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GUIDELINE

G1139

THE TECHNICAL SPECIFICATION OF VDES

Edition 1.0

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10, rue des Gaudines - 78100 Saint Germain en Laye, France
Tél. +33 (0)1 34 51 70 01 - Fax +33 (0)1 34 51 82 05 - contact@iala-aism.org
www.iala-aism.org
International Association of Marine Aids to Navigation and Lighthouse Authorities
Association Internationale de Signalisation Maritime

DOCUMENT HISTORY

Revisions to this IALA document are to be noted in the table prior to the issue of a revised document.

Date	Details	Approval
December 2017	1st issue	Council 65

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1. INTRODUCTION

1.1. PURPOSE OF THE DOCUMENT

This Guideline has been prepared to provide technical information required in the development of VDES equipment, which integrates the functions of VHF data exchange (VDE), application specific messages (ASM) and the automatic identification system (AIS) in the VHF maritime mobile band (156.025-162.025 MHz).

This document refers to ITU Recommendation ITU-R M.2092-0, and is not intended to replace that document. The IALA Guideline on Technical Specifications of VDES provides additional detail on VDES, and will be amended as required to reflect experience in implementing the technical solutions for VDES. As this IALA Guideline is revised, input will be included, as appropriate, as a working document towards a revision of ITU-R M.2092. It is intended that this input will be provided to the appropriate working group of ITU following the results of the ITU WRC-19.

Persons using this document are encouraged to provide comments, corrections and further input on developments to IALA. In addition, persons who are implementing VDES are invited to participate in further work on the system through the IALA ENAV Committee. It is noted that, as VDES develops, any deployment of VDES will need to comply with the appropriate ITU regulation, once they are agreed.

It is noted that, following WRC-15, the full satellite capability of VDES is being studied at ITU and will be reviewed at WRC-19. This IALA Guideline includes the full capability (including satellite).

1.2. BACKGROUND

AIS is well recognised and accepted as an important tool for safety of navigation and is a carriage requirement for SOLAS vessels (Class-A). With increasing demand for maritime VHF data communications, AIS has become heavily used for maritime safety, maritime situational awareness and port security. As a result, high loading of AIS 1 and AIS 2 created a need for additional VHF data channels. Using the VHF marine band (International Radio Regulations Appendix 18) AIS can broadcast data to vessels in the vicinity of the AIS unit. AIS can also transmit an addressed message.

International Telecommunications Union (ITU) has recognised the efficiency and the necessity for digital communications, has produced technical standards and has revised the VHF marine band (Radio Regulations Appendix 18) to designate channels for data transmission. It is recognized that both analogue voice communications and digital communications will share the band. The VDES, as envisioned by IALA and presented to ITU, addresses the identified need to protect AIS along with essential digital communications contributions for e-Navigation and GMDSS Modernization.

Both voice and data communications coexist in the VHF marine band. The developments in maritime radio technology, including the introduction of software defined radios (SDR) coupled with enhanced capabilities for digital data exchange over existing VHF marine band spectrum resulted in the development of the VHF Data Exchange System (VDES). VDES builds on the experience gained through the development of AIS, and also provides the capability to transmit to a specific vessel (addressed); to all units in the vicinity (broadcast); to a group of vessels (addressed); or to a fleet of vessels (addressed).

Consequential to WRC-15, the ITU standard for VDES, Recommendation ITU-R M.2092-0, was approved. A remaining outstanding issue is the approval of the satellite component for the VDE channels which is targeted for approval at WRC-19.

The expected implementation pf VDES is provided in Figure 1.

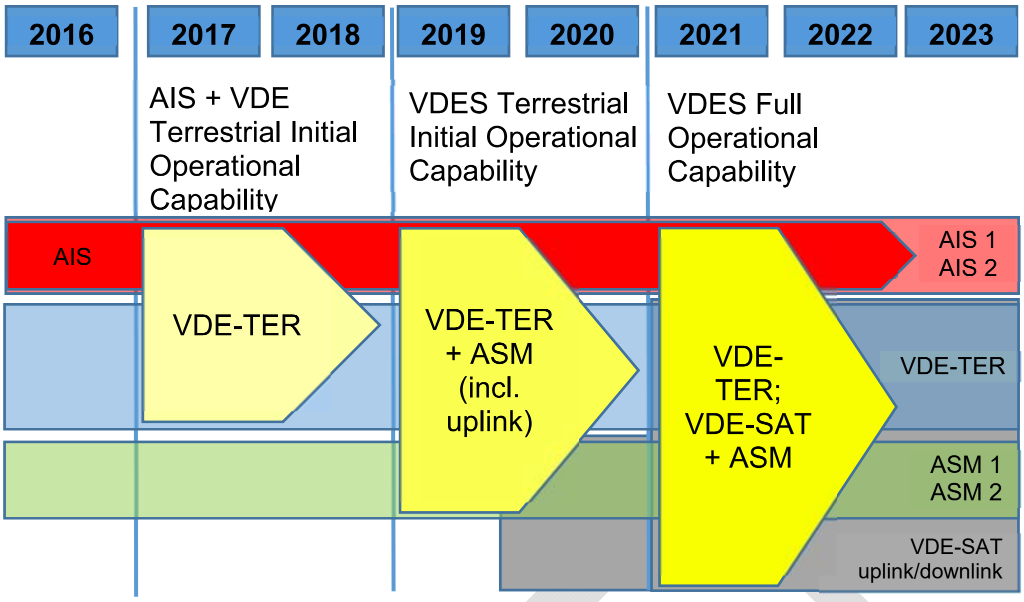

Figure 1. *Implementation of VDES*

The introduction of VDES is expected to happen through four operational phases:

1 (2016) AIS exists as defined by ITU.R M.1371-5 on the AIS frequencies, and Coastal Stations use the ASM and VDE frequencies for Voice VHF.

2 (2017-2018) Post WRC-15 - AIS+ASM: Regionally, where there is an urgent need for offloading the AIS VDL from significant ASM traffic, it is recommended to allow the introduction of 4-channel AIS + ASM devices. These devices may receive and transmit ASM on the ASM1 and ASM2 frequencies, but shall discontinue their transmit capability, using the existing GMSK modulation after January 1st 2019 unless a software upgrade enables them to participate in the modulation and access scheme agreed for the ASM frequencies according Recommendation ITU-R M.2092. Note that the ASM frequencies will need to be shared with the VHF voice service from Coast Stations in many areas during this time frame.

3 (2019) the WRC-19 will consider and decide regarding VDE-SAT.

4 (2019-2020) Post WRC-19 operational capability established. Note that both the ASM and VDE frequencies may still need to be shared with the voice VHF service in many areas.

5 (2021+) When a satellite service is developed, full operational capability of the VDES including the Satellite frequencies can be achieved.

1.3. DOCUMENT STRUCTURE

The document is provided in a series of Annexes.

Annex A - provides common technical elements of VDES

Annex B - describes the technical characteristics of the ASM channel that will support applications specific messages in order to improve the efficiency of application-specific message transmissions and to protect the original function of the AIS. The ASM channels will also support a satellite uplink.

Annex C - describes the technical characteristics of the VDE terrestrial channels providing an efficient terrestrial data transfer link enabling a wide variety of applications for the maritime community.

Annex D - describes the technical characteristics of VDE-SAT Service that will support multi-cast multi-package data transfers and shore originated unicast multi-package data transfers via satellite.

Annex E - describes the characteristics necessary for each component of the VDES to share the available spectrum such that impact between services is minimized and AIS is respected.

2. OPERATIONAL CHARACTERISTICS

In general, VDES should meet the following:

1 The system should give its highest priority to the automatic identification system (AIS) position reporting and safety related information.

2 The system installation should be capable of receiving and processing the digital messages and interrogating calls specified by this Recommendation.

3 The system should be capable of transmitting additional safety information on request.

4 The system installation should be able to operate continuously while under way, moored or at anchor.

5 The system should use for the terrestrial links time-division multiple access (TDMA) techniques, access schemes and data transmission methods in a synchronized manner as specified in the Annexes.

6 The system should be capable of various modes of operation, including the autonomous, assigned and polled modes.

7 The system should provide flexibility for the users in order to prioritize some applications and, consequently, adapt some parameters of the transmission (robustness or capacity) while minimizing system complexity.

8 The system should address the use cases identified in Report ITU-R M.2371.

2.1. GENERAL DESCRIPTION OF VDES

A detailed overview of VDES, and VDES operations, is provided in IALA Guideline 1117 (latest edition). In essence, The VDES provides a variety of means for the exchange of data between maritime stations, ship-to-ship, ship-to-shore, shore-to ship, ship-to-satellite and satellite-to-ship. The VDES functionally includes the AIS, either by integration, by interface connection or by radio frequency connection.

2.2. VDES FUNCTIONS AND FREQUENCY USAGE

The system concept, including VDES functions and frequency usage are illustrated pictorially in Figure 2 (full system). Please note – SAT Up is received only by Satellite.

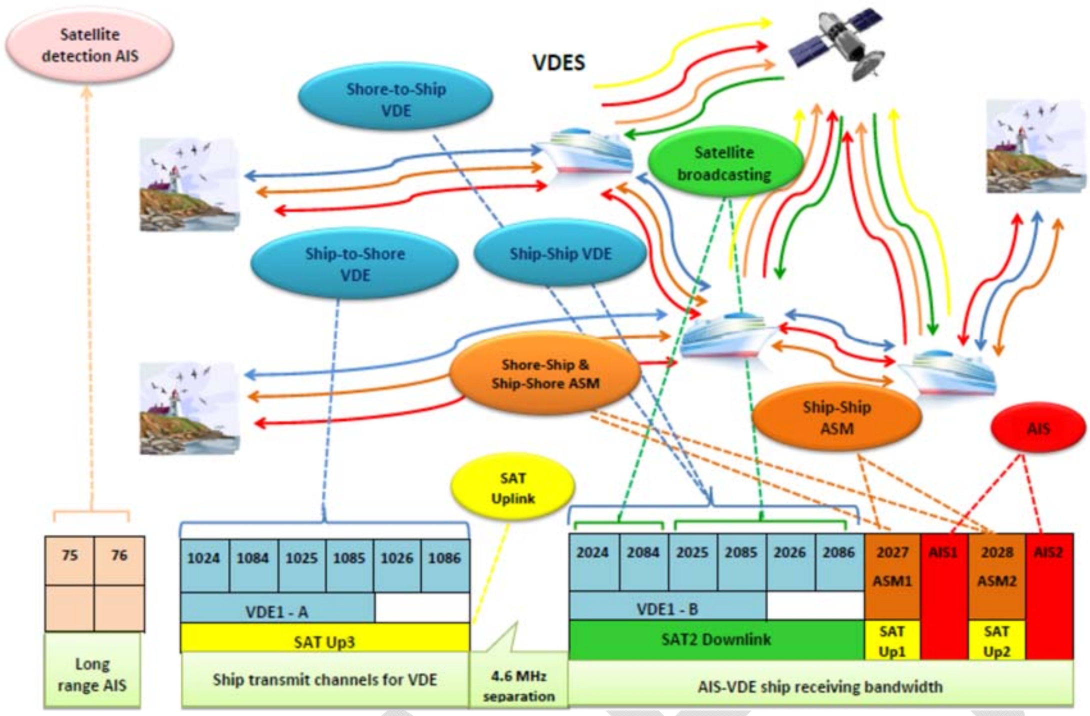

Figure 2. VDES functions and frequency use – full system

3. VDES CHANNEL USAGE IN ACCORDANCE WITH ITU RR APPENDIX 18

This section provides information on channel usage between terrestrial stations and between satellite and terrestrial stations.

3.1. VDES: DATA EXCHANGE BETWEEN TERRESTRIAL STATIONS

- AIS 1 (channel 2087) and AIS 2 (channel 2088) are AIS channels, in accordance with Recommendation ITU-R M.1371
- ASM 1 (channel 2027) and ASM 2 (channel 2028) are the channels used for application specific messages (ASM)
- 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.

3.2. VDES: DATA EXCHANGE BETWEEN SATELLITES AND TERRESTRIAL STATIONS

- AIS 1 (channel 2087) and AIS 2 (channel 2088) are terrestrial AIS channels that are also used as uplinks for receiving AIS messages by satellite
- Long Range AIS using channel 75 and channel 76 are specified channels to be used as uplinks for receiving AIS messages by satellite. SAT Up1 (channel 2027) and SAT Up 2 (channel 2028) are used for receiving ASM by satellite
- SAT Up3 (channels 1024, 1084, 1025, 1085, 1026 and 1086) are used for ship-to-satellite VDE uplinks
- SAT Downlink (channels 2024, 2084, 2025, 2085, 2026 and 2086) are used for satellite-to-ship VDE downlinks.

4. IDENTIFICATION

Identification and location of all active maritime stations is provided automatically by means of the AIS. All VDES stations should be uniquely identified. For the purpose of identification, a unique numerical identifier is used as defined by the following:

- If the unique identifier has a range which is less than 999999999, then this number is defined by the latest version of Recommendation ITU-R M.585.
- If the unique identifier has a range which is greater than 999999999, then this is number is free form.

5. PRESENTATION INTERFACE PROTOCOL

For VDES transceivers:

- data may be input via the presentation interface to be transmitted by the VDES station;
- data received by the VDES station should be output through the presentation interface.

6. TECHNICAL CHARACTERISTICS

A general overview of the technical aspects of VDES is provided in IALA Guideline 1117. This section provides more detailed technical characteristics.

6.1. SHIPBORNE VDES RECEIVERS ARE PROTECTED

As in AIS, shipborne VDES receivers are on the upper legs of RR Appendix 18, 4.6 MHz above the lower legs, which facilitates protection by filtering from receiver blocking by ships VHF radios.

6.2. SAT DOWNLINK

The satellite downlink complies with the power flux-density (PFD) mask described in Table A4-1 to minimize interference to terrestrial services and to maximize reception by ship VDES stations.

6.3. VDES1 USES BOTH LEGS OF THE DUPLEX CHANNELS

Channel capacity is utilized for the duplex channels in VDE1 by using the lower legs (VDE1-A) for ship-to-shore and the upper legs (VDE1-B) for shore-to-ship and ship-to-ship digital messaging.

Table 1 describes the RR Appendix 18 channels used for the various applications of VDES.

Table 1 - RR Appendix 18 channels for VHF data exchange systems applications: Automatic identification system, application specific messages, VHF data exchange

RR Appendix 18 channel number		Transmitting frequencies (MHz)	
		Ship stations (ship-to-shore) (long range AIS) Ship stations (ship-to-satellite)	Coast stations Ship stations (ship-to-ship) Satellite-to-ship
AIS 1		161.975	161.975
AIS 2		162.025	162.025
75 (long range AIS)		156.775 (ships are Tx only)	N/A
76 (long range AIS)		156.825 (ships are Tx only)	N/A
2027 (ASM 1)		161.950 (2027)	161.950 (2027)
2028 (ASM 2)		162.000 (2028)	162.000 (2028)
24/84/25/85 (VDE 1)	24/84/25/85/26/86 (Ship-to-satellite, satellite-to-ship)	100/150 kHz channel (24/84/25/85, lower legs (VDE1-A) merged) Ship-to-shore (24/84/25/85/26/86) Ship-to-satellite	100/150 kHz channel (24/84/25/85, upper legs (VDE1-B) merged) Ship-to-ship, Shore-to-ship (24/84/25/85/26/86) Satellite-to-ship
24	24	157.200 (1024)	161.800 (2024)
84	84	157.225 (1084)	161.825 (2084)
25	25	157.250 (1025)	161.850 (2025)
85	85	157.275 (1085)	161.875 (2085)
	26	157.300 (1026)	161.900 (2026)
	86	157.325 (1086)	161.925 (2086)

6.4. VHF DATA EXCHANGE SYSTEM FUNCTIONS AND FREQUENCY USAGE ENGINEER’S PERSPECTIVE

The VDES functions and frequency usage from an engineer’s perspective are illustrated pictorially in Figure 3.

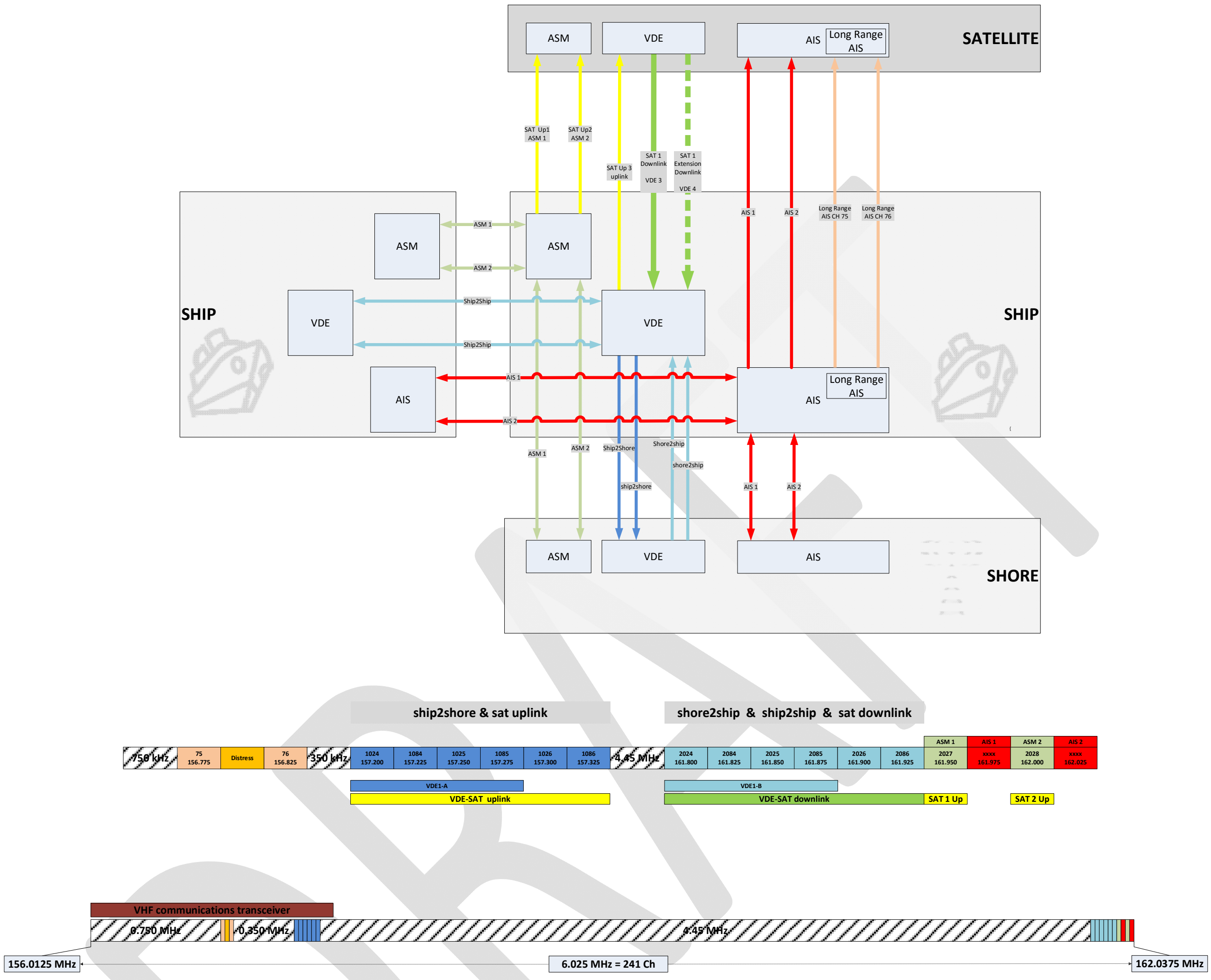

Figure 3. VHF data exchange system functions and frequency usage engineer’s perspective

7. FUNCTIONS OF VDES

The priority and timing of transmissions shall be in accordance with the following service priorities:

Highest Priority 1: AIS transmissions on AIS channels

Priority 2: specified and approved ASM transmissions on ASM channels

Priority 3: all other data exchange on VDE channels

The VDES receivers shall always be active. It is understood that transmissions by own equipment will impair reception by own equipment on own ship.

