer | | |
| Presentation Layer | | |
| Session Layer | | |
| Transport Layer | | |
| Network Layer  VDE1-A VDE1-B | | |
| Link Management Entity (LME) Layer |  | Link Management Entity (LME) Layer |
| Data Link Service (DLS) Layer | Data Link Service (DLS) Layer |
| Medium Access Control (MAC) Layer | Medium Access Control (MAC) Layer |
| Physical Layer | Physical Layer |
| RX (shore)/ TX(ship) |  | RX(ship/shore?) / TX (shore) |
| Rx: Receiver  Tx: Transmitter | | |

The VDES architecture should utilize the open systems interconnection layers 1 to 4 (physical layer, link layer, network layer, transport layer) as illustrated in Figure 3.

Figure 3

open systems interconnection layers 1-4

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Layer 4: |  | Transport | | ITU-R M.1371 |  |
|  | Layer 3: |  | Network | |  |
|  | Layer 2: |  | Data Link | |  |
|  | Layer 1: |  | Access | |  |
|  | Channels |  | VDE | ASM | AIS |  |

## Transport layer

The transport layer is responsible for converting data into transmission packets of correct size and sequencing of data packets.

### Network layer

The network layer is responsible for the management of priority assignments of messages, distribution of transmission packets between available channels, and data link congestion resolution.

### Link layer

The link layer orders VDE messages into 8bit bytes for assembly of transmission packets.

Applies error correction coding, scrambling and interleaving. Calculate CRC and appends to data to complete creation of transmission packets.

#### 1.2.3.3 Media access control

Provides a method for granting access to the data transfer to the VHF data link (VDL). The method used is a TDMA scheme using a common time reference.

### Physical layer

Converts binary data into transmission symbols. Assembles transmission symbols, synchronization, and other overhead symbols to transmission packets. Converts transmission packets to appropriate analogue signal for the transmitter, according to the selected modulation and channelization scheme.

# Physical layer (Ship/Shore)

## Parameters

## General

## Transmission media

Data transmissions are made in the VHF maritime mobile band. Data tranmissions are made within the spectrum allocated for VDE1-A and VDE1-B. The spectrum may be used as 25kHz, 50 kHz and 100kHz channels. Additional spectum may be available for VDE communication on a regional basis.

## Multi-channel operation

### Ship to ship communication uses the VDE1-B spectrum in a simplex mode

### Ship to shore communication uses the VDE1-A spectrum for transmission and VDE1-B spectrum for reception. Shore to ship communication uses the VDE1-B spectrum for transmission and VDE1-A and VDE1-B spectrum for reception.

When 25kHz channels are combined to form either a 50kHz or 100kHz bandwidth, the following methodology shall be used ... (bulletin board???)

## Transceiver characteristics

### Transmit power

The maximum average power shall not exceed 25W per 25kHz, 50kHz and 100Khz used spectrum at a time. Spectral mask, Emission Assumptions

-Insert figures from 1842 or 1371

25kHz as AIS,







Possible Modulation schemes for future considerations

(Create table of modulation, and related parameters)

GFSK

GMSK

PI/4 QPSK

OQPSK (Pi/4 QPSK)

8PSK

16APSK, 16PSK

64 APSK

4x16QAM

32APSK

32OFDM (multicarrer)

Current Transmission waveforms for VHF data exchange

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Bandwidth | 25 kHz |  | 50 kHz | 100 kHz |
| Modulation | π/4 QPSK |  | 16-QAM,  16 multi-carriers,  2.7 kHz spacing | 16-QAM,  32 multi-carriers,  2.7 kHz spacing |
| Modulation Category | PSK modulation |  | QAM modulation | QAM modulation |
|  |  |  |  |  |

## 

### Carrier Frequency error

3ppm

### Symbol timing accuracy

10 ppm

### Transmitter Timing Jitter

1% RMS of symbol duration (or may be expressed as 104 microseconds but will need a table based on symbol rate)

### Slot Transmission Accuracy

UTC Direct operation:104 Micro sec for a mobile unit

## Bit rates

## Adaptive modulation and coding scheme mechanisms

The VDE terrestrial link should enable the usage of different modulation and coding schemes. This mechanism needs to work in an adaptive and autonomous manner without the necessity of the base station participation in the process.