The VDES should support the following: Automatic Identification System; Application-Specific Messages; VDE Terrestrial; VDE Satellite; VDES sharing options.

Automatic Identification System

The AIS will operate as defined by Recommendation ITU-R M.1371.

8. DEFINITIONS / ACRONYMS AND REFERENCES

The definitions of terms used in this Guideline can be found in the International Dictionary of Marine Aids to Navigation (IALA Dictionary) at http://www.iala-aism.org/wiki/dictionary and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

8.1. DEFINITIONS

Control Station	Coast base station, satellite or other VDES station that is transmitting bulletin board and provides routing services to the maritime cloud.

8.2. ACRONYMS

3GPP	Third generation partnership project
ACK	Acknowledgement
ADDC	Assigned data transfer
ACPR	Adjacent channel power ratio
AIS	Automatic identification system
AOS	Acquisition-of-signal
APSK	Amplitude phase shift keying
ARQ	Automatic repeat request
ARSC	Announcement response channel
ASC	Announcement signalling channel
ASM	Application-specific messages
ATDMA	Allocated Time-Division Multiple Access
AWGN	Additive white Gaussian noise
BBSC	Bulletin board signalling channel
BCH	Bose Chaudhuri Hocquenghem, an error-correcting-code
BER	Bit error rate
BPSK	Binary phase shift keying
BT	Bandwidth-time
CEPT	European conference of postal and telecommunications administrations
CDMA	Code division multiple access
CG	Coding gain
CIR	Carrier to interference ratio
C/M	Carrier to multipath
CNR	Carrier to noise ratio
COMSTATE	Communication state
CPM	Continuous phase modulation
CQI	Channel quality indicator

CR	Code rate
CRC	Cyclic redundancy check
CRL	Configuration revision level
CS	Carrier sense
CIRM	Comité International Radio Maritime
CSTDMA	Carrier sense time division multiple access
CW	Continuous wave
DA	Doherty amplifier
DLS	Data link service
DPD	Digital pre-distortion
EDN	End delivery notification
EDF	End delivery failure
EIRP	Equivalent isotropic radiated power (e.i.r.p.)
ERP	Effective radiated power (e.r.p.)
ET	Envelope tracking
FATDMA	Fixed access time-division multiple access
FEC	Forward error correction
FIFO	First-in first-out
GMSK	Gaussian-filtered minimum shift keying
GNSS	Global navigation satellite system
HS	Hexslots
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICAO	International Civil Aviation Organization
ID	Identification
IEC	International Electrotechnical Commission
IMO	International Maritime Organization
IP	Internet protocol
LC	Logical channels
LEO	Low-earth orbiting
LFSR	Linear feedback shift register
LME	Link management entity
LNA	Low noise amplifier
LOS	Loss-of-signal
LSB	Least significant bit
MEO	Medium-earth orbiting
MAC	Media access control

MCS	Modulation and coding scheme
MDC	Multicast data channel
MMSI	Maritime mobile service identity
MSB	Most significant bit
NF	Noise figure
NM	Nautical mile
NRZI	Non-return to zero inversion
OFDM	Orthogonal frequency division multiplexing
OSI	Open systems interconnection
PAPR	Peak to average power ratio
PC	Physical channels
PL	Physical layer
PFD	Power flux-density
ppm	parts per million
PSK	Phase shift keying
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
RADC	Random access short messaging channel
RATDMA	Random access time-division multiple access
RAC	Random access channel
RF	Radio frequency
RSC	Recursive systematic convolutional
RQSC	Random access resource request
RR	Radio regulations
RSSI	Received signal strength indication
SCTDMA	Slot carrier sense time division multiple access
SFTP	Secure file transfer protocol
SI	Selection interval
SMTP	Simple mail transfer protocol
SNMP	Simple network management protocol
SNR	Signal to noise ratio
SOLAS	Safety of Life at Sea Convention
SOTDMA	Self-organized time division multiple access
SS	Spreading sequences
Sym	Symbol
SYNC	Synchronization

TBB	Terrestrial bulletin board
TBBSC	Terrestrial bulletin board signalling channel
TDMA	Time division multiple access
UDC	Unicast data channel
UDP	User data protocol
UTC	Coordinated universal time
VDE	VHF data exchange
VDES	VHF data exchange system
VDE-SAT	VHF data exchange-satellite
VDL	VHF data link
VHF	Very high frequency

8.3. REFERENCES

[RD-1] ETSI EN 302 583 (V1.2.1) – Digital Video Broadcasting (DVB); Framing Structure, channel coding and modulation for Satellite Services to Handheld devices (SH) below 3 GHz.

[RD-2] TM Synchronization and Channel Coding. Recommendation for Space Data System Standards, CCSDS 131.0-B-2. Blue Book. Issue 2. Washington, D.C.: CCSDS, August 2011.

[RD-3] R. Mueller, On Random CDMA with Constant Envelope, ISIT 2011.

[RD-4] Recommendation ITU-R P.372 – Radio Noise.

[RD-5] Recommendation ITU-T V.42 (03/2002) – Series V: Data Communication over the Telephone Network – Error control – Error-correcting procedures for DCEs using asynchronous-synchronous conversions.

ANNEX A COMMON TECHNICAL ELEMENTS OF VDES

This annex describes those elements of VDES that may be common across the ASM and VDE Channels.

A 1. PROTOCOL LAYER

A 1.1. PROTOCOL LAYER OVERVIEW

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 4. The responsibilities of the OSI layers for preparing VDES data for transmission and explained further in this section.

Application layer
Presentation layer
Session layer
Transport layer
Network layer
Link layer
Physical layer

Figure 4. Seven-layer OSI model

A 1.2. PHYSICAL LAYER

This layer provides transmission and reception of raw bit streams over a physical medium including signal modulation, filtering/shaping upon transmission, and amplification, filtering, time and frequency synchronization, demodulation, and decoding upon reception.

A 1.2.1. TRANSMISSION ACCURACY FIGURES

A 1.2.1.1 Symbol timing accuracy (at the output)

The timing accuracy of the transmit signal should be better than 5 ppm.

A 1.2.1.2 Transmitter timing jitter

The timing jitter should be better than 5% of the symbol interval (peak value).

A 1.2.1.3 Slot transmission accuracy at the output

The slot transmission accuracy should be better than 100 µs peak relative to UTC time reference for ship stations.

A 1.2.2. FRAME STRUCTURE

The system uses the Recommendation ITU-R M.1371 concept of a frame. A frame equals one (1) minute and is divided into 2 250 slots. Access to the data link is, by default, given at the start of a slot. The VDES frame structure is identical and synchronized in time to UTC (as in AIS). The general slot formats are shown in Figure 5 and Figure 6.

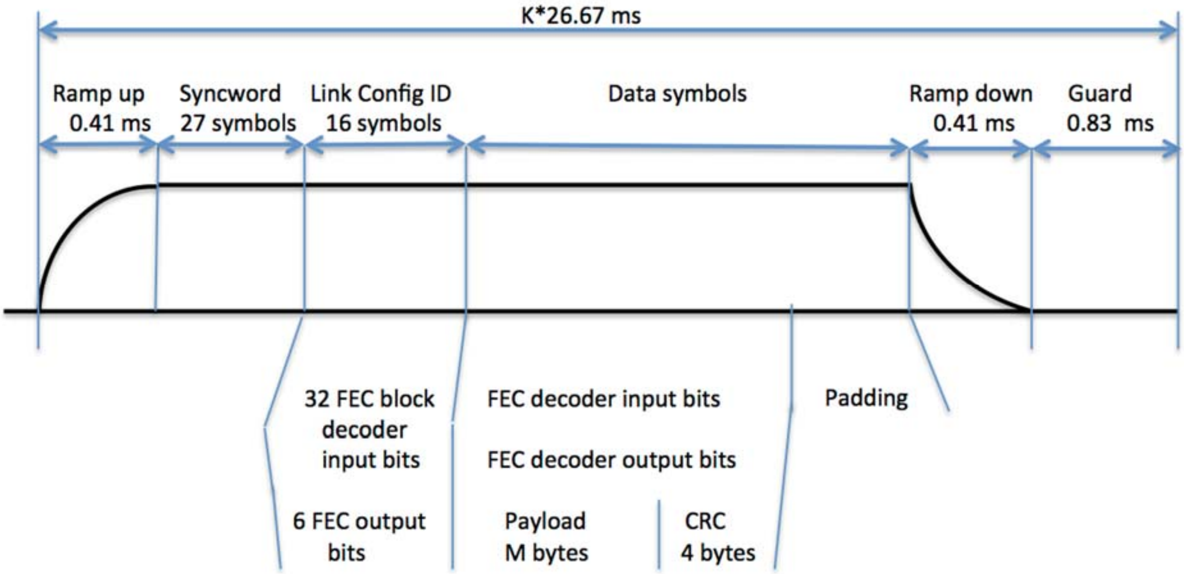

Figure 5. ***ASM-TER and VDE-TER General Packet Format***

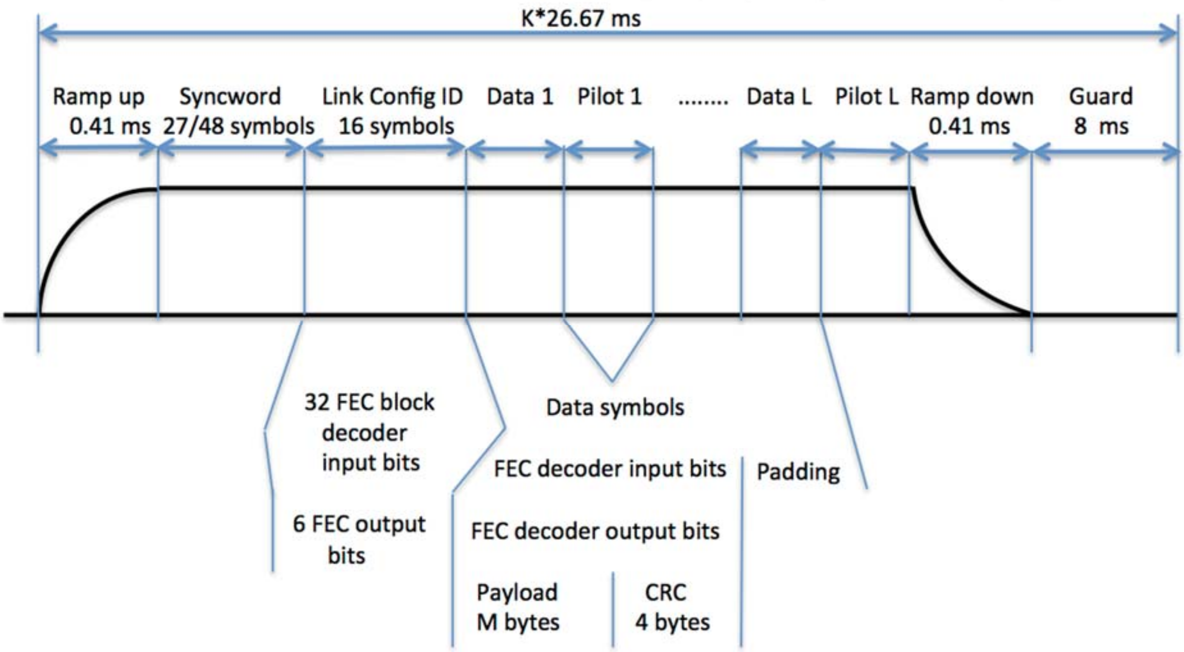

Figure 6. ***ASM-SAT and VDE-SAT General Packet Format***

A 1.2.2.1 Frame hierarchy definition

The frame hierarchy is shown in Figure 7. The frame hierarchy definition is independent of the assigned bandwidth to the VDE channel

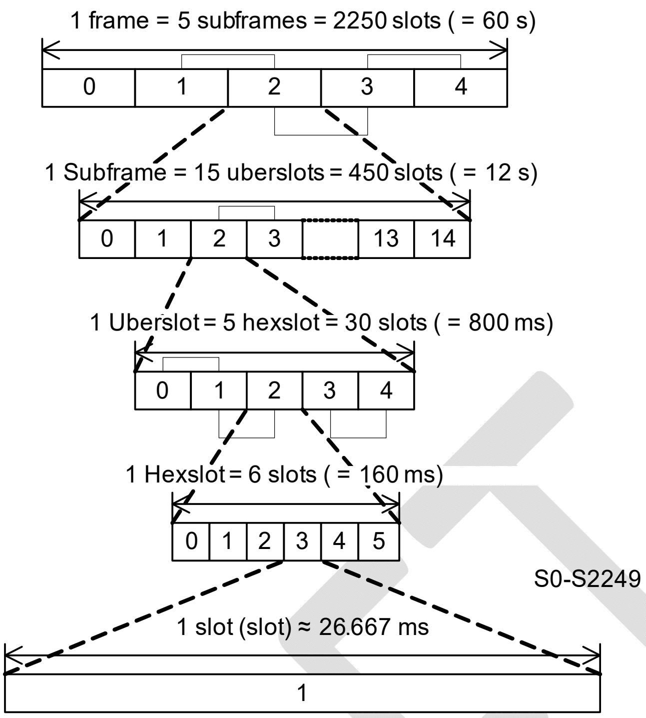

Figure 7. Frame Hierarchy for shared frequency

A 1.2.2.1.1 Slot

The slot is a time interval of approximately 26.667 ms (60 000 / 2 250 = 80/3 ≈ 26.667).

The slot should be cyclically numbered by a slot number ranging from 0 to 5.

A 1.2.2.1.2 Hexslot

Six slots should form a Hexslot (HS). The HS has duration of 160 ms. The HS should be numbered cyclically from 0 to 4. The HS should be incremented after every 6 slots.

A 1.2.2.1.3 Uberslot

Five Hexslots should form a Uberslot (US). The US should have duration of 800 ms. The US should be numbered by a US Number. The US should be cyclically numbered from 0 to 14. The US should be incremented whenever the Hexslot returns to 0.

A 1.2.2.1.4 Sub frame

Fifteen US should form a sub frame. The sub frame should have a duration of 12 seconds. The sub frame should be numbered by a sub frame number. The PL-frame should be cyclically numbered from 0 to 4. The sub frame should be incremented whenever the US returns to 0.

A 1.2.3. BURST TRANSMISSION STRUCTURE

A 1.2.3.1 Ramp up

The ramp up time from −50 dBc to −1.5 dBc of the power shall controlled rise time and occur in 416 µs. A gradual ramp-up period provides important spectral shaping to reduce energy spread outside the desired signal modulation bandwidth, and reduces interference to other users of the current and adjacent channel. The Ramp-up pattern shown in Table 2 is mapped as defined in section A 1.2.3.3 *Bit mapping for training sequence*.

Table 2 - Ramp-up symbol patterns for VDES

Link Config ID		Ramp-Up Time (ms)	Ramp-Up # of transmission symbols	Ramp-UP Pattern
ASM-TER CH BW 16kHz	1, 2, 3, 5, 6, 7, 8, 9, 10	0.41	4	0, 0, 1, 1
VDE-TER CH BW 25kHz	11, 12, 13	0.41	8	0, 0, 1, 1, 0, 0, 1, 1
VDE-TER CH BW 50kHz	14, 15, 16	0.41	16	0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1
VDE-TER CH BW 100kHz	17, 18, 19	0.41	32	0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 1

A 1.2.3.2 Training sequence

Table 3 shows the syncwords used for VDES.

Table 3 - SYNCWORDS for VDES

Usage	Symbol size	Sequence	Type	Comment
ASM-TER VDE-TER	27	1 1111100110101 0000011001010	1+ Barker13+ inverted Barker13	TC under consideration
ASM-SAT VDE-SAT	27	010001010010010000000110011	Best autocorrelation for differential detection	Based on search. Looses 0.3% of packets at E_s/N_0 of 5 dB
VDE-SAT	48	000100011110011011000001010111011010110111101000		Needs to work at E_s/N_0 of -2 dB

The Double Barker sequence used for ASM-TER and VDE-TER allows for detection of the 2 correlation peaks and the 13 bit known noise in between. Furthermore, the correlation peak size indicates frequency offset.

A 1.2.3.3 Bit mapping for training sequence and signal information

For training and signal information, following mapping applies:

- 1 maps to $\pi/4$ QPSK symbol 3 (1, 1) (see Figure 12)
- 0 maps to $\pi/4$ QPSK symbol 0 (0, 0).

For $\pi/4$ QPSK bit mapping, see A 1.2.8.

A 1.2.3.4 Link Configuration Id

The Link Configuration Id defines the channel configurations. The Link Configuration Id is used to index the table of channel configurations, see Tables 7, 8, 9, and 10.

The Link Configuration Id follows the training sequence for transmissions, see Figure 5 and Figure 6.

The Link Configuration Id consists of 6 bits (D0, D1, D2, D3, D4, D5) encoded into a sequence of 32 bits using biorthogonal (32,6) code.

The link configuration id is not used by the SAT link.

A 1.2.3.5 Data with CRC-32

The data payload with its appended CRC-32 is interleaved (refer to Table 4) encoded (refer to A 1.2.4.1), scrambled (refer A 1.2.6) and bit mapped.

Unused payload data is zero-filled.