### Training sequence

The particular modulation coding schemes (MCS) should be encoded into the training sequence as follows:

|  |
| --- |
| (D0, D0, D0, D0, D0, D0, D0, D0, D0, D0, D0 + 1, 0, 1, 1, 0, 1, 1, 1, 0, 0, 0) Modulo 2 |
| (D1, D1, D1, D1, D1, D1, D1, D1, D1, D1, D1 + 1, 0, 1, 1, 0, 1, 1, 1, 0, 0, 0) Modulo 2 |
| (D2, D2, D2, D2, D2, D2, D2, D2, D2, D2, D2 + 1, 0, 1, 1, 0, 1, 1, 1, 0, 0, 0) Modulo 2 |
| (D3, D3, D3, D3, D3, D3, D3, D3, D3, D3, D3 + 1, 0, 1, 1, 0, 1, 1, 1, 0, 0, 0) Modulo 2 |

Where 1, 0, 1, 1, 0, 1, 1, 1, 0, 0, 0 is a Barker code (length 11) with a very low autocorrelation function (sidelobe level ratio about -20,8 dB). This will maximize the detection probability. The potential 180 degrees phase error may be eliminated for instance with the usage of the start flag (or any known sequence within the header).

Training sequence should be always modulated using GMSK.

Only the data block should be coded, scrambled and modulated according to the selected MCS scheme. Modulation and coding schemes should be for instance defined according to the given below table.

| **Modulation and coding scheme** | **D0, D1, D2, D3**  **values** | **CQI value** | **Total throughput**  **[kbps]\*** | **Total data bitrate (user data + framing overhead) [kbps]** |
| --- | --- | --- | --- | --- |
| No transmission | | 0 | - | - |
| MCS-1  (GMSK, CR=1/2) | 0, 0, 0, 1 | 1 | 76,8 | 38,4 |
| MCS-2  (GMSK, CR=3/4) | 0, 0, 1, 0 | 2 | 76,8 | 57,6 |
| MCS-3  (π/4 DQPSK, CR=1/2) | 0, 0, 1, 1 | 3 | 153,6 | 76,8 |
| MCS-4  (π/4 DQPSK, CR=3/4) | 0, 1, 0, 0 | 4 | 153,6 | 115,2 |
| MCS-5  (8PSK, CR=3/4) | 0, 1, 0, 1 | 5 | 230,4 | 172,8 |
| MCS-6  (8PSK, CR=5/6) | 0, 1, 1, 0 | 6 | 230,4 | 192 |
| MCS-7  (16QAM SC, CR=3/4) | 0, 1, 1, 1 | 7 | 307,2 | 230,4 |
| MCS-8  (16QAM SC, CR=5/6) | 1, 0, 0, 0 | 8 | 307,2 | 256 |
| MCS-9  (16QAM 32MC, CR=7/8) | 1, 0, 0, 1 | 9 | 307,2 | 268,8 |
| TBD | 1, X, X, X | TBD |  |  |
| \*) An assumption: 76,8 ksym/s in 100 kHz bandwidth (Roll-off factor: 0,3) | | | | |

CQI (Channel Quality Indicator) values should correspond directly to the BER.

The calculation of the BER should be based on the known sequences within the frame.

CQI value of the received message should be contained within the ACK/NACK messagesuch that the next transmission may use a different MCS.

ACK/NACK message should be modulated with GMSK.

## The change of the MCS should be initiated by the link layer and the transmission should start with the GMSK. The slot time duration should be the same regardless of the MCS chosen.

## Data encoding (Bit-to-symbol mapping)

-Wait for more Krzysztof input

The bit to symbol mapping shall for FSK and GMSK modulations be gray coded.