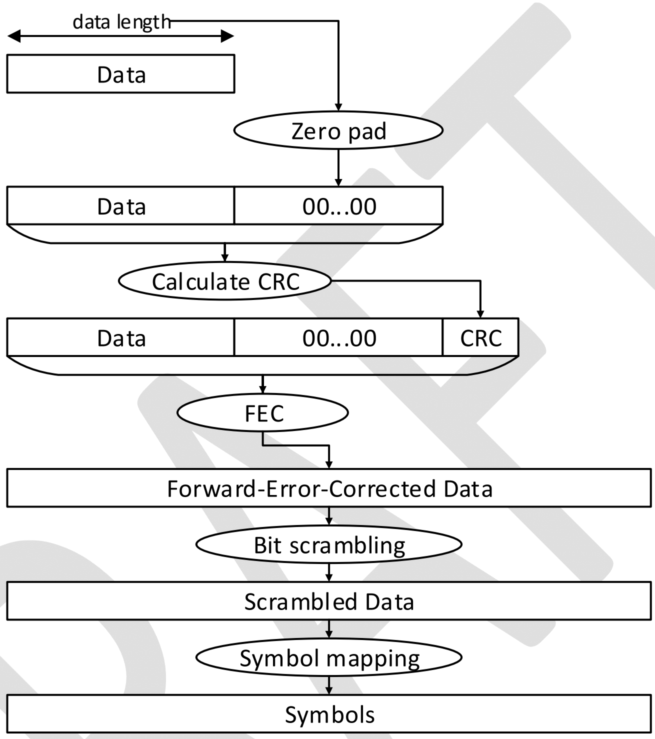

Figure 8. Order of operations for TDMA; if CR=1 FEC is not applied

A 1.2.3.6 Bit scrambling

Scrambling of the user data is required to avoid the power spectral density to be concentrated in the narrow band. Refer to A 1.2.6 for the detailed definition of the scrambler sequence.

A 1.2.3.7 Guard time

The guard time consists of the ramp down time from full power to −50 dBc of less than or equal to 416 µs. The remaining time is for delay and jitter.

A 1.2.4. Forward Error Correction

A 1.2.4.1 Encoder Structure

This paragraph defines the general structure of the forward error correction encoder to be used on the satellite and the terrestrial component of the VDES. The overall structure follows the specification in the ETSI EN 302 583 standard [RD-1].

The general encoder structure is depicted in Figure 9. The encoder consists of two recursive systematic convolutional (RSC) encoders concatenated in parallel. Each encoder produces 3 output bits per input bit. The first RSC encoder produces the bits X, Y_0 and Y_1, while the second encoder produces the bits X', Y'_0 and Y'_1. The <pi> block in Figure 9 represents the interleaving function as described in section A 1.2.4.3.

The first encoder gets as input a word **u** of k bits, with k, as specified in A 1.2.4.3. The second encoder input is denoted by **u**' and it is a permuted version of the vector **u**. The input **u** is the data (including padding and CRC), with MSB of each byte first. For example, if the data is 0x7F, 0xA5, … **u** will be 01111111 10100101 ….

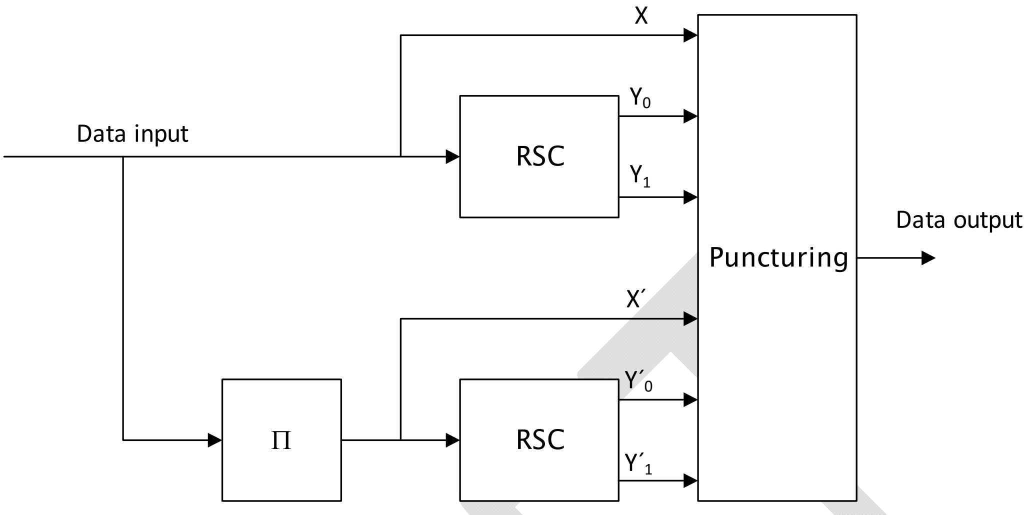

Figure 9. Turbo encoder structure (high-level)

A 1.2.4.2 Constituent codes

The constituent codes are specified by the transfer function

$$G(D) = \left[1 \quad \frac{n_0(D)}{d(D)} \quad \frac{n_1(D)}{d(D)}\right]$$

where

$$n_0(D) = 1 + D + D^3$$
$$n_1(D) = 1 + D + D^2 + D^3$$
$$d(D) = 1 + D^2 + D^3.$$

The constituted encoder definition is provided in Figure 10. For the first k clocks the switch is in position (a), i.e. information is fed into the encoder. For the subsequent 6 clocks, the switch is moved to position (b) to handle the RSC trellis termination. In the first 3 termination clocks, only the RSC 1 (upper branch) is output, while in the subsequent 3 termination clocks, only the output of RSC 2 (lower branch) is provided. The termination is thus given by the sequence of 6 termination bits (X, Y_0, Y_1, X', Y'_0, Y'_1) with X output first.

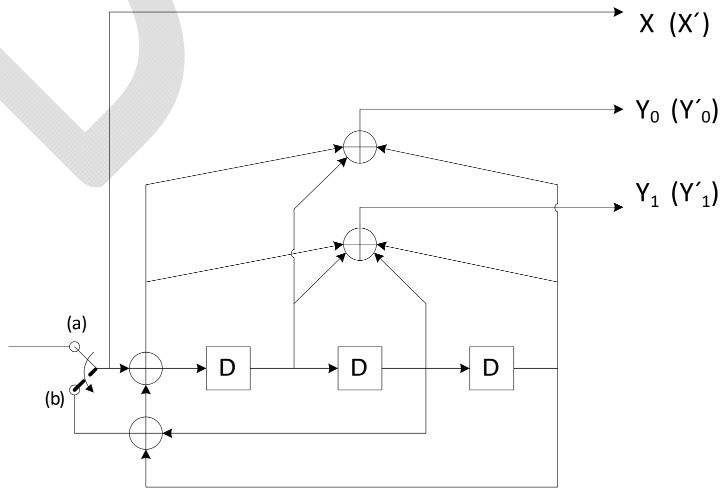

Figure 10. RSC code encoder

A 1.2.4.3 Interleaver definition

The interleaver specification follows [RD-2].

First factorize $k = k_1 k_2$, where the parameters k_1 and k_2 depend on the choice of the respective code, where k is the information block length. Then select prime numbers and puncturing parameters values as given in Table 4.

Table 4 - Interleaver and Puncturing Parameters for Different Information lengths / code rates

Link Conf ID	Nominal code rate	Information length	$k_1 \| k_2$	$p_1 \| p_2 \| p_3 \| p_4 \| p_5 \| p_6 \| p_7 \| p_8$	Puncturing ID	Tail ID
4	3/4	952	4|238	113|31|59|163|29|181|101|11	8	8a
5*	3/4	288	2|144	31|37|43|47|53|59|61|67	8	8
6*	3/4	672	2|336	31|37|43|47|53|59|61|67	8	8
7*	3/4	1056	2|528	31|37|43|47|53|59|61|67	8	8
8*	1/2	192	2|96	31|37|43|47|53|59|61|67	6	6
9*	1/2	448	2|224	31|37|43|47|53|59|61|67	6	6
10*	1/2	704	2|352	31|37|43|47|53|59|61|67	6	6
11	1/2	432	2|216	31|37|43|47|53|59|61|67	6	6
12	3/4	972	2|486	31|37|43|47|53|59|61|67	8	8
13	3/4	1296	2|648	31|37|43|47|53|59|61|67	8	8
14	1/2	896	2|448	31|37|43|47|53|59|61|67	6	6
15	3/4	2016	4|504	31|37|43|47|53|59|61|67	8	8
16	3/4	2688	4|672	31|37|43|47|53|59|61|67	8	8
17	1/2	1792	4|448	31|37|43|47|53|59|61|67	6	6
18	3/4	4032	4|1008	31|37|43|47|53|59|61|67	8	8
19	3/4	5376	8|672	31|37|43|47|53|59|61|67	8	8
20	1/4	96	2|48	37|83|211|61|107|101|149|167	2	2a
21	2/3	736	2|368	139|17|241| 47|109|11|29|163	7a	7a
22	2/3	3120	8|390	17|31|61|67|101|103|113|131	7a	7b
23	2/3	4544	4|1136	197|157|13|191|241|101|149|109	7a	7b
24	5/6	3788*2	4|947	83|251| 7| 47| 79| 5|227|73	9	9

*) No previous definitions or simulations results available, but a default configuration suggested.

Table 4 will be extended as different information block lengths are defined.

This FEC will be calculated by first choosing prime numbers p_q, $q \in (1, ..., 8)$ as given in Table 4.

The following operations shall be performed for $s \in (1, ..., k)$ to obtain the permutation numbers $\pi(s)$:

$$m = (s-1) \bmod 2$$

$$i = floor\ ((s-1)\ /(2k_2))$$

$$j = floor\ ((s-1)\ /2)) - ik_2$$

$$t = (19i + 1) \bmod (k_1/2)$$

$$q = t \bmod 8 + 1$$

$$c = (p_q j + 21m) \bmod k_2$$

$$\pi(s) = 2(t + ck_1/2 + 1) - m$$

The permutation numbers shall be interpreted such that the s^{th} bit read out after interleaving is the $\pi(s)^{th}$ bit of the input information block.

A 1.2.4.4 Rate Adaptation

Rate adaptation is obtained by puncturing the encoder output as in § 5.3.1 of [RD-1], as recalled in Table 5 for the first *k* clocks, and as in [RD-1].

The puncturing table for the termination part is given in Table 6. The last two rows of Table 6 are not part of [RD-1].

Table 5 - Puncturing Patterns for Data Bit Periods

Punc. Pattern ID		Code Rate	Punc. Pattern ($X; Y_0; Y_1; X'; Y'_0; Y'_1$ | $X; Y_0; Y_1; X'; Y'_0; Y'_1$ | …)
0		1/5	1;1;1;0;1;1
1		2/9	1;0;1;0;1;1 | 1;1;1;0;1;1 | 1;1;1;0;0;1 | 1;1;1;0;1;1
2		1/4	1;1;1;0;0;1 | 1;1;0;0;1;1
3		2/7	1;0;1;0;0;1 | 1;0;1;0;1;1 | 1;0;1;0;0;1 | 1;1;1;0;0;1
4		1/3	1;1;0;0;1;0
5		2/5	1;0;0;0;0;0 | 1;0;1;0;0;1 | 0;0;1;0;0;1 | 1;0;1;0;0;1 | 1;0;1;0;0;1 | 0;0;1;0;0;1 | 1;0;1;0;0;1 | 1;0;1;0;0;1 | 0;0;1;0;0;1 | 1;0;1;0;0;1 | 1;0;1;0;0;1 | 0;0;1;0;0;1
6		1/2	1;1;0;0;0;0 | 1;0;0;0;1;0
7		2/3	1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;1;0;0;1
7a		2/3	1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;1;0;0;1;0
8		3/4	1;0;1;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;1
9		5/6	1;0;0;0;0;0 | 1;1;0;0;0;0 | 1;0;0;0;1;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0

For each rate, the puncturing table shall be read first from left to right and then from top to bottom.

Within a puncturing pattern, a ‘0’ means that the symbol shall be deleted and a ‘1’ means that a symbol shall be passed. A ‘2’ or a ‘3’ means that two or three copies of the symbol shall be passed. This is relevant for the termination periods. In particular

- For the rate 1/5 turbo code (Punct_Pat_ID=0), the tail output symbols for each of the first three tail bit periods shall be $XXXY_0Y_1$, and the tail output symbols for each of the last three tail bit periods shall be $X'X'X'Y'_0Y'_1$.
- For the rate 2/9 turbo code (Punct_Pat_ID=1), the tail output symbols for the first and the second output period shall be $XXXY_0Y_1$, for the third output period XXY_0Y_1, for the fourth and fifth output period $X'X'Y'_0Y'_1$, and for the sixth (last) output period $X'X'X'Y'_0Y'_1$.
- For the rate 1/4 turbo code (Punct_Pat_ID=2), the tail output symbols for each of the first three tail bit periods shall be XXY_0Y_1, and the tail output symbols for each of the last three tail bit periods shall be $X'X'Y'_0Y'_1$.

All other code rates shall be processed similar to the given examples above with the exact puncturing patterns to be derived from [RD-1].

The puncturing table for the termination part is given in Table 6. The last rows of the table are introduced in this document to obtain higher rates and are not part of [RD-1].

Table 6 - Puncturing and Repetition Patterns for Tail Bit Periods (last 6 clocks)

Punct. Pattern ID	Code Rate	Punct. / Rep. Pattern (X; Y_0; Y_1; X'; Y'_0; Y'_1 | X; Y_0; Y_1; X'; Y'_0; Y'_1 | …)
0	1/5	3;1;1;0;0;0 | 3;1;1;0;0;0 | 3;1;1;0;0;0 | 0;0;0;3;1;1 | 0;0;0;3;1;1 | 0;0;0;3;1;1
1	2/9	3;1;1;0;0;0 | 3;1;1;0;0;0 | 2;1;1;0;0;0 | 0;0;0;2;1;1 | 0;0;0;2;1;1 | 0;0;0;3;1;1
2	1/4	2;1;1;0;0;0 | 2;1;1;0;0;0 | 2;1;1;0;0;0 | 0;0;0;2;1;1 | 0;0;0;2;1;1 | 0;0;0;2;1;1
2a	1/4	1;1;1;0;0;0 | 1;1;1;0;0;0 | 1;1;1;0;0;0 | 0;0;0;1;1;1 | 0;0;0;1;1;1 | 0;0;0;1;1;1
3	2/7	1;1;1;0;0;0 | 2;1;1;0;0;0 | 2;1;1;0;0;0 | 0;0;0;2;1;1 | 0;0;0;1;1;1 | 0;0;0;1;1;1
4	1/3	2;1;0;0;0;0 | 2;1;0;0;0;0 | 2;1;0;0;0;0 | 0;0;0;2;1;0 | 0;0;0;2;1;0 | 0;0;0;2;1;0
5	2/5	1;1;1;0;0;0 | 1;1;1;0;0;0 | 1;0;1;0;0;0 | 0;0;0;1;1;1 | 0;0;0;1;1;1 | 0;0;0;1;0;1
6	1/2	1;1;0;0;0;0 | 1;1;0;0;0;0 | 1;1;0;0;0;0 | 0;0;0;1;1;0 | 0;0;0;1;1;0 | 0;0;0;1;1;0
7	2/3	1;0;0;0;0;0 | 1;0;1;0;0;0 | 1;0;1;0;0;0 | 0;0;0;1;0;0 | 0;0;0;1;0;1 | 0;0;0;1;0;1
7a	2/3	1;1;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 0;0;0;1;1;0 | 0;0;0;1;0;0 | 0;0;0;1;0;0
7b	2/3	1;1;0;0;0;0 | 1;1;0;0;0;0 | 1;1;0;0;0;0 | 0;0;0;1;1;0 | 0;0;0;1;1;0 | 0;0;0;1;1;0
8	3/4	1;0;1;0;0;0 | 1;0;1;0;0;0 | 1;0;1;0;0;0 | 0;0;0;1;0;1 | 0;0;0;1;0;1 | 0;0;0;1;0;1
8a	3/4	1;0;1;0;0;0 | 1;0;1;0;0;0 | 1;0;1;0;0;0 | 0;0;0;1;0;1 | 0;0;0;1;0;1 | 0;0;0;1;0;0
9	5/6	1;1;0;0;0;0 | 1;0;0;0;0;0 | 1;0;0;0;0;0 | 0;0;0;1;1;0 | 0;0;0;1;0;0 | 0;0;0;1;0;0

For each rate, the puncturing table shall be read first from left to right and then from top to bottom.

A 1.2.5. CRC

The 32 bit ITU-T V.42 [RD-5] polynomial 0x04C11DB7 CRC is appended to the last segment of the datagram. The CRC is calculated over all fragments of the datagram datagram (including any zero padding) with MSB of each byte processed first. The resulting 32 bit CRC is appended MSB first so the receiver can verify that the result is 0x00000000 when calculated over data+padding+CRC.

$F(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^{8} + x^{7} + x^{5} + x^{4} + x^{2} + x + 1$

Initial state: 0xFFFFFFFF

A 1.2.6. Bit scrambling

The bit scrambler shown in Figure 11 uses the polynom:

$F(x)=1 + x^{-14} + x^{-15}$

and the initialization sequence as indicated in the top of the figure. For each new encoding block, the bit scrambler is re-initialized.

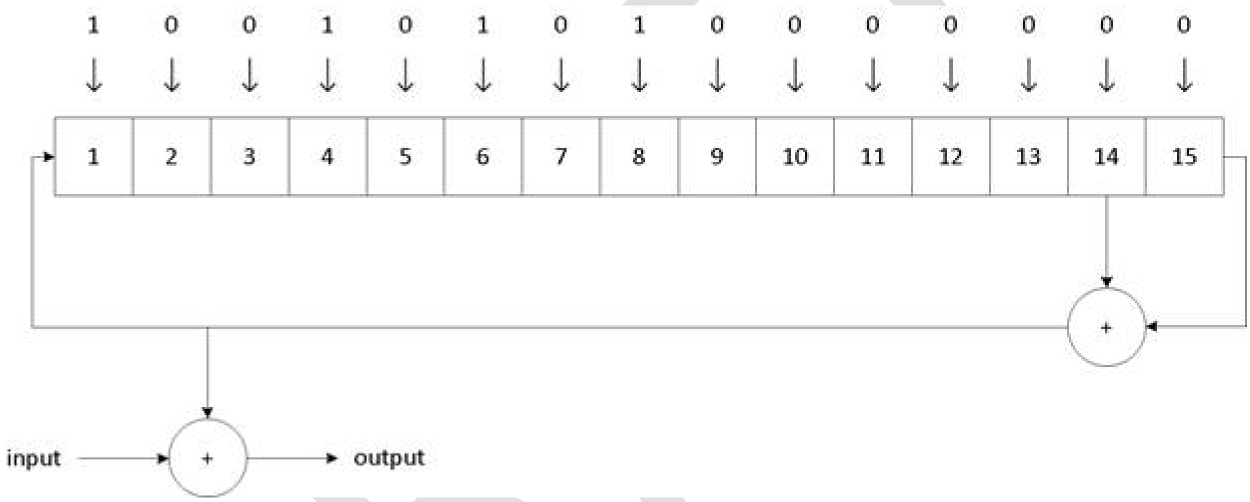

Figure 11. Bit scrambling

A 1.2.7. Modulation Coding Schemes

All MCS formats are defined in the Link Configuration ID in Tables 7, 8, 9 and 10 (refer to Figure 5 and Figure 6). The Channel Quality Indicator (CQI) value is used by the Adaptive Coding and Modulation (ACM) mechanism.