## Forward error correction –DLR to provide more input

The turbo code with the code rate of ½ or lower should be used. Different code rates will be obtained with the puncturing technique.

### Signalling FEC

### Data packet FEC Turbo is 3 GPP.

### Performance measure, Packet error ratio (1e-1, 1e-2 with ARQ, 1e-3)

* + - 1. Channel definition (e.g. AWGN)

Signal to noise ratios thresholds per MODCODS

## Interleaving (multi-packet) -DLR input and ESA

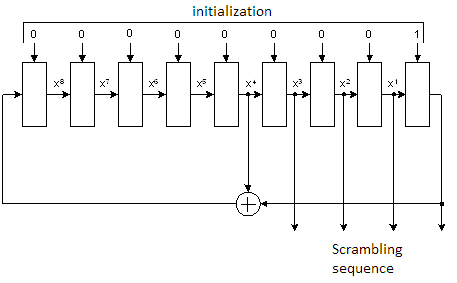
## Synchronisation (Preamble, postamble? ) + Pysical Layer Header

-Hans input, Krzysztof input

## Bit scrambling

Scrambling of the user data is required to avoid the power spectral density to be concentrated in the narrow band.

Scrambler should be based on the linear feedback shift register (LFSR). For instance it may be defined by the polynomial *x9 + x4 + 1*. The scrambling pseudo-random sequence in this case would be 511 bits long (29-1) and the scrambler scheme would be as follows:



The scrambling sequence (least significant bits of the register) should be added modulo-two with the data bits obtained after the FEC encoding. The number of bits will depend on the modulation scheme used in the particular case. When the 16QAM modulation is exploited then the last four bits of the register need to be XOR-ed with the four bits creating the 16QAM symbol. For each consecutive symbol the register should be shifted by the number of bits creating the scrambling sequence (i.e. 4 in a case of 16QAM).

The scrambler should be initialized with the sequence 00000001 for each frame.

### Data link sensing

Handled by link layer

### Transmitter power

The transmitter may use several power level settings, not to exceed 25W.

### Shutdown procedure

The transmitter shall have an automatic shutdown procedure after 1 seconds, to prevent stuck transmitters. The function shall be independant from software control.

## Link budget analysis

### Assumed parameters

### Range vs throughput

MODCOD Table (PER=10^-2) of Bitrate/Modulation/Coding scheme / Eb/No

Transmission waveforms for VHF data exchange

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Bandwidth | 25 kHz |  | 50 kHz | 100 kHz |
| Modulation | π/4 DQPSK |  | 16-QAM,  16 multi-carriers,  2.7 kHz spacing | 16-QAM,  32 multi-carriers,  2.7 kHz spacing |
| Modulation Category | PSK modulation |  | QAM modulation | QAM modulation |
| Data Rate (raw)\* | 28.8 kbit/s |  | 153.6 kbit/s | 307.2 kbit/s |
| Sensitivity\*\* | -107 dBm (min) ‑112 dBm (typical) |  | -98 dBm (ships) -103 dBm (base stations) | -98 dBm (ships) -103 dBm (base stations) |

## Framing Structure

VDE communication uses the concept of frames and slots, as defined by ITU-R M.1371, to quantize the communication channel into time segments and should be synchronized to slot boundaries of AIS A VDE frame is divided into 2250 slots. The VDE slot is the minimum adressable time segment of the VDE data link. The VDE frame is in turn part of a VDE superframe, spanning a number of VDE frames. The number of VDE frames shall correspond to the largest adressable VDE Data Link time unit. Each frame is 60s long, syncronized to UTC.



#### TDMA frame

Six timeslots should form a TDMA frame. The TDMA frame has duration of 160 ms.

The TDMA frames should be numbered by a Frame Number (FN). The FN should be cyclically numbered from 1 to 5. The FN should be incremented at the end of each TDMA frame.

#### 2.2.2.2 Timeslot numbering

The timeslots within a TDMA frame should be numbered from 1 to 6 and a particular timeslot should be referenced by its Timeslot Number (TN).

#### Subslot

The timeslots may be divided into 2 subslots. The subslots within a timeslot should be numbered from 1 to 2 and a particular subslot should be referenced by its SubSlot Number (SSN).

#### 2.2.2.4 Multiframe

Five TDMA frames should form a multiframe. The multiframe should have duration of 800 ms.

The multiframes should be numbered by a Multiframe Number (MN). The MN should be cyclically numbered from 1 to 15. The MN should be incremented whenever the TDMA FN returns to 1.

#### 2.2.2.5 Superframe

Fifteen multiframes should form a superframe. The superframe should have duration of 12 s.

The superframes should be numbered by a SuperFrame Number (SFN). The SFN should be cyclically numbered from 1 to 5. The SFN should be incremented whenever the MN returns to 1.

#### 2.2.2.6 Hyperframe

The hyperframe should be the longest recurrent time period of the TDMA structure. Five superframes should form a hyperframe. The hyperframe should have duration of 60 s.

### VDES Slots

The VDE slot is an integer fraction of an AIS slot. The VDE slot size shall therefore be 2/(75\*n) seconds, where n is an integer. The slot determines the the minimum amount of link load to be occupied by short messages. Short slots allowes access to the data link to more actors, and reduces unnessescary large link overhead for short messages. The slot size shall be long enough to fit control channel data amount, such as FATDMA reservations and acknowledgements, with the most robust MSC (modulation and coding sheme) available.

The time slot is a time interval of approximately 26.667 ms (60000/2250 = 80/3 ≈ 26.667). For PSK modulation, the time slot corresponds to 384 symbol durations, each one with a duration of approximately 69.4 µs ((60000000/2250)/384 = 625/9 ≈ 69.4). For QAM modulation, the time slot is divided into 64 modulation symbol durations, each one with a duration of approximately 416.7 µs ((60000000/2250)/64 = 1250/3 ≈ 416.7). The timeslots may be subdivided into 2 subslots.

The physical content of a time slot is carried by a burst.

### Data transfer packet size

The data transfer packet size may vary depending on the amount of data to be transmitted. The minimum size is one VDE slot, and the maximum consists of multiple VDE slots corresponding in time to a five AIS slots

## zModulation

### Channel Bandwidth

VDE capable systems shall be able to operate on the four 25kHz duplex channels, 24,84,25,85, allocated for data communication according to RR Appendix 18.

The 100kHz channel on VDE-A may be divided into two 50kHz channels or four 25kHz channels. The 100kHz channel on VDE-B may be divided into two 50kHz channels or four 25kHz channels.

The lower set of 25 kHz channels, 1024, 1084, 1025, 1085, are refered to as VDE1-A. The corresponding upper set of channels, 2024, 2084, 2025, 2085, are referred to as VDE1-B.

### Symbol rates

|  |  |  |  |
| --- | --- | --- | --- |
| Bandwidth | 25 kHz | 50 kHz | 100 kHz |
| Symbol rate |  |  |  |



# Link layer

## MAC layer (Media access control )

Provides a method for granting access and coordinating traffic for the data transfer s on the VHF data link (VDL). The method used is a TDMA scheme using a common time reference based on UTC.

### Base station media access

Base stations are configured to create fixed FATDMA allocations for periodic tranmissions, and will use the control channelling mechanism to pre allocate additional link access.

### Ship-ship media access

### Ship-shore media access

The AIS-based TDMA slot structure (2250 slots/minute/frame) and access schemes (ITDMA, CSTDMA and FATDMA) that are used for VDES are defined in Recommendation   
[ITU-R M.1371‑5](http://www.itu.int/rec/R-REC-M.1371/en). This TDMA organization scheme protects the integrity of the AIS and is used in a similar way to organize and synchronize the ASM and VDE transmissions.

### Channel access schemes

The access schemes, as defined below, should coexist and operate simultaneously on the TDMA channel.