Table 7 - ASM Link Configuration ID parameters

PL format #	ASM-MCS-1.16-1	ASM-MCS-1.16-2	ASM-MCS-1.16-3	ASM-MCS-1.16-4	ASM-MCS-1.16-5	ASM-MCS-1.16-6	ASM-MCS-1.16-7	ASM-MCS-1.16-8	ASM-MCS-1.16-9	ASM-MCS-1.16-10	
Li nk Config ID	1	2	3	4 (SAT)	5	6	7	8	9	10	
Channel BW	16										kHz
Roll off filtering	0,35										
Signal BW	13,0										kHz
Symbol rate	9,6										ksps
Burst size	1	2	3	3	1	2	3	1	2	3	slots
Guard time	0,83			8	0,83						ms
Burst duration	25,8	52,5	79,2	72,0	25,8	52,5	79,2	25,8	52,5	79,2	ms
Symbols/ burst	248	504	760	691	248	504	760	248	504	760	symbols
Ramp-up/down	4/4										symbols
Ramp-up/down	0,41/0,41										ms
Syncword size	27										symbols
Syncword modul.	PI/4 QPSK (00/11 only)										
Link Config ID symbols	16										symbols
Link Config ID modul.	Pi/4 QPSK										
Net symbols/ burst	197	453	709	640	197	453	709	197	453	709	symbols
Channel bits	394	906	1418	1280	394	906	1418	394	906	1418	bits
Padding/ flush bits	10			11	10						bits
FEC decoder input symbols	192	448	704	634.5	192	448	704	192	448	704	symbols
FEC decoder input bits	384	896	1408	126	384	896	1408	384	896	1408	bits
FEC output bits	384	896	1408	952	288	672	1056	192	448	704	bits
FEC output bytes	48	112	176	119	36	84	132	24	56	88	bytes
Modul.	PI/4 QPSK										
Bits / symbol	2										
FEC rate	1			3/4				1/2			
E_s/N_0 on AWGN	11,0	11,0	11,0	4,5	5,3	5	4,8	3,6	3	2,8	dB
$C/(N_0+I_0)$ threshold	50,8	50,8	50,8	44,3	45,1	44,8	44,6	43,4	42,8	42,6	dBHz
Minimum CQI value	50	51	53	43	45	45	45	43	43	43	

Table 8 - VDE-TER Link Configuration ID parameters

PL format #	TER-MCS-1.25	TER-MCS-3.25	TER-MCS-5.25	TER-MCS-1.50	TER-MCS-3.50	TER-MCS-5.50	TER-MCS-1.100	TER-MCS-3.100	TER-MCS-5.100	
Link Config ID	11	12	13	14	15	16	17	18	19	
Channel BW	25			50			100			kHz
Roll off filtering	0,3									
Signal BW	25,0			49,9			99,8			kHz
Symbol rate	19,2			38,4			76,8			ksps
Burst size	1									slot
Guard time	0,83									ms
Burst duration	25,8									ms
Symbols/burst	496			992			1984			symbols
Ramp-up/down	8/8			16/16			32/32			symbols
Ramp-up/down	0.41/0.41									ms
Syncword size	27									symbols
Syncword modulation	PI/4 QPSK (00/11 only)									
Link Config ID size	16 (32,6 block code)									symbols
Link Config ID modulation	PI/4 QPSK									
Net symbols/burst	437			917			1877			symbols
Channel bits	874	1311	1748	1834	2751	3668	3754	5631	7508	bits
Padding/flush	10	15	20	42	63	84	170	255	340	bits
FEC decoder input symbols	432			896			1792			symbols
FEC decoder input bits	864	1296	1728	1792	2688	3584	3584	5376	7168	bits
FEC output bits	432	972	1296	896	2016	2688	1792	4032	5376	bits
FEC output bytes	54	122	162	112	252	336	224	504	672	bytes
Modulation	PI/4 QPSK	8PSK	16 QAM	PI/4 QPSK	8PSK	16 QAM	PI/4 QPSK	8PSK	16 QAM	
FEC rate	1/2	3/4	3/4	1/2	3/4	3/4	1/2	3/4	3/4	
E_s/N_0 on AWGN	1,0	7,9	10,2	1,0	7,9	10,2	1,0	7,9	10,2	dB
$C/(N_0+I_0)$ threshold	43,8	50,7	53,0	46,8	53,7	56,0	49,9	56,8	59,1	dBHz
Minimum CQI value	42	53	56	46	57	59	49	60	62	

Table 9 - VDE-SAT Uplink Configuration ID parameters

PL format	SAT-MCS-1.50-2	SAT-MCS-1.50-3	SAT-MCS-1.50-4	SAT-MCS-3.50-2	SAT-MCS-5.50	
Link Config ID	20	21	22	23	24**	
Channel bandwidth	50					kHz
Roll off filtering	0,25					
Signal bandwidth	42,0					kHz
CDMA chiprate	33,6					kcps
Codelength	16					chips
Symbol rate	2,1	33,6				ksps
Burst size	5	1	3			slots
Guard time	8					ms
Burst duration	125,3	18,7	72,0			ms
Symbols/burst	263	627	2419			symbols
Ramp-up/down	14/14*					symbols
Ramp-up/down	0.41/0.41					ms
Syncword size	48	27				symbols
Syncword modulation	QPSK/CDMA (00/11)	PI/4 QPSK (00/11)				
Link Configuration ID size	0	16 (32,6 block code)				symbols
Link Configuration ID modulation	NA	PI/4 QPSK				
Pilot symbol distance	17	NA		20		symbols
Total pilot symbols	12	0		71		symbols
Net symbols/burst	201	556	2348	2277	2277	symbols
Channel bits	352	1112	4696	6831	9108	bits
Padding/flush bits	18	8	16	15	8*2	bits
FEC decoder input symbols	192	552	2340	2272	2277	symbols
FEC decoder input bits	384	1104	4680	6816	4546*2	bits
FEC output bits	96	736	3120	4544	3788*2	bits
FEC output bytes	11	92	390	568	947	bytes
Modulation	QPSK/ CDMA	PI/4 QPSK		8PSK	16QAM	
FEC rate	1/4	2/3			5/6	
E_s/N_0 on AWGN	-0,9	3,9	3,9	8,0	12,2	dB
$C/(N_0+I_0)$ threshold	32,3	49,2	49,2	53,3	57,5	dBHz
Minimum CQI value	32	49	51	54	58	

*) For spread sequence it is 14/14 chips.

**) FEC block is split into two sub-blocks in order to avoid very long FEC block.

Table 10 – VDE-SAT Downlink Configuration ID Parameters

PL format	SAT-MCS-0.50-1	SAT-MCS-1.50-1	SAT-MCS-3.50-1	SAT-MCS-0.100	SAT-MCS-0.150	SAT-MCS-0.300	SAT-MCS-0.500	
Link Config ID	25	26	27	28	29	30	31	
Channel BW	50			100	150	300	500	kHz
Roll off filtering	0,25							
Signal BW	42,0			90,0	141,0	291,0	492	kHz
CDMA chiprate	33,6			72,0	112,8	232,8	393,6	kcps
Codelength	8			4				chips
Symbol rate	4,2	33,6		18,0	28,2	58,2	98,4	ksps
Burst size	90							slots
Guard time	8							ms
Burst duration	2392,0							ms
Symbols/burst	10046	80371		43056	67454	139214	235372	symbols
Ramp-up/down	14/14			30/30	47/47	97/97	163/163	symbols / chips
Ramp-up/down	0.41/0.41							ms
Syncword size	48	27		48				symbols
Syncword modulation	BPSK/ CDMA	PI/4 QPSK (00 /11)		BPSK/CDMA				
Link Config ID	16 (32,6 block code)							symbols
Link Config ID modulation	BPSK/ CDMA	PI/4 QPSK		BPSK/CDMA				
Pilot distance	20							symbols
Total pilots symbols	497	4015		2146	3364	6947	11749	symbols
Net symbols/burst	9457	80300		40786	67296	138956	234982	symbols
Channel bits	9457	160600	240900	40786	67296	138956	234982	bits
Padding/flush	1	24	4	2	0	12	22	bits
FEC decoder input symbols	9457	80300	80300	40786	67296	138956	234982	symbols
FEC decoder input bits	9456	160576	240896	40784	67296	138944	234960	bits
FEC output bits	4728	40144	120448	20392	33648	69472	117480	bits
FEC output	591	5018	15056	2549	4206	8684	14685	bytes
Modulation	BPSK/ CDMA	PI/4 QPSK	8PSK	BPSK/CDMA				
FEC rate	1/2	1/4	1/2	1/2				
E_s/N_0 on AWGN	-2,0	-2,4	5,0	-2,0				dB
$C/(N_0+I_0)$ thres	34,2	42,9	50,3	40,6	42,5	45,6	47,9	dBHz
Minimum CQI value	33	44	52	40	44	47	49	

A 1.2.8. BIT MAPPING

The bit mappings used throughout the Annexes are shown in Figures 12, 13, 14 and 15.

The first output from the bit scrambler is mapped to the MSB of the first symbol, the second bit to the next bit in the symbol, and so on until the LSB of the symbol has been filled, then mapping continues in the next symbol. If more bits are needed to complete the last symbol, 0 shall be used.

The initial state of the alternating π/4 QPSK bit mapping is defined such that the first symbol of the training sequence is mapped to the constellation defined by points $\{(1+j)/\sqrt{2}, (-1+j)/\sqrt{2}, (-1-j)/\sqrt{2}, (1-j)/\sqrt{2}\}$ (shown in green in Figure 12); the next symbol is mapped to the constellation defined by points $\{1+0j, 0+j, -1+0j, 0-j\}$ (shown in purple in Figure 12); and so on.

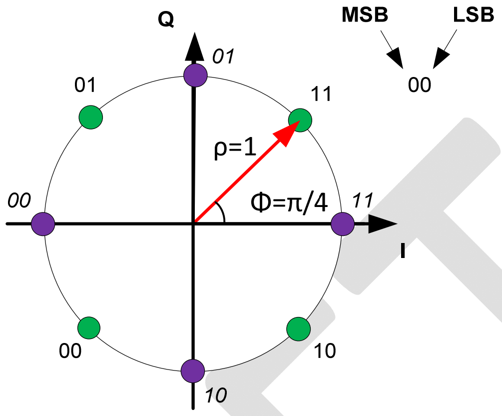

Figure 12. *Bit Mapping for π/4 QPSK*

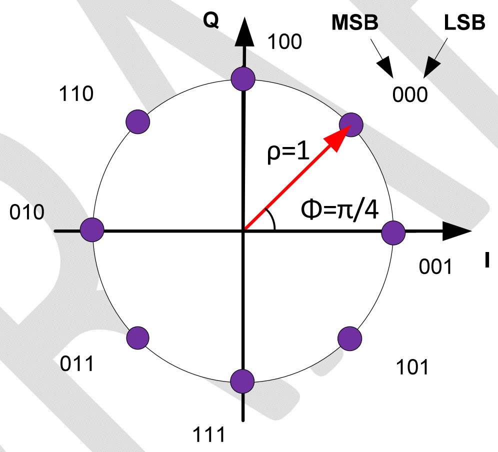

Figure 13. *8PSK symbol to bit mapping*

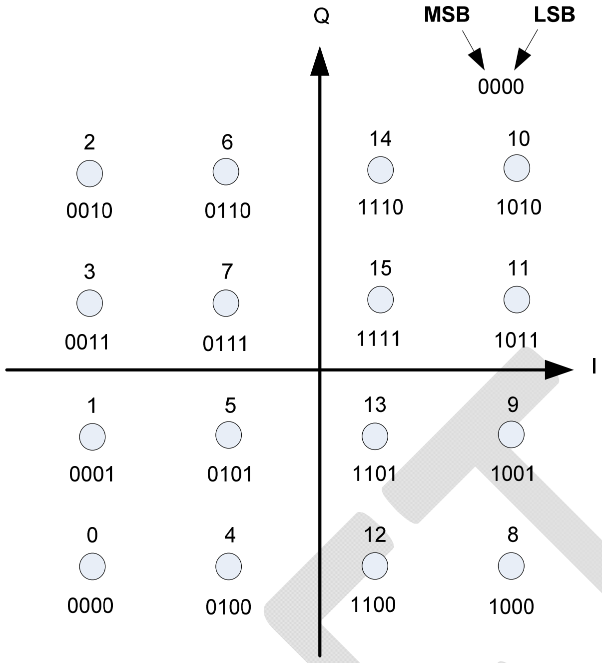

Figure 14. Bit Mapping for 16QAM

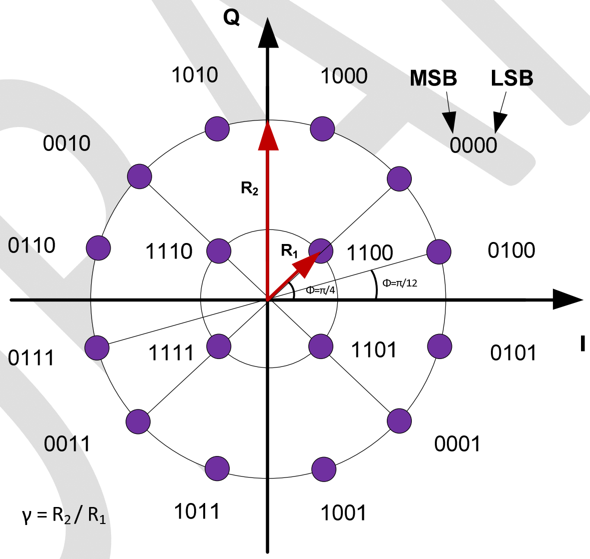

Figure 15. 16APSK bit to symbol mapping

The 16 APSK modulation constellation is composed of two concentric rings of uniformly spaced 4 and 12 PSK points, respectively in the inner ring of radius R_1 and outer ring of radius R_2.

The ratio of the outer circle radius to the inner circle radius ($\gamma = R_2/R_1$) shall be equal to 3. R_1 shall be set to $1/\sqrt{7}$, R_2 shall be set to $3/\sqrt{7}$ in order to have the average signal energy equal to 1.

Similar to AIS, when data is output on the VHF data link it should be grouped in bytes of 8 bits from top to bottom of the table associated with each message in accordance with ISO/IEC 13239:2002. Each byte should be output with least significant bit first.

A 1.2.9. ANTENNA GAIN FOR VDES SHIP STATIONS

Existing ship antennas may be used for VDES. The maximum antenna gain for these antennas ranges from 2 dBi to 10 dBi.

A ship antenna with a minimum gain at 0 degrees elevation of 2 dBi at the receiver input is required.

A 1.2.10. NOISE AND INTERFERENCE LEVEL

The noise floor is a function of many sources such as vessel electronics, other radio equipment, power supplies, etc., and sensitivity is also reduced by RF cabling losses and the LNA noise figure. Table 11 presents representative values for the receiver noise figure.

Table 11 - Ship receiver noise figure calculations

Antenna noise temperature*	245.0	K
LNA noise figure	6.0	dB
LNA noise temperature	813.8	K
Feed loss noise temp at LNA	0.0	K
Antenna noise temp at LNA	245.0	K
System noise temp at LNA	1058.8	K
System noise temp at LNA	30.2	dBK

* The galactic background antenna noise temperature is 245 K at 160 MHz [RD-4].

A 1.2.11. TRANSMITTER REQUIREMENTS FOR VDES

A 1.2.11.1 Transmitter power

Except for Annex B, Table 12 defines the requirements for VDE station transmitters, for the transmit spectrum mask, see Figure 16. The resolution bandwidth for the mask measurement is 300Hz.

Table 12 - Transmitter parameters

Transmitter parameters	Requirements	Condition
Frequency error	1.5 ppm	normal
Maximum transmit power capability	For ship stations: Transmit average power should be at least 1 watt and not exceed 25 watts at the transmitter output. For shore stations: Transmit average power should be at least 12.5 watt and not exceed 50 watts at the base of the antenna. ±1.5 dB normal, +2/−6 dB extreme	Conducted
Maximum adjacent power levels for 25 kHz channel	$\Delta fc < \pm 12.5$ kHz: 0 dBc ± 12.5 kHz $< \Delta fc < \pm 25$ kHz: below the straight line between −25 dBc at ±12.5 kHz and −70 dBc at ±25 kHz ± 25 kHz $< \Delta fc < \pm 62.5$ kHz: −70 dBc	
Maximum adjacent power levels for 50 kHz channel	$\Delta fc < \pm 25$ kHz: 0 dBc ± 25 kHz $< \Delta fc < \pm 37.5$ kHz: below the straight line between −25 dBc at ±25 kHz and −70 dBc at ±37.5 kHz ± 37.5 kHz $< \Delta fc < \pm 125$ kHz: −70 dBc	
Maximum adjacent power levels for 100 kHz channel	$\Delta fc < \pm 50$ kHz: 0 dBc ± 50 kHz $< \Delta fc < \pm 62.5$ kHz: below the straight line between −25 dBc at ±50 kHz and −70 dBc at ±62.5 kHz ± 62.5 kHz $< \Delta fc < \pm 250$ kHz: −70 dBc	
Spurious emissions	−36 dBm −30 dBm	9 kHz to 1 GHz 1 GHz to 4 GHz

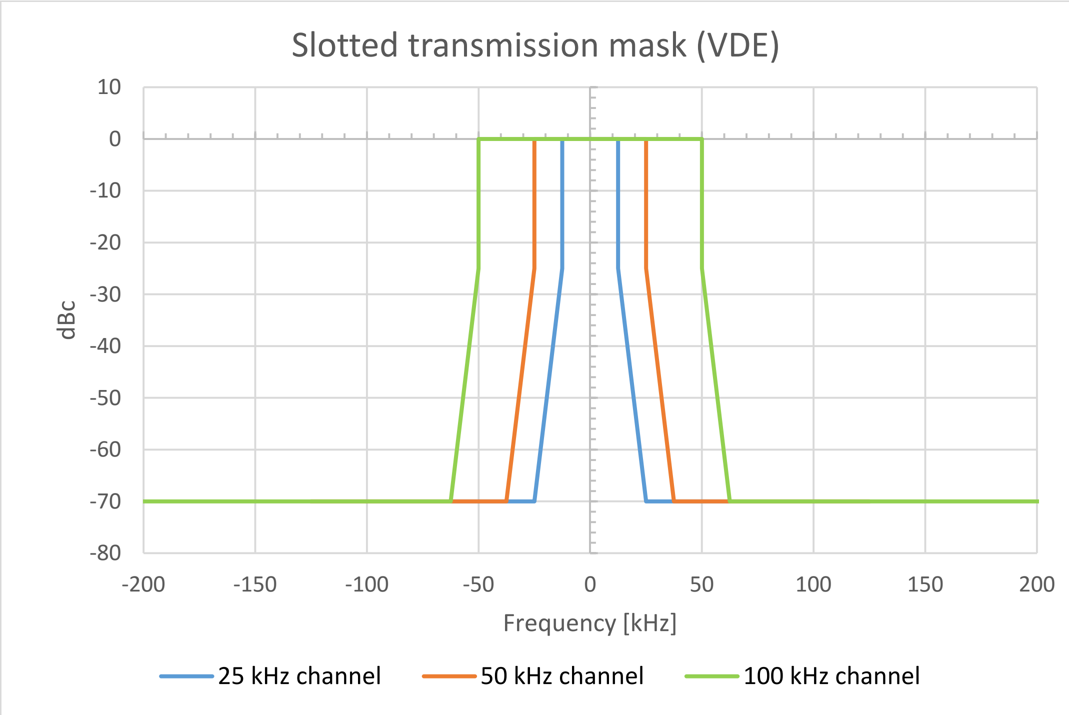

Figure 16. Slotted Transmission Mask (VDE)

A 1.2.11.2 Ship e.i.r.p. vs. elevation angle

The minimum ship e.i.r.p. vs elevation angle is shown in Table 13. There are no minimum e.i.r.p. requirements above 80 degrees elevation. Table 13 is based on a linear transmitter meeting the maximum Adjacent Channel Interference levels defined in Table 12. For saturated operation, the e.i.r.p. shall be 3 dB higher.

Table 13 - Minimum ship e.i.r.p. vs. elevation angle

Ship elevation angle	Ship antenna gain	Minimum ship e.i.r.p. with 6 W transmitter
degrees	dBi	dBW
0	3	10.8
10	3	10.8
20	2.5	10.3
30	1	8.8
40	0	7.8
50	−1.5	6.3
60	−3	4.8
70	−4	3.8
80	−10	−2.2
90	−20	−12.2

A 1.2.11.3 Shutdown procedure

An automatic transmitter hardware shutdown procedure and indication should be provided in case a transmitter continues to transmit for more than 2 s. This shutdown procedure should be independent of software control.

A 1.2.11.4 Safety precautions

The VDES installation, when operating, should not be damaged by the effects of open circuited or short-circuited antenna terminals.

A 1.3. LINK LAYER

This layer ensures reliable transmission of data frames between ships, ship and shore, and ship and satellite. Both connection oriented and store and forward (e.g. satellite) transfer are supported. In the case of store and forward transfer, the packet protocols are terminated at both the ship and Control Station ends.

The link layer is divided into three sub-layers with the following tasks:

A 1.3.1. LINK MANAGEMENT ENTITY

Assemble Unique Word, format header, Physical Layer Frame (PL-Frame) headers, pilot tones (satellite) and VDES message bits into packets.

A 1.3.2. DATA LINK SERVICES

Calculates and adds CRC check sum and completes the PL-Frame/packet.

A 1.3.3. RESOURCE MANAGEMENT

The connection between ship and shore is normally session oriented where a Logical Channel is reserved for a particular ship either for a certain amount of data transfer or time duration.

Ship originated short messages can be sent on the Random Access Channels without resource allocation.

During heavy network loading, the network control may introduce time dispersion for resource requests or only allow traffic with high priority levels.

A 1.3.4. DATA STRUCTURES

Data is generally transferred as packets using fixed duration Logical Channel Frames, and consist of one or multiple data packets, zero padding and a 4 byte CRC.

Long data packets are fragmented and sent over multiple Logical Channel frames.

The two cases are shown in Figure 17.

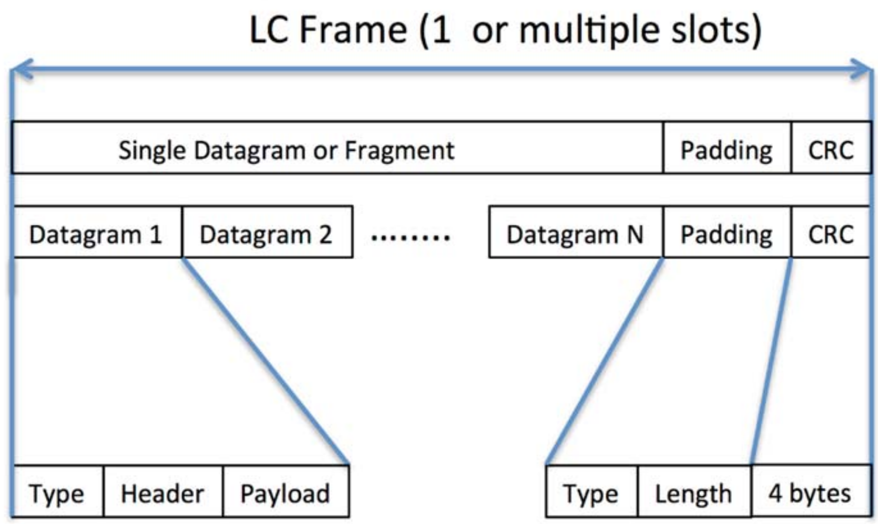

Figure 17. Single/Multiple datagram, zero padding and CRC structure

Note that the zero padding is defined as a separate sub-packet. The 4 byte CRC is always at the end of the frame. Preamble and FEC flushing bits are not shown.

A 1.3.5. ADAPTIVE CODING AND MODULATION/RATE ADAPTION

The signal and interference environment is expected to change with time and location. The Control Station may measure channel quality of the received ship signal and request the ship to adjust the Modulation and Coding Scheme to maximize throughput.

Similarly, a ship will report a Channel Quality Indicator (CQI) equivalent to received C/N_0 (based on a Link Adaption Model) to the Control Station which then will adjust the Modulation and Coding Scheme to maximize throughput.

A 1.3.6. SIGNALLING PACKETS

Signalling packets are used for data management and control whilst data packets are used for information transfer.

A 1.3.7. TO SHIP SIGNALLING PACKETS

These are used for ship paging, resource allocation and data transfer handling.

All packets contain a 1 byte packet type and a variable length header defining the length, ship ID and various other parameters.

14 defines the To ship signalling packets.

Table 14 - To ship signalling packets

Media Access Control				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	000	1	Type	
2	0 to 2^{16}-1	2	Length	6: Total packet size in bytes, fixed at 6 bytes
3	0-255	1	Media Access priority level	0: All accesses allowed 1: High priority only 2: Medium priority 3: Low priority 255: No accesses allowed
4	0-255	1	Random Access spreading interval	Randomly selected from RA Logical Channel group, randomly selected within LC group
5	0-255	1	System status	0: Normal 10: Busy 20: Temporally out of service 30: Scheduled out of service
To ship Announcement/Paging				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	001 or 002	1	Type	001: Paging a specific ship for in-coming datagram 002: Paging a specific ship for mobility management update
2	0 to 2^{16}-1	2	Length	Total packet size in bytes, variable
3		4	Source ID	Source of the request
4	0 to 2^{32}-1	4	Ship ID #1	

	………			
Last	0 to 2^{32}-1	4	Ship ID #N	

Multicast resource allocation announcement				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	003	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0-255	1	Type of multicast	1: Group multicast 2: Area multicast
4	0-255	1	Logical Channel no	
5	0-255	1	Session ID	To support multiple sessions within a logical channel
6	0 to 2^{32}-1	4	Datagram size in bytes	

Unicast to ship resource allocation announcement				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	004	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID #1	
4	0-255	1	Logical Channel no	
5	0-255	1	Session ID	Multi session support
6	0-255	1	ACK Logical Channel	
7	0-255	1	ACK LC Subchannel	Set to 0 if not used
8	0-255	1	CQI	
	………			
	0 to 2^{32}-1	4	Ship ID #N	
	0-255	1	Logical Channel	
	0-255	1	Session ID	
	0 to 2^{32}-1	4	Datagram size in bytes	
	0-255	1	ACK Logical Channel	
	0-255	1	CQI	
Last	0-255	1	ACK LC Subchannel	

Unicast resource allocation announcement to ship originated requests				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	005	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID #1	
4	0-255	1	Logical Channel no	
5	0-255	1	Session ID	Multi stream support

Unicast resource allocation announcement to ship originated requests				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
6	0-255	1	Logical Channel Subchannel	0: When full LC frame is allocated, 1-255 indicates the logical subframe number that will be used
7	0-255	1	CQI	
	………			
	0 to 2^{32}-1	4	Ship ID #N	
	0-255	1	Logical Channel	
	0-255	1	Session ID	Multi stream support
	0-255	1	CQI	
Last	0-255	1	Logical Channel Subchannel	

To ship Access Denied/Resource de-allocation				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	006	1	Type	This can be used both at system access and during a given session
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID #1	
4	0-255	1	Reason for Reject/Clear	0: Unrecognised ship ID 1: Unrecognised packet 2: Access denied by operator 3: Protocol error 4: System reset 5: All sessions cleared 6: Cleared for high priority traffic 7: Timeout 8: Shore address not recognised 9: Requested service not supported 10: Ship requested de-allocation 11: Called ship not reachable
	………			
	0 to 2^{32}-1	4	Ship ID #N	
	0-255	1	Session ID	
Last	0-255	1	Reason for Reject/Clear	

Control station ACK/ACM				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	007	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID #1	
4	0-255	1	Session ID	
5	0-255	1	ACM or EDN	0: Maintain MCS 1: Increment MCS (higher rate) 2: Decrease MCS 3: End Delivery Notification

Unicast resource allocation announcement to ship originated requests				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
6	0 to 2^{16}-1	2	ACK/NACK mask	Relevant bit set for failed fragments 1 to 16
7	0-255	1	CQI	
8	0-255	1	Power setting	0: Maintain Power Level 1: Increase Power Level 2: Decrease Power Level
	………			
	0 to 2^{32}-1	4	Ship ID #N	
	0-255	1	Session ID	
	0-255	1	ACM or EDN	0: Maintain MCS 1: Increment MCS (higher rate) 2: Decrease MCS 3: End Delivery Notification
	0-255	1	CQI	
	0-255	1	Power setting	0: Maintain Power Level 1: Increase Power Level 2: Decrease Power Level
Last	0 to 2^{16}-1	2	NACK mask	Relevant bit set for failed fragments 1 to 16

A 1.3.8. FROM SHIP SIGNALLING PACKETS

These are used for ship resource request and data transfer handling. A special very short (11 byte) packet is used for unusual interference conditions and uses a 16 bit CRC.

Table 15 defines the from ship signalling packets.

Table 15 - From ship signalling packets

Ship response to Announcement/Paging				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	010	1	Type	
2	0 to 2^{16}-1	2	Length	Fixed, 12 bytes
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0 to 2^{32}-1	4	Terminal capabilities	Update to reflect mask values
6	0 to 2^{24}-1	3	Coarse latitude, +/- 90 degrees N, 2s complement 1/10th minute resolution, relative the service area NW corner	
7	0 to 2^{24}-1	3	Coarse longitude, +/- 180 degrees E, 2s complement, 1/10th minute resolution relative to the service area SE corner	
8	0-255	1	CQI	Received C/N_0 in dBHz

Very short response to Announcement (11 bytes) – satellite only				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	011	1	Type	
2	0 to 232-1	4	Ship ID	
3	0-255	1	Session ID	
4	0-255	1	Terminal capabilities	1: Compliant 2092-1 2: Compliant 2092-2
5	0 to 216-1	2	CRC-2	16 bit CRC used

Ship resource request				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	
1	012	1	Type	
2	0 to 2^{16}-1	2	Length	
3	0 to 2^{32}-1	4	Source ID	
4	0-255	1	Session ID	
5	0 to 2^{32}-1	4	Destination ID	
6	0 to 2^{32}-1	4	Terminal capabilities	mask
7	0 to 2^{32}-1	4	Datagram size in bytes	
8	0-255	1	CQI	Received C/N0 in dBHz
9	0-255	1	Priority	0 Default
10	0-255	1	Communications mode	0: Default 1: Direct ship to ship mode

Ship ACK/ACM				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	013	1	Type	
2	0 to 2^{16}-1	2	Length	
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0 to 2^{16}-1	2	ACK/NACK mask	Relevant bit set for failed fragments 1 to 16
6	0-255	1	CQI	Received C/N_0 in dBHz
7	0-255	1	ACM or EDN	0: Maintain MCS 1: Increment MCS (higher rate) 2: Decrease MCS 3: End Delivery Notification
8	0-255	1	Power setting	0: Maintain Power Level 1: Increase Power Level 2: Decrease Power Level

Very short ACK/ACM (11 bytes) – satellite only				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	014	1	Type	
2	0 to 2^{32}-1	4	Ship ID	
3	0-255	1	Session ID	
4	0 to 2^{16}-1	2	ACK/NACK mask	Relevant bit set for failed fragments 1 to 16
5	0-255	1	CQI	Received C/N_0 in dBHz
6	0 to 2^{16}-1	2	CRC-2	16 bit CRC used

Ship de-allocation request				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	015	1	Type	Release the allocated resources
2	0 to 2^{16}-1	2	Length	
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	Session ID 0 clear all ship connections
5	0-255	1	Reason for de-allocation	1: Time-out, 2: Retry limit exceeded 3. End of session

Very short ship clear session (11 bytes) – satellite only				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	016	1	Type	
2	0 to 2^{32}-1	4	Ship ID	
3	0-255	1	Session ID	
5	0-255	1	Reason for disconnection	1: Time-out, 2: Retry limit exceeded
6	0 to 2^{16}-1	2	CRC-2	16 bit CRC used

A 1.3.9. SHIP TO SHIP SIGNALLING

These are used to set up connections with other ships in the area. RATDMA is used to select a Logical Channel for the data transfer. All signalling takes place on Logical Channel 0 defined on the Bulletin Board.

Table 16 shows the signalling packet content.

Table 16 - Ship to ship signalling outside Control Station service area

Ship paging ship				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	90	1	Type	
2	0 to 2^{16}-1	2	Length	Total packet size in bytes, variable
3	0 to 2^{32}-1	4	Source Ship ID #	
4	0-255	1	Priority	Default 0
5	0 to 2^{32}-1	4	Destination Ship ID #	
6	0 to 2^{32}-1	4	Terminal capabilities	
Ship response to Paging				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	
1	091	1	Type	
2	0 to 2^{16}-1	2	Length	
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0 to 2^{32}-1	4	Terminal capabilities	
6	0 to 2^{24}-1	3	Coarse latitude, +/- 90 degrees N, 2s complement 1/10th minute resolution, relative the service area NW corner	
7	0 to 2^{24}-1	3	Coarse longitude, +/- 180 degrees E, 2s complement, 1/10th minute resolution relative to the service area SE corner	
8	0-255	1	CQI	Received C/N_0 in dBHz
9	0-255	1	Logical Channel no	
10	0-255	1	Session ID	Multi stream support
11	0-255	1	Logical Channel Subchannel	0: When full LC frame is allocated

Ship to ship short message				
Field no	**Value (DEC)**	**Size (bytes)**	**Function**	**Comment**
1	92	1	Type	
2	2^{16}-1	2	Length	
3	2^{32}-1	4	Originating ship ID	
4	2^{8}-1	1	Session ID	
5	2^{32}-1	4	Destination ship ID	
6	2^{8}-1	1	Retransmission no	Handles lost ACKs

7		Variable	Payload	
Ship to ship short message ACK				
Field no	**Value (DEC)**	**Size (bytes)**	**Function**	**Comment**
1	92	1	Type	
2	2^{16}-1	2	Length	
3	2^{32}-1	4	Originating ship ID	
4	2^{8}-1	1	Session ID	
5	2^{32}-1	4	Destination ship ID	
6	2^{8}-1	1	ACK/NACK/Reject	0: ACK 1: NACK 3: Communications refused

A 1.4. DATA TRANSFER PACKETS

A 1.4.1. SHORE ORIGINATED DATA

Multicast data is transmitted on a shared Logical Channel, whilst Unicast date can be either time multiplexed or carried on an allocated LC.

Several short datagrams that fit within a LCF Frame are sent sequentially. Zero padding packets are added at the end to fill the LCF.

Large datagrams that exceeds the capacity of a Logical Channel Frame is transferred as multiple fragments. Each fragment is sequentially numbered 0 to 15, and a 2 byte bit map is used to request retransmission of one or multiple fragments. Datagrams with more than 15 fragments use modulo 15 numbering.

The packet types are defined in Table 17.

Table 17 - To ship data packet types

Bulletin Board datagram				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	020	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3		Variable	Payload	Bulletin Board fixed fields
Zero padding variable length				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	021	1	Type	
2	0-255	1	Length	Total number of zero bytes
Zero padding single byte				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	022	1	Type	1 byte zero padding

Group Multicast start datagram				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	023	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Destination	Group ID
4	0 to 2^{16}-1	2	Number of fragments	
5		Variable	Payload	Multicast content

Area Multicast start datagram				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	024	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3		3	Coarse latitude, +/- 90 degrees N, 2s complement 1/10th minute resolution, relative the service area NW corner	AIS format
4		3	Coarse longitude, +/- 180 degrees E, 2s complement, 1/10th minute resolution relative to the service area SE corne	AIS format
5	0 to 2^{16}-1	2	Number of fragments	
6		Variable	Payload	Multicast content

Network operator text message to all ships				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	025	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3		Variable	Payload	ASCII text message

Network operator binary message to all ships				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	029	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3		Variable	Payload: Data format to be defined in the payload	Binary

To ship Start Fragment/Single Fragment				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	026	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{16}-1	2	Number of fragments; for single fragment message / short message: number of fragments = 1	
4	0 to 2^{32}-1	4	Ship ID	
5	0-255	1	Session ID	
6		Variable	Payload	

To ship Continuation Fragment				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	027	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID	0: For multicast
4	0-255	1	Session ID	
5	0-255	1	Fragment no	
6		Variable	Payload	

To ship End Fragment				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	028	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0-255	1	Fragment no	Modulo 15, 1 to 15.
6		Variable	Payload	

To ship short unicast message				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	30	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
4	0 to 2^{32}-1	4	Ship ID	
5	0-255	1	Session ID	
6		Variable	Payload	

A 1.4.2. DATA TRANSFER FROM SHIP

These packet formats are similar to the shore originated formats and given in Table 18. Short messages can be transferred using the Random Access signalling channel. The very short (11 byte) packet is used for unusual interference conditions and uses a 16 bit CRC and predefined terrestrial addressing.