### Incremental time division multiple access

ITDMA should be used for creation of transmission chains for multi transmission data packets;

### Carrier sense time division multiple access

Used for single VDE slot transmissions or as initial transmission when starting ITDMA transmission chain.

### Random access time division multiple access

RATDMA is used when a station needs to allocate a slot, which has not been pre-announced. This is generally done for the first transmission slot during data link network entry, or for messages of a non-repeatable character.

### Random access time division multiple access algorithm

The RATDMA access scheme should use a probability persistent (p-persistent) algorithm as described in ITU-R M.1371 Annex ? Section ?.

### Fixed access time division multiple access

FATDMA should be used by base stations only. FATDMA allocated slots should be used for repetitive messages, as well to reserve slots for remote targets that has requested to transmit on the VDE1-A channel.

### Fixed access time division multiple access algorithm

Access to the data link should be achieved with reference to frame start.

FATDMA reservations apply within a range of 120 nautical miles from the reserving base station. VDE stations (except when using FATDMA) should not use FATDMA reserved slots within this range. FATDMA reservations do not apply beyond 120 nautical miles from the reserving base station. All stations may consider these slots as available.

### Fixed access time division multiple access parameters

* Start slot - The first slot (referenced to frame start) to be used by the station
* Increment - Increment to next block of allocated slots.
* Block size - Determines the default number of consecutive slots which are to be reserved at each increment

### Broadcast

### Assignement (resoure allocation)

### Slotted ALOHA random access

### Multipacket transfer

## Signalling (control) protocol (VDE Base station) – Hans input,

## Data transfer protocol

## Automati Repeat Request

To facitilate control of ship-shore communication -Johan input

# Link layer –JRC,HANS,Others?

## Packet format signalling

3.1.1 Cyclic redundancy check

## Packet format data transfer

### Cyclic redundancy check

Recommended to increase from 16 bits to minimum 20, preferable 32

### Encapsulation (e.g Packet ID,)

# Transport layer

# 

INFORMATIVE ANNEX – Link budget

### Transmit (minimum) antenna gain (Antenna Pattern)

Since the shipborne antenna is required to receive the VDES satellite downlink at high elevation angles, the 0dBd (2.1dBi) option is selected. To achieve optimum satellite reception, this antenna should be mounted as high as possible, preferably on an extension pole, on the ship to minimize obstructions to the antenna’s view of the horizon. For the terrestrial VDES base station, the 6dBd (8dBi) option is selected. These two antennas are used in the propagation range predictions in Annex 2.

Figure 7 presents a mask for the receiving antenna gain as a function of elevation that would allow the received signal from satellite to be at constant power level at the receiver input for a wide range of elevation angles, taking into account the PFD constraints imposed on the VDE-SAT downlink (ref. Table 3 of Annex 1). Although this mask may not represent the antenna pattern associated with a commercially available antenna, it could serve as a guide for designing an antenna to enhance the satellite reception. The same mask is also applicable to the design of shipborne antenna for VDE terrestrial link due its high directivity in the horizontal direction. Annex 3 provides further rationale for the selection of this mask.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Antenna type | 1 element | 2 elements stacked | 3 elements stacked | 4 elements stacked |
| Gain to horizon | 2 dBi | 3 dBi | 6 dBi | 9 dBi |

For antenna patterns, refer to Annex 4 (VDES-SAT)

### Range (min and max)

Propagation range predictions for VHF data exchange system terrestrial links

# 1 Introduction

This is an informative annex. The excellent propagation characteristics of AIS are well established and appreciated. The propagation range predictions for the 100 kHz VDE ship-to-shore and shore-to-ship links follow below.