Table 18 - From ship Data packet formats

Short RA message from ship (with ACK)

Field no	Value (Dec)	Size (Bytes)	Function	Content
1	040	1	Type	
2	0 to 2^{16}-1	2	Length	
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0-255	1	CQI	Received C/N_0 in dBHz
6		4	Destination	
7		Variable	Payload	

Very short RA message from ship (11 bytes, with ACK) – satellite only

Field no	Value (Dec)	Size (Bytes)	Function	Content
1	041-056	1	Type	16 types of content/
2	0 to 2^{32}-1	4	Ship ID	
3	0-255	1	Destination	Preset IPv 6 list
4		3	Payload	
5	0 to 2^{16}-1	2	CRC-2	16 bit CRC used

Short RA message from ship (without ACK)

Field no	Value (Dec)	Size (Bytes)	Function	Content
1	057	1	Type	
2	0 to 2^{16}-1	2	Length	
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5		4	Destination ID	6
6		Variable	Payload	

Very short RA message from ship (11 bytes, without ACK) – satellite only				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	058-073	1	Type	16 types of content
2	0 to 2^{32}-1	4	Ship ID	
3	0-255	1	Destination	Preset IPv 6 list
4		3	Payload	
5	0 to 2^{16}-1	2	CRC-2	16 bit CRC used

From ship Start Fragment/Single Fragment				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	074	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{16}-1	2	Number of fragments / short message: number of fragments = 1	
4	0 to 2^{32}-1	4	Ship ID	
5	0-255	1	Session ID	
6		4	Destination ID	
7		Variable	Payload	

From ship Continuation Fragment				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	075	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0-255	1	Fragment no	
6		Variable	Payload	

From ship End Fragment				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	076	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Ship ID	
4	0-255	1	Session ID	
5	0-255	1	Fragment no	
6		Variable	Payload	

Zero Padding Variable length				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	080	1	Type	
2	0-255	1	Length	Total number of zero bytes
Zero Padding Single byte				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	081	1	Type	1 byte zero padding

A 1.4.3. MEDIA ACCESS CONTROL

Provides methods for granting data transfer access.

A 1.4.4. DATA ENCAPSULATION

The data segments of each PL-Frame contain multiple variable length encapsulated datagrams. Each datagram contains the following encapsulation fields:

- Datagram type (1 byte)
- Datagram size (3 bytes)
- Ship ID (4 bytes)
- Transaction ID (4 bytes, optional)
- Datagram sequence number (2 bytes, for multisegment datagrams)
- Source ID (8 bytes, optional)
- Datagram payload (variable)
- Data padding (variable, less than 8 bits)
- CRC (4 bytes).

A 1.4.5. CYCLIC REDUNDANCY CHECK

Refer to A 1.2.5.

A 1.4.6. AUTOMATIC REPEAT REQUEST (ARQ)

Datagrams may or may not use ARQ, this is defined for each datagram type. An ARQ will request selective retransmission of a specific lost datagram segment.

A 1.4.7. ACKNOWLEDGEMENT (ACK)

All datagrams without CRC errors are acknowledged over the satellite link.

A 1.4.8. END DELIVERY NOTIFICATION (EDN)

All datagrams successfully delivered to the destination will be notified to the source.

A 1.4.9. END DELIVERY FAILURE (EDF)

All datagrams not successfully delivered within the timeout or retry limit will be notified to the source.

A 1.4.10. PHYSICAL AND LOGICAL CHANNELS

VDES will operate under a wide range of conditions that vary with location and time. The capacity mix used for to/from ship signalling and data channels can therefore be reconfigured over the air to optimise performance. A network can use up to 13 Logical Channels (LC) each using a configurable number of timeslots at a particular frequency, a default Link Configuration ID (PL format) and a defined function (data/signalling).

VDE-TER uses 7 configurable Logical Channels for signalling and 5 permanently allocated to user data.

VDE-SAT uses 12 Logical Channels for signalling and data.

Logical Channels are used in signalling and for resource allocations and use a 4 bit field.

The Logical Channel Position uses a 7 bit field.

A 1.4.10.1 Physical channels

The Physical channels parameters are defined in Tables xxx. The channels can be 13 (ASM), 25, 50, 100, 150, 300 or 500 kHz wide. Adaptive Coding and Modulation (ACM) functionality is supported when CQI information is provided on the links.

ASM is defined as Random Access Channels using SOTDMA and ACK from a Control Station is sent on the general ASC. The ASM reception flag on the Bulletin Board is set when this functionality is provided. The ASM uplink frequencies are given in Figure 3.

A 1.4.10.2 Logical channels

A LC is defined by the following parameters:

- Logical Channel number (0-12 for 1/2 frequencies, 0-36 for 3/6 frequencies)
- Logical Channel Position (Satellite uplink only, 0-90)
- Function (Random Access, Announcement, Ship originated data, Ship terminated data and Bulletin Board)
- VDE-SAT may use combined functions (Bulletin Board + Assignments, Assignments+ Downlink Data)
- Centre frequency (up to 6)
- Size in slots (0, 1, 2, 3, 5, 30, 90 or 180 slots)
- Default Link Configuration ID (0-63)

The LCs are defined on a Bulletin Board retransmitted every minute starting at slot 0. LC 0 defines the Bulletin Board.

The VDE-TER lowest frequency starts with LC 0. The next frequency starts with LC13. VDE-SAT LCs starts with the highest frequency.

The Terrestrial Bulletin Board is transmitted on the lowest frequency only and the Satellite Bulletin Board on the highest frequency only.

A1.4.10.2.1 Signalling logical channels

The following to ship signalling LC functionality/content is defined:

- Bulletin Board (Network ID, network configuration, system information, network operator message)
- Announcement channel (Bulletin Board version, ship paging, resource allocation (LC)/ LC Position no/access reject reason, uplink minimum access priority level, random access randomizing channels, random access retry interval, received CQI, ACK/selective NACK, Message ACK, connection disconnect/reason, End Delivery Notifications)

The following from ship signalling LC functionality/content is defined:

- Random Access Data (short message, CQI, ACK supported flag)
- Random Access Resource request (priority level, CQI, datagram size, retry count)
- Random Access ACK (message ID, CQI, ACK/selective NACK, End Delivery Notification)

Assigned Signalling (message ID, CQI, ACK/selective NACK, End Delivery Notification)

A1.4.10.2.2 Bulletin Board

The Bulletin Board content is defined in Table 19.

Table 19 - VDES Bulletin Board construction (fixed fields)

Name	Description	Total size (bytes)	Comment
Network (area of applicability) ID	The ID/type of the Network	4	The first 2 bits (MSB) define the Bulletin Board type. 00 is used for ship to shore 01 is used for shore to ship 10 is used for ship to ship 11 is used for satellite The remaining 30 bits are used to uniquely address up to 1.07 10^9 networks
Control Station ID	The Station number within a Network	1	
Bulletin Board version	Version number of this Bulletin Board	2	All valid versions are stored in the ship terminal (includes Configuration Message)
Validity of this version	Lifetime of this version in number of 1 minute frames	2	Up to 45 days
Logical Channel definitions	Logical Channel, Link Configuration ID, slot size, function	TER: 42 SAT: 72	See TABLE A1-15, A1-16, A1-17 Up to 37 Logical Channels using 6 frequencies defined. Additional Logical Channels can be defined in a Configuration Message, see TABLE A1-19
Modulation, coding and protocol versions supported	Discrete combinations	1	Defines a mandatory base set and optional more capable versions. Network ID segmentation could be used to distinguish different network types. ASM reception flag one of the parameters for satellite.
Service Area Point 1	Packet defining the Service Area North East corner	7	GNSS rectangle as defined in Recommendation ITU-R M.1371
Service Area Point 2	Packet defining the Service Area South West corner	7	
System Configuration Message	Logical Channel number for the Configuration Message containing additional parameters/data	1	Used for additional data/information that does not fit within a standard Bulletin Board. Defined in Table 5. Set to 0 when not used.
Expansion	Future use	9	
Authentication and integrity sequence		32	Optional. Filled with zeros if not used.
Padding		0	TBD
	Fixed field size	108/139=8	TER/SAT Bytes

The relationship between LC and Physical Layer for Ship to shore, Shore to ship, Ship to Ship and Satellite to/from Ship mappings are shown in Figures 18, 19, 20 and 21.

VDE-TER Default slot to LC mapping

VDE-TER uses hex slot numbering and all signalling takes place in Hex slot 0. There are TDMA 5 user data channels, each use exclusively one Hex slot (1 to 5). The 5 User Data Channels corresponds to Logical Channels 8 to 12. Each data channel has a dedicated Assignment Channel used for signalling (ASC1 to ASC5).

The function, default Link Configuration ID and number of slots for Logical Channels 0 to 6 are set by the Control Station, and repeated until the end of the frame is reached. (slot 2249). The Control Station can optimise the capacity used for random access and signalling based on traffic loading. Logical Channel 7 is not used in VDE-TER and has a size of 0 slots.

Logical channel	1					2	3	4	5	6		6	Logical channel
0	RACH					ASC1	ASC2	ASC3	ASC4	ASC5	....	ASC5	
1	User Data Channel 1 (UDCH1) associated with ASC1										....		8
2	User Data Channel 2 (UDCH2) associated with ASC2										....		9
3	User Data Channel 3 (UDCH3) associated with ASC3										....		10
4	User Data Channel 4 (UDCH4) associated with ASC4										....		11
5	User Data Channel 5 (UDCH5) associated with ASC5										....		12
TDMA channel number	0	1	2	3	4	5	6	7	8	9		374	Logical channel
	Hex slot												

Figure 18. VDE-TER Ship to Shore default slot to LC mapping (lower leg)

Logical channel	0					1	2	3	4	5	6		5	Logical channel
0	TBB					ASC 1	ASC 2	ASC 3	ASC 4	ASC 5	RACH	....	ASC 5	
1	User Data Channel 1 (UDCH1) associated with ASC1											....		8
2	User Data Channel 2 (UDCH2) associated with ASC2											....		9
3	User Data Channel 3 (UDCH3) associated with ASC3											....		10
4	User Data Channel 4 (UDCH4) associated with ASC4											....		11
5	User Data Channel 5 (UDCH5) associated with ASC5											....		12
TDMA channel number	0	1	2	3	4	5	6	7	8	9	10		374	Logical channel
	Hex slot													

Figure 19. VDE-TER Shore to Ship default slot to LC mapping (upper leg)

By monitoring the Terrestrial Bulletin Board, ships will determine if they are within a Control Station service area and not initiate ship-to-ship transmissions when interference to ship to shore communications is likely.

Logical channel	0					1	2	3	4		5	6		5	Logical channel
0	TBB					ASC 1	ASC 2	ASC 3	ASC 4		ASC 5	RACH	....	ASC 5	
1		User Data Channel 1 (UDCH1) associated with ASC1											....		8
2		User Data Channel 2 (UDCH2) associated with ASC2											....		9
3		User Data Channel 3 (UDCH3) associated with ASC3											....		10
4		User Data Channel 4 (UDCH4) associated with ASC4											....		11
5		User Data Channel 5 (UDCH5) associated with ASC5											....		12
TDMA channel number	0	1	2	3	4	5	6	7	8		9	10		374	Logical channel
		Hex slot													

Figure 20. VDE-TER Ship to Ship default slot to LC mapping (upper leg)

VDE-SAT default Bulletin Board

Hex slot numbering is not used by VDE-SAT because physical layer formats with length 1, 3, 5 are used on uplink and 90 slots is used for downlink. Global slot numbering from 0 to 2249 is used.

Figure 21 shows the default half-duplex satellite LC channel mapping.

	SBB+ ASC	ASC+ Data Down	Data Down 1	Data Down 2	Data Down 3	Data Down 4	Data Up 1	Data Up 2	Data Up 3	Data Up 4	Data Up 5	Data Up 6	RACH
Global start slot	0	90	180	270	360	450	540	570	600	630	660	690	720
Size in slots	90	90	90	90	90	90	30	30	30	30	30	30	90
Logical channel	0	1	2	3	4	5	6	7	8	9	10	11	12

Repeat 1		ASC+ Data Down	Data Down 1	Data Down 2	Data Down 3	Data Down 4	Data Up 1	Data Up 2	Data Up 3	Data Up 4	Data Up 5	Data Up 6	RACH
Global start slot		810	900	990	1080	1170	1260	1290	1320	1350	1380	1410	1440
Size in slots		90	90	90	90	90	30	30	30	30	30	30	90
Logical channel		1	2	3	4	5	6	7	8	9	10	11	12

Repeat 2		ASC+ Data Down	Data Down 1	Data Down 2	Data Down 3	Data Down 4	Data Up 1	Data Up 2	Data Up 3	Data Up 4	Data Up 5	Data Up 6	RACH
Global start slot		1530	1620	1710	1800	1890	1980	2010	2040	2070	2100	2130	2160
Size in slots		90	90	90	90	90	30	30	30	30	30	30	90
Logical Channel		1	2	3	4	5	6	7	8	9	10	11	12

Figure 21. VDE-SAT half duplex default slot to LC mapping (upper and lower leg)

Downlink slots are transmitted by the satellite 2 ms before UTC epoch, and uplink slots are received 2 to 10 ms after UTC epoch. This could cause the satellite to 4 to 12 ms of a packet when switching from receive to transmit. The last receive slot before a transmit slot is therefore not used. For the default configuration, the last RACH slot is not used.

The VDE-SAT and ASM-SAT uplink formats use slots lengths 1, 3 and 5 and these are repeated until all allocated/assigned slots in a Logical Channel are used.

In the default Bulletin Board, all uplink data Logical Channels are 30 slots long and may contain 30, 10 or 6 assigned transmissions for burst lengths 1,3 or 5 slots. These slots are assigned using the LC number and a LC Position (LCP). The LC Position number can range from 1 to 90 (7 bit field).

For the default Bulletin Board, a ship can only transmit 3 times during a 1-minute frame. There are also three periods of 12 s when the ship is not transmitting, thereby providing quiet periods when ships with 10s AIS reporting interval can be detected.

Table 20 shows the Logical Channel parameters for a frequency pair. For VDE-TER the lowest frequency pair starts with LC 0, the 2nd start with 13. Up to 127 LCs can be supported. For VDE-SAT the highest frequency starts with LC 0.

The ship equipment shall prevent any transmission on channels 16 and 70 for all Bulletin Board settings.

Table 20 - Logical Channel definition

Name	Value	Field size (bits)	Comment
Frequency 1: Ship rx Channel Frequency Index (CFI)	156-162.0375 MHz, 12.5 kHz step Channels 0-482 Centre frequency= 156+0.0125*CFI	9	VDES upper leg: 465: 161.8125 MHz (TER default) 469: 161.8625 MHz 473: 161.9125 MHz (SAT default)
Frequency 2: Ship tx CFI	156-162.0375 MHz, 12.5 kHz step Channels 0-482	9	VDES lower leg: 97: 157.2125 MHz (TER default) 101: 157.2625 MHz 105: 157.3125 MHz (SAT default) ASM: 476: 161.950 MHz 480: 162.000 MHz
BB Link Configuration ID Logical channel 0	0-63	6	The symbol rate, bandwidth, burst duration, modulation and coding are defined in Table 4.
BB size in slots	TER: 0, 1, 2, 3 or 5 SAT: 0, 90 or 180	3	Defaults: TER: 5 (011) SAT: 90 (001)
BB data flag	0 or 1	1	Set to 1 if signalling is transmitted on the Bulletin Board Logical Channel. Default 0.
ASM ACK flag	0 or 1	1	Set to 1 if ASM messages either channel is acknowledged. Default 0.
Logical Channel 1			
Tx flag	0 or 1	1	0 for ship receive, 1 for transmit, default 0
Link Configuration ID	0-63	6	
Size in slots	0, 1, 2, 3, 5, 30, 90 or 180	3	Logical channel not used: 0 (000)
Function	TER: 1: RACH 2: ASC 1 3: ASC 2 4: ASC 3 5: ASC 4 6: ASC 5 SAT: 1: RACH 2: ASC 3: ASC/Data down 4: Data Down 5: Data Up	3	Default: TER: Fig xx SAT: Fig yy
………………….			Frequency + BB= 29 bits Each Logical Channel=13 bits
Logical Channel N TER: N=6 SAT: N=12			
Tx flag	0 or 1	1	0 for ship receive, 1 for transmit, default 0
Link Configuration ID	0-63	6	
Size in slots	0, 1, 2, 3, 5, 30, 90, 180	3	Default: 90 (111) Not used: 0 (000)
Function	TER: 0: Bulletin Board 1: RACH 2: ASC general 3: ASC 1 4: ASC 2 5: ASC 3 6: ASC 4 7: ASC 5 SAT: 0: Bulletin Board	3	Default: TER: Fig xx SAT: Fig yy

Name	Value	Field size (bits)	Comment
	1: RACH 2: ASC 3: ASC/Data Down 4: Data Down 5: Data Up		
	Total/Channel	TER: 14 Bytes SAT: 24 Bytes	TER: 29+ 6*13+ 5 spare=112 bits=14 B SAT: 29+12*13+7 spare=192 bits=24 B
	Total 3 channels	TER: 42 B SAT: 72 B	

Configuration Message

The Configuration Message, Table 21, has a variable length data format and is used to handle additional information that is not defined or does not fit within the Bulletin Board.

Table 21 - Configuration Message construction (variable fields)

Name	Description	Total size (bytes)	Comment
Channel Formats	Additional frequencies/slot usage	42/72	TER new channel
Free text message	Containing up to 254 ASCII characters	256	Network operator message to all ships, information only. Includes 8 bit packet type and 8 bit message length
Padding	A zero filling sequence with no content.	3	Includes 8 bit packet type and 16 bit length

Digital Signature of Bulletin Board

It is assumed that a Public Key Infrastructure (PKI) is established with primarily IMO as Certificate Authority (CA), and that ITU-T X.509 (10/2016) is used for public key certificates and the PKI implementation. The PKI will serve several systems and among these VDES. For VDES the primary purpose is to attach a digital signature to the Bulletin Board (BB) issued by a VDES control station to authenticate the control station transmitting the BB.

Ships will need to retrofit a dedicated PKI unit to their bridge system, or build the functionality into the VDES equipment. This unit provides cryptographic services to both general and bridge network applications. The unit will utilize a smartcard for tamper-proof storage of the security credentials.

In case the verification of the signature fails on the VDES mobile station this shall be flagged to the user. The system shall continue its operation as if the signature was verified.

Cryptographic algorithm for the end-entities digital signatures is the Elliptic Curve Digital Signature Algorithm (ECDSA). The Elliptic Curve Cryptography (ECC) public key shall therefore be 256 bit. With this key size, the recommendations from RFC 5480 states that the minimum bits of security should be 128, the message digest algorithm SHA-256, and the curve secp256r1. The lifetime of the selected key material is 3 years.

Communication with separate PKI unit shall be based on network protocol.

A 1.5. NETWORK LAYER

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

A 1.5.1. DATA TRANSFER PROTOCOLS

The following downlink protocols shall be supported:

- Shore originated multicast

- Shore originated unicast
- Ship originated short message
- Ship to ship unicast inside/outside controlled areas (note for Hans , new drawing)
- Ship to ship short message
- Shore originated short message

A 1.5.1.1 Shore originated Multicast without ACK

The sequence diagram for shore originated multicast without ACK is shown in Figure 22. The transfer starts with a resource allocation. The diagram shows a large multi-fragmented datagram. Both predefined groups and geographical areas are supported.

The datagram payload has source, destination and format encapsulated for routing and presentation purposes.

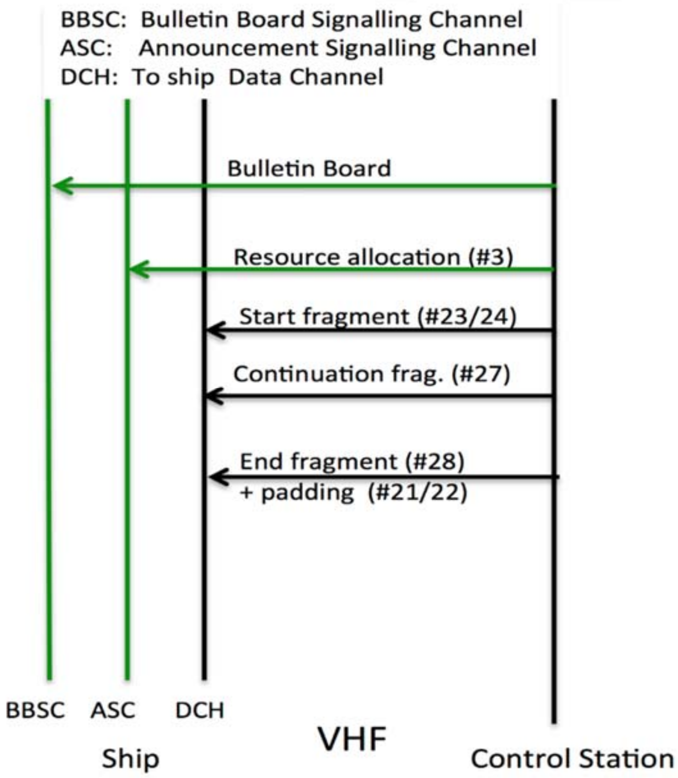

Figure 22. Shore originated Multicast message sequence diagram

A 1.5.1.2 Shore originated Unicast

The sequence diagram for shore originated unicast is shown in Figure 23. The transfer starts with a ship/ ship paging to verify that it is within coverage. The ships response packet contains terminal capabilities and received signal quality. At the Control Station, this is used to allocate an exclusive Logical Channel for the transfer. The diagram shows a large multi-fragmented datagram. Normally up to 16 fragments are sent before the ship sends a selective NACK indicating which fragments have to be resent. The Logical Channel is kept allocated until all fragments have been received by the ship and a ACK has been received or a retry limit has been exceeded.

The datagram payload has source, destination and format encapsulated for routing and presentation purposes.

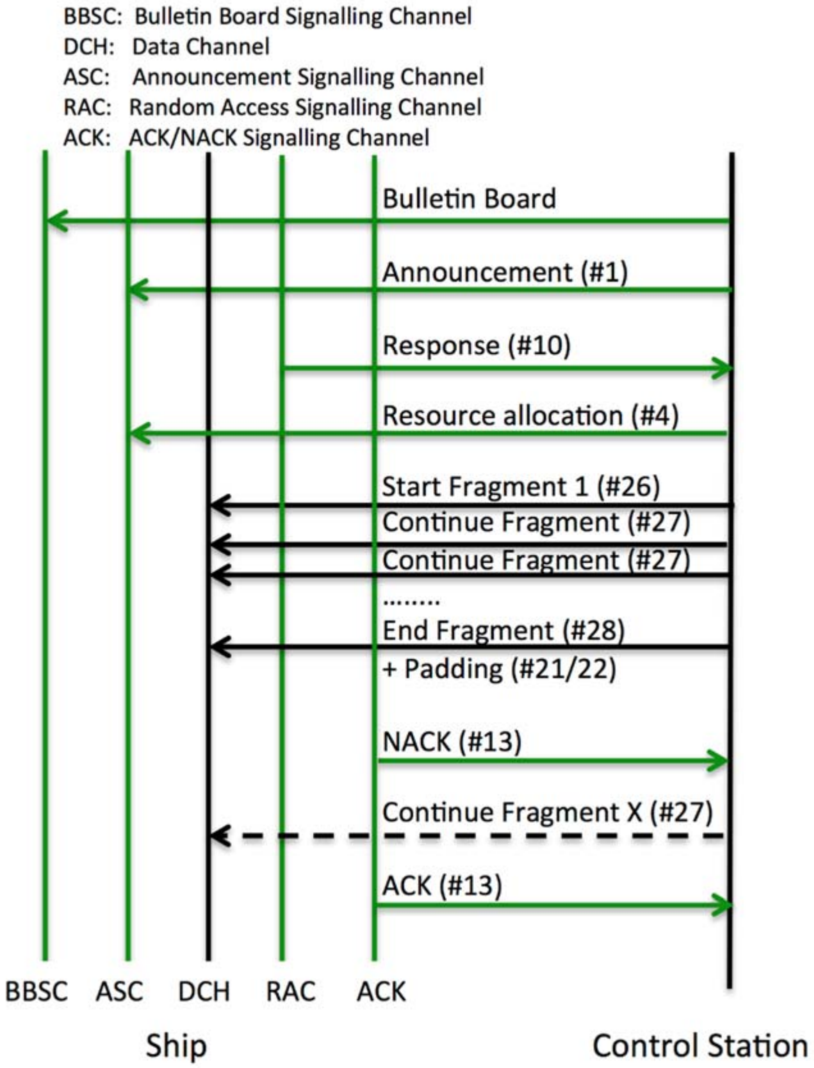

Figure 23. Shore originated Unicast message sequence diagram

A 1.5.1.3 Ship originated short message

The timing diagram for ship originated short message is shown in Figure 24. This protocol is used for short messages that fit within a single transmission burst. A random slot in the randomizing interval given in the MAC signalling is used for the transmission. Zero padding is added as required. 16 byte IPv6 addressing is used.

When maximum robustness is needed a special fixed 11 byte packet is used. 16 different packet types define the content. All types can select from 255 pre-assigned terrestrial addresses. A 16 bit CRC is used for these packets.

The Control Station sends and ACK when the message is received correctly, otherwise the ship may automatically retry until the retry limit is reached.

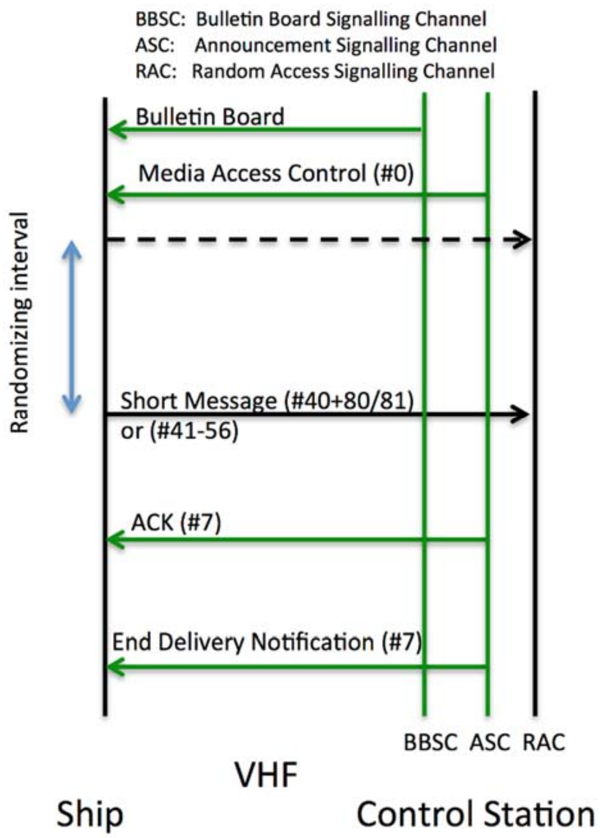

Figure 24. Short message sequence diagram

A 1.5.1.4 Ship originated data transfer

The sequence diagram for ship originated data transfer is shown in Figure 25. The transfer starts with the ship requesting Control Station resources. The Control Station allocate an exclusive Logical Channel for the transfer. The diagram shows a large multi-fragmented datagram. Normally up to 16 fragments are sent before the Control Station sends a selective NACK indicating which fragments have to be resent. The Logical Channel is kept allocated until all fragments have been received by the Control Station and the final ACK has been received or the retry limit has been exceeded.

The End Delivery Notification is optional and defined in the datagram payload, it is mainly used in store-and-forward systems.

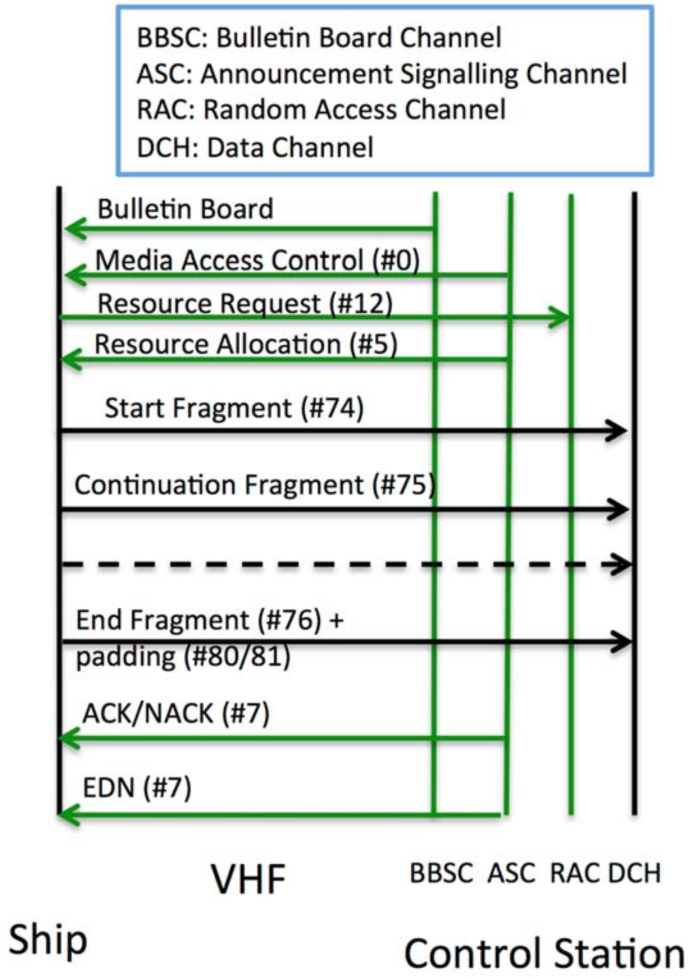

Figure 25. Ship originated data message sequence datagram

A 1.5.1.5 Ship to ship short message

Resource and mobility management

Ships outside the Control Station range may communicate directly. In this case AIS receptions may be used to determine if a ship is within range, combined AIS/VDES transceivers will set a bit in their periodic AIS report that indicates VDES support.

To minimize transmissions to ships outside communications range, sending short messages or paging other ships shall not use more than 1% of the signalling channel (LC 0) slots when the signalling channel is loaded less than 1% averaged over 1 minute. During heavier loading, the activity rate shall be reduced to 0,01%.

The sequence diagram for ship to ship short message transfer is shown in Figure 26.

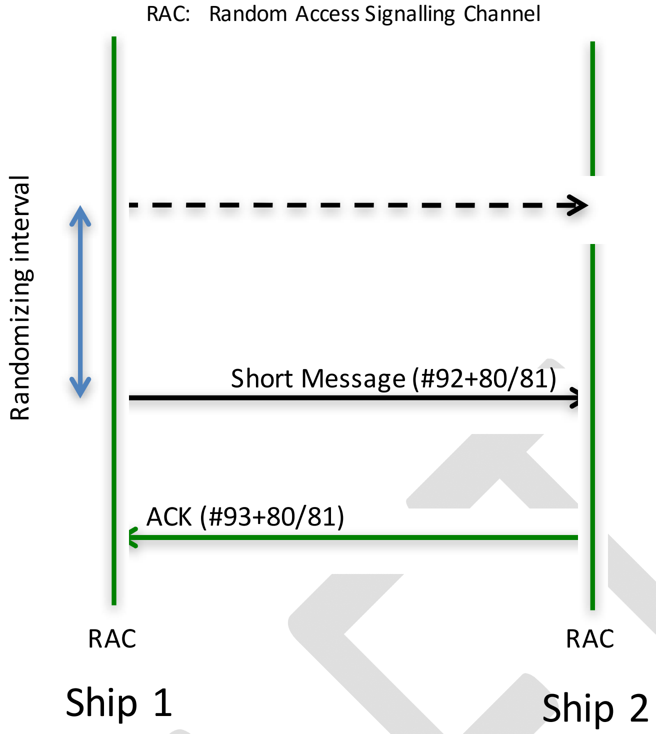

Figure 26. Ship to ship short message transfer message sequence diagram

A 1.5.1.6 Ship to ship communications

The sequence diagram for ship originated data transfer is shown in Figure 27. Ship to ship communications uses a modified RATDMA protocol where up to 6 Logical Channels are defined. Logical Channel 0 is used for signalling. The called ship selects the quietest channel.

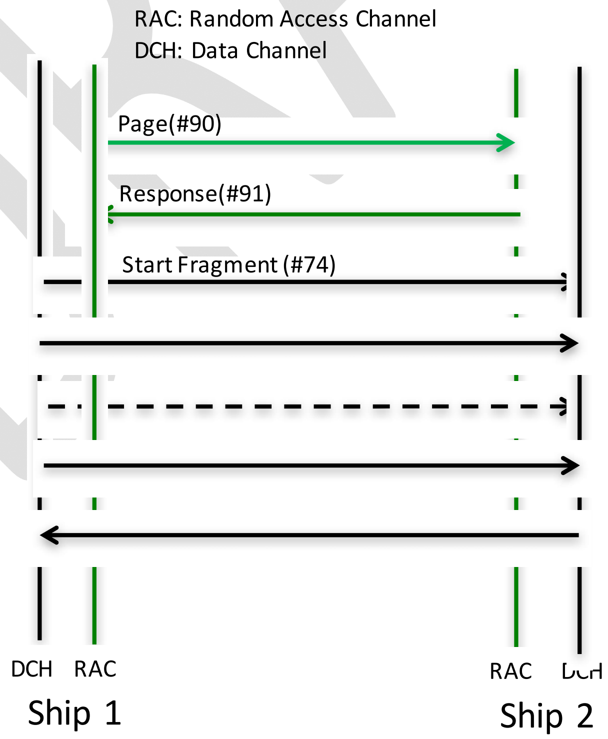

Figure 27. Ship to ship message sequence diagram

A 1.5.1.7 Ship to ship short message

The Control Station service area is defined on its Bulletin Board. Within this service area the Control Station manages the VDES resources to minimize interference.

AIS receptions may be used to determine if a ship is within range, combined AIS/VDES transceivers will set a bit in their periodic AIS reports that indicates VDES support.

The resource is de-allocated by the Control Station if the called ship is unreachable.

Field 4 in packet type #6 is set to 11 if the destination ship is not reachable.

See the sequence diagram in Figure 28.

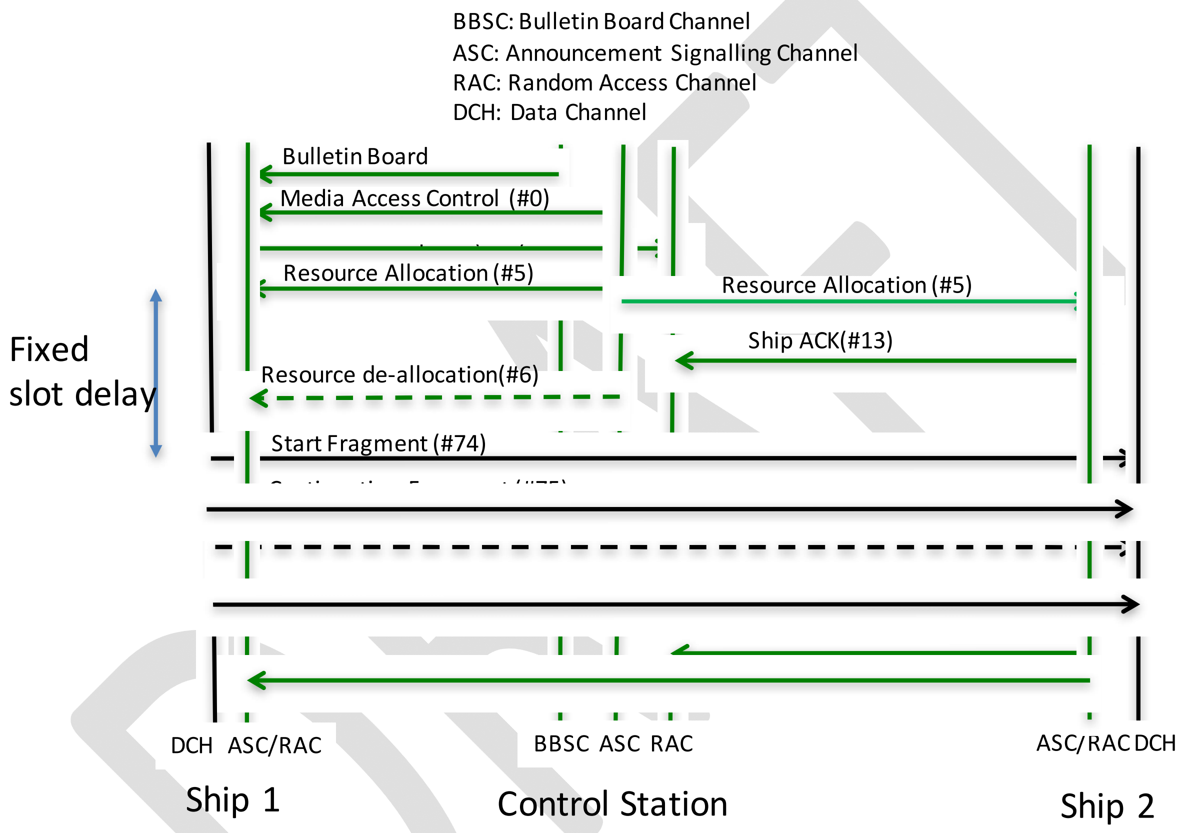

Figure 28. Ship to ship short message via control station message sequence diagram

A 1.5.1.8 Ship to ship short message

Resource and mobility management

Ships outside the Control Station range may communicate directly. In this case AIS receptions may be used to determine if a ship is within range, combined AIS/VDES transceivers will set a bit in their periodic AIS report that indicates VDES support.