# 2 Ship-to-shore application

## 2.1 Basis for the coverage assessment

This coverage assessment is based on Recommendation [ITU-R P.1546-4](http://www.itu.int/rec/R-REC-P.1546/en) (assuming no ducting), taking into account the antenna height and the seawater propagation path:

Height of antenna (Base Station): 75 meters (see graph for various heights)

Assumed Transmitter power for ships: 12.5 Watts

Tx ships antenna minimum gain: 2dBi (0dBd)

Rx shore antenna gain: 8dBi (6dBd)

Pr: -103dBm (VDE shore station sensitivity)

## 2.2 Purpose for use of the Recommendation ITU-R P.1546-4 propagation curve

Recommendation [ITU-R P.1546-4](http://www.itu.int/rec/R-REC-P.1546/en) prescribes the use of the propagation curves ( §3 from Annex 5 and Figure 4 (Figures 13 and 14 of this Annex) from Annex 1, see below), assuming no ducting and a smooth earth/sea surface. This analysis may be used as a reference point for field test measurements that usually include some ducting, depending on weather, atmospheric conditions, and other factors.

## 2.3 Determination of transmitting/base antenna height, *h*1

Recommendation [ITU-R P.1546-4](http://www.itu.int/rec/R-REC-P.1546/en) specifies (§3 of Annex 5) the transmitting/base antenna height, *h*1, to be used in calculation depending on the type and length of the path. For sea paths *h*1 is the height of the antenna above mean sea level; for land paths *h*1 is the height above average terrain.

## 2.4 Determination of the minimum field strength (sensitivity threshold) at the VHF data exchange base receiving site

For ship-to-shore:

Power received (linear formula): Pr = Gr Er²c²/480π²f²

Rearranged: Er = √ (480π²f² Pr /Gr c2), where

Er = field strength in volts/meter

Gr = gain of receiving antenna = 6.3 = 8dBi

c = speed of light in free space = 3 x 108 meters/second

f = VDE ship-to-shore frequency = 1.57 x 108 (157 MHz)

Pr = 5x10-14 watts = -133dBW = -103dBm

Thus,

Er = 3.21 x 10-6 = 3.21 µV/m = +10.1dB µV/m

The logarithmic formula can also be used to calculate Pr (dBm):

Pr (dBm) = 42.8 - 20logF + 20logE + G, where

G = antenna gain in dBi = 8dBi

F = frequency in MHz = 157

Pr (dBm) = 42.8 – 43.9 – 109.9 + 8 = -103dBm (-133dBW)

## 2.5 Determine the range to the +10.1dBu (-103dBm) coverage limit for a seawater propagation path

Calculate the effective radiated power:

Ps = Pt + G

Pt = 10 log 12.5 – 30 = -19dBk (19dB below 1 kW)

G = 2dBi = +0dBd (0dB over a dipole)

Thus Ps = -19 +0 = -19dBk ERP

Fe = F – Ps  (vertical scale reference for the propagation graph in Figure 4 of Recommendation ITU-R P.1546-4, Figure 13 of this Annex)

F = +10.1dBu

Ps = -19dBk

Thus Fe = 10.1 – (-19) = +29.1dB

## 2.6 Determine the seaward ship-to-shore coverage range from Figure 13:

The +10.1dBu (-103dBm) range is 85km, which is 46NM (use *h*1 = 75m).

## 2.7 Determine the received signal strength indication values for various other ranges

The reference point received signal strength indication (RSSI) = -103dBm at a range of 85km (46NM) is determined above. For other ranges, the RSSI value is determined from the propagation curve (Figure 13) for the assumed antenna height of 75m. RSSI values in 10dB increments above the sensitivity threshold are shown in Table 7 below.

Table 7

VHF data exchange base station received signal strength indication value vs. distance ship-to-shore

|  |  |
| --- | --- |
| -103 dBm | 85 km (46NM) |
| -93 dBm | 60 km |
| -83 dBm | 40 km |
| -73 dBm | 25 km |
| -63 dBm | 15 km |
| -53 dBm | 8 km |
| -43 dBm | 4.5 km |



Figure 13

Figure 1

+29.1 dB reference -103dBm

85km (46NM) ship-to-shore Coverage range for -103dBm shore antenna height = 75m

# 3 Shore-to-ship application

## 3.1 Basis for the coverage assessment

Referring to section 2 above, consider the reverse direction, shore-to-ship, signal levels at the ship receiving site, the shore transmitter power of 50 Watts and the shore-to-ship frequency of 162 MHz:

Height of antenna (VDES Base Station): 75 meters (see graph for various heights)

Transmitter power of VDES on shore: 50 Watts (at base of shore antenna)

Tx shore antenna gain: 8 dBi (6 dBd)

Rx ships antenna gain: 2 dBi (0 dBd)

Pr: -98 dBm (VDE ship station sensitivity)

### 3.1.1 Determination of the minimum field strength (sensitivity threshold) at the VHF data exchange ship receiving site

For shore-to-ship:

Power received (linear formula): Pr = Gr Er²c²/480π²f²

Rearranged: Er = √ (480π²f² Pr /Gr c2), where

Er = field strength in volts/meter

Gr = gain of receiving antenna = 1.62 = 2.1 dBi

c = speed of light in free space = 3 x 108 meters/second

f = VDE shore-to-ship frequency = 1.62 x 108 (162 MHz)

Pr = 1.58 x 10-13 watts = -128 dBW = -98 dBm

Thus,

Er = 11.61 x 10-6 = 11.61 µV/m = +21.3 dB µV/m

The logarithmic formula can also be used to calculate Pr (dBm):

Pr (dBm) = 42.8 - 20logF + 20logE + G, where

G = antenna gain in dBi = 2.1 dBi

F = frequency in MHz = 162

Pr (dBm) = 42.8 – 44.1 – 98.7 + 2.1 = -98 dBm (-128 dBW)

### 3.1.2 Determine the range to the +21.3 dBu (-98 dBm) coverage limit for a seawater propagation path

Calculate the effective radiated power:

Ps = Pt + G

Pt = 10 log 50 – 30 = -13dBk (13dB below 1 kW)

G = 8dBi = +6dBd (6dB over a dipole)

Thus Ps = -13 +6 = -7dBk ERP

Fe = F – Ps  (vertical scale reference for the propagation graph in Figure 4 of Recommendation ITU‑R P.1546-4, Figure 2 of this Annex)

F = +21.3 dBu

Ps = -7 dBk

Thus Fe = 21.3 – (-7) = +28.3 dB

Note that since this value of Fe is within 1dB of the value calculated in Section 2.5 because the reduced sensitivity of the ship station is compensated by the higher power and antenna gain of the shore base station.

### 3.1.3 Determine the seaward shore-to-ship coverage range from Figure14

The +28.3 dBu (-98 dBm) range is 85 km, which is 46 NM (use *h*1 = 75 m). This is the same as the ship-to-shore coverage range, an ideal balanced two-way coverage, which confirms the proposed choices of antennas and transmitter power values for the shipborne and shore VDES stations.

### 3.1.4 Determine the received signal strength indication values for various other ranges

The reference point: RSSI = -98 dBm at a range of 85 km (46 NM) is determined in 2.6 above. For other ranges, the RSSI value is determined from the propagation curve (Figure 14) for the assumed antenna height of 75 m. RSSI values in 10 dB steps above and below the -98 dBm threshold sensitivity for the shipborne VDE receiver are shown in Table 8 below.

Table 8

VHF data exchange ship station received signal strength indication value vs. distance shore-to-ship

|  |  |
| --- | --- |
| -118 dBm | 170 km |
| -108 dBm | 130 km |
| -98 dBm | 85 km (46NM) |
| -88 dBm | 60 km |
| -78 dBm | 40 km |



Figure 14

Figure 2

85 km (46NM) shore-to-ship Coverage range for -98 dBm shore antenna height = 75 m

+28.3 dB reference -107 dBm

* + - 1. Anomaly Due to Inversion (Delay Tolerance due to the distance up to a few msec)

### Receive antenna gain

### Receive noise floor

### Link C/N0

### Source of Self Interference (assumptions about the interference)

### Received signal to noise plus Interference level