To minimize transmissions to ships outside communications range, sending short messages or paging other ships shall not use more than 1% of the signalling channel (LC 0) slots when the signalling channel is loaded less than 1% averaged over 1 minute. During heavier loading, the activity rate shall be reduced to 0,01%.

The sequence diagram for ship to ship short message transfer is shown in Figure 29.

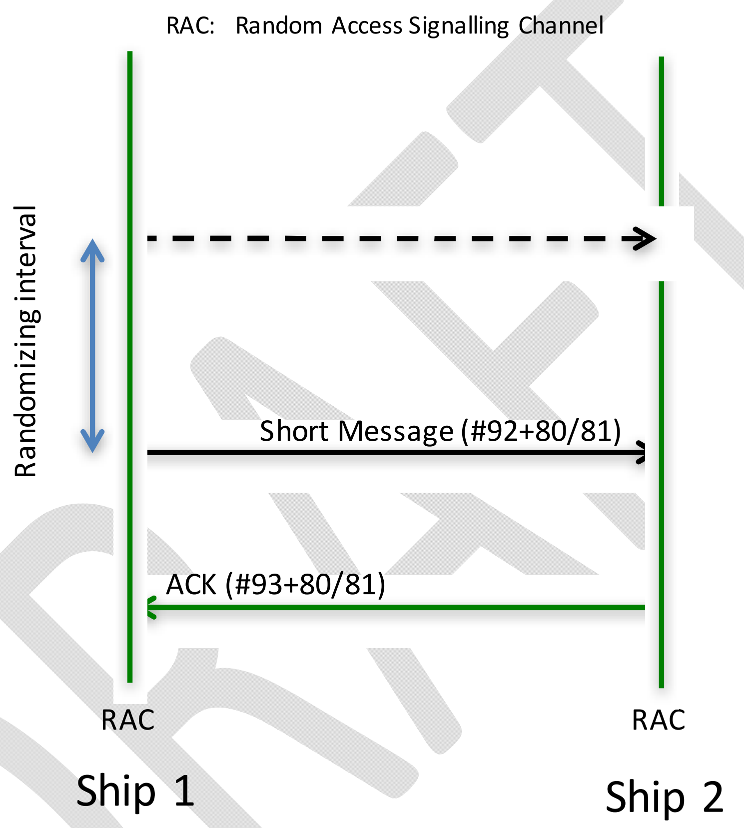

Figure 29. Ship to ship short message sequence diagram

A 1.5.1.9 Ship to ship communications

Ship to ship communications uses a modified RATDMA protocol where up to 6 Logical Channels are defined. Logical Channel 0 is used for signalling. The called ship selects the quietest channel.

The sequence diagram for ship to ship to ship communications transfer is shown in Figure 30.

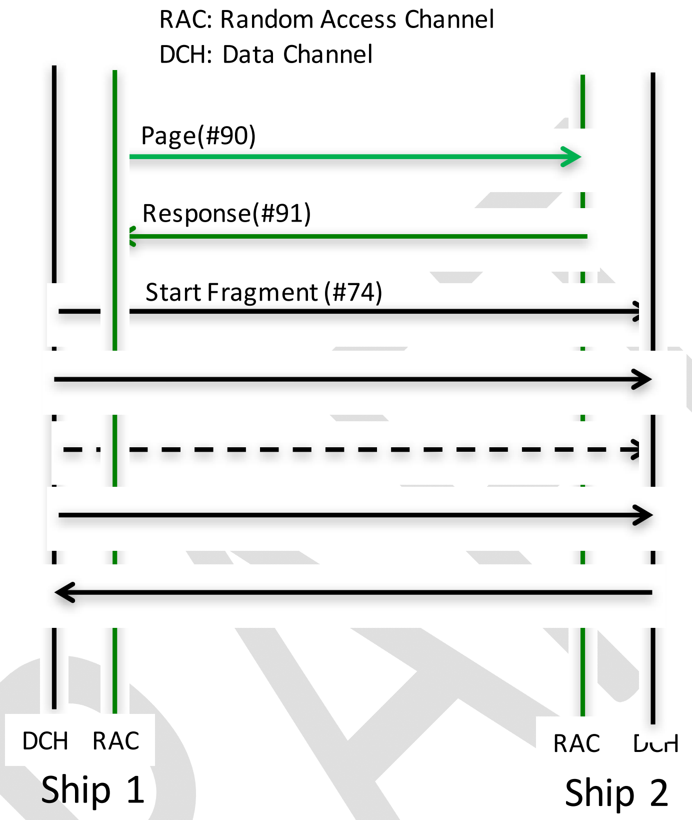

Figure 30. Ship to ship message sequence diagram

A 1.5.1.10 Ship to ship short message

The Control Station service area is defined on its Bulletin Board. Within this service area the Control Station manages the VDES resources to minimize interference.

AIS receptions may be used to determine if a ship is within range, combined AIS/VDES transceivers will set a bit in their periodic AIS reports that indicates VDES support.

The resource is de-allocated by the Control Station if the called ship is unreachable.

Field 4 in packet type #6 is set to 11 if the destination ship is not reachable.

See the sequence diagram in Figure 31.

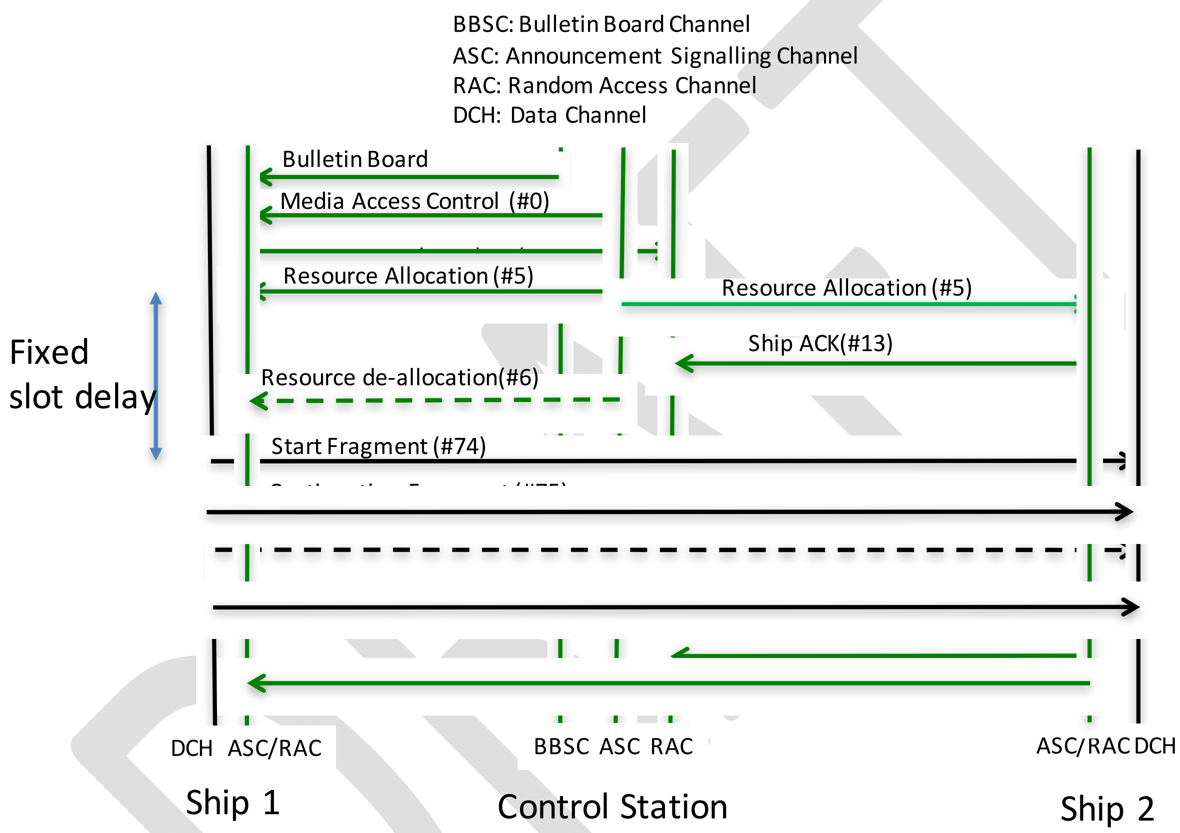

Figure 31. Ship to ship short message via control station message sequence diagram

A 1.6. TRANSPORT LAYER

This layer ensures reliable transmission of the data segments between ships, ship and shore, and ship and satellite, including segmentation, acknowledgement and multiplexing.

A 1.6.1. PRESENTATION INTERFACE PROTOCOL

Data, which is to be transmitted by the station, may be input via the presentation interface; data, which is received by the station, should be output through the presentation interface. The formats and protocol used for this data stream are defined by IEC 61162 series.

A 1.6.2. END TO END PROTOCOLS

Existing Internet protocols such as UDP, SNMP, secure file transfer protocol (SFTP), simple mail transfer protocol (SMTP) are used.

Terrestrial IP protocols are assumed to be terminated at the Control Station gateway.

A 1.6.3. SHIP, APPLICATION AND DEVICE PHYSICAL ADDRESSING

Most commercial ships use a 7-digit IMO number of which the last is a checksum, thus the IMO system can address 1 million ships. The 4 byte VDES physical addressing field has 4.3×10^9 unique IDs. The Control Station or the access network will therefore include a Network Address Translator that converts either a 16 byte IPv6 address or a 7 digit IMO number to this 4 byte ship ID.

The number of networked applications / devices on ships is growing fast and the datagrams will, where needed, include sub addresses.

A 1.6.4. TERRESTRIAL NETWORK ADDRESSING

IPv6 with 16 byte addressing is used.

To support multiple connections/applications from a ship, up to 255 sessions with unique IDs can be supported, these can be routed to different IPv6 addresses.

A 1.6.5. MOBILITY MANAGEMENT

Last transaction coarse position or AIS location data stored in the Control Station database is used to route paging of ships.

A 1.6.6. ADDRESSING OF SHIPS, GATEWAYS AND DEVICES

VDES will be accessed from shore using Internet, and it is desirable to use standard protocols such as email.

A database at the gateway will allow shore users to define their own meaningful ship, gateway and device names.

ANNEX B TECHNICAL CHARACTERISTICS OF THE APPLICATION SPECIFIC MESSAGE (ASM) CHANNELS FOR THE VDES IN THE VHF MARITIME MOBILE BAND

B 1. INTRODUCTION

This section describes those elements of the ASM that are unique to ASM operation. It contains a description of the different protocols according to the OSI layer model and recommends implementation details for each layer. For those elements that are common, the cross reference into Annex 1 is provided.

The system should use TDMA techniques in a synchronized manner.

This Annex describes the characteristics of the TDMA access schemes which include random access TDMA (RATDMA), Multiple Incremental TDMA (MITDMA), fixed access TDMA (FATDMA), techniques. Slot carrier sense TDMA (SCTDMA) may be implemented as an option. The behaviour should be in accordance with Recommendation ITU-R M.1371-5 Annex 7.

B 1.1. OSI LAYERS

Refer to Annex A.

B 1.1.1. PHYSICAL LAYER

Convert digital transmission packet to π/4 Quadrature Phase-Shift Keying (QPSK) signal to modulate transmitter.

B 1.1.2. LINK LAYER

The link layer is divided into three sub-layers with the following tasks.

B 1.1.2.1 Link management entity

This sub layer has the following functions:

- Assemble ASM message bits
- Order the ASM message bits into 8-bit byte for assembly of transmission packet.

B 1.1.2.2 Data link services

This sub layer has the following functions:

- Calculate CRC of the ASM message bits (see A 1.2.5)
- Append CRC to ASM message to complete creation of transmission packet contents.
- Complete assembly of transmission packet.

B 1.1.2.3 Media access control

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.

B 1.1.3. NETWORK LAYER

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

B 1.1.4. TRANSPORT LAYER

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

B 2. PHYSICAL LAYER

B 2.1. PARAMETERS

B 1.1.5. GENERAL

The physical layer is responsible for the transfer of a bit-stream from an originator, out on to the data link. The performance requirements for the physical layer are summarized in Tables 22, 23 and 24.

The low setting and the high setting for each parameter is independent of the other parameters.

Table 1 - Minimum required time division multiple access transmitter characteristics

Parameter name	Units	Low setting	High setting
Channel spacing (encoded according to RR Appendix 18 with footnotes)(1)	kHz	25	25
ASM 1 (2027)(1)	MHz	161.950	161.950
ASM 2 (2028)(1)	MHz	162.000	162.000
Transmit output power	W	1	12.5

(1) See Recommendation ITU-R M.1084, Annex 4.

B 1.1.6. TRANSMISSION MEDIA

Data transmissions are made in the VHF maritime mobile band. Data transmissions should use ASM 1 and/or ASM 2 channels.

B 1.1.7. MULTI-CHANNEL OPERATION

The ASM station should be capable of receiving on two parallel channels and transmitting on two independent channels. Two separate TDMA receiving processes should be used to simultaneously receive on two independent frequency channels. One TDMA transmitter may be used to enable TDMA transmissions on one or two independent frequency channels.

ASM transmission should alternate between the two ASM channels

MITDMA linked transmissions should be on the same channel.

B 2.2. TRANSCEIVER CHARACTERISTICS

The transceiver should perform in accordance with the characteristics set forth herein, see Table 23 and Figure 32. The resolution bandwidth for the mask measurement is 300Hz.

Table 23 - Minimum required time division multiple access transmitter characteristics

Transmitter parameters	Requirements
Carrier power error	±1.5 dB
Carrier frequency error	± 500 Hz
Slotted modulation mask	Δfc < ±8 kHz: 0 dBc ±8 kHz < Δfc < ±16 kHz: below the straight line between −25 dBc at ±8 kHz and −60 dBc at ±16 kHz ±16 kHz < Δfc < ±25 kHz: below the straight line between −60 dBc at ±16 kHz and −70 dBc at ±25 kHz ±25 kHz < Δfc < ±62.5 kHz: −70 dBc
Spurious emissions	−36 dBm: 9 kHz ... 1 GHz −30 dBm: 1 GHz ... 4 GHz

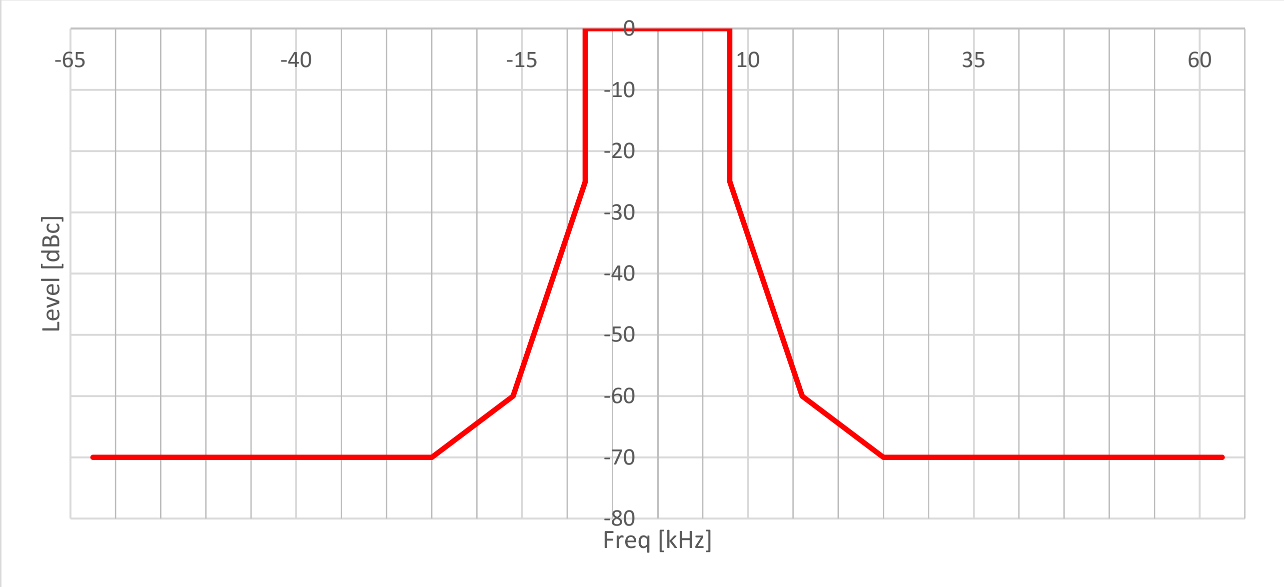

Figure 32. ASM Slotted modulation mask

Table 24 - Minimum required time division multiple access receiver characteristics without FEC

Receiver parameters	Requirements
Sensitivity	20% PER @ −107 dBm
Error behaviour at high input levels	1% PER @ −77 dBm 1% PER @ −7 dBm
Adjacent channel selectivity	20% PER @ 70 dB
Spurious response rejection	20% PER @ 70 dB
Intermodulation response rejection	20% PER @ 74 dB
Spurious emissions	−57 dBm (9 kHz to 1 GHz) −47 dBm (1 GHz to 4 GHz)
Blocking	20% PER @ 86 dB

B 2.3. MODULATION SCHEME

The base modulation is defined by the Link Configuration Id, see Table 7.

For the modulation bit mapping, see Annex A.

B 2.4. FREQUENCY STABILITY

The frequency stability of the VHF radio transmitter/receiver should be ±500 Hz or better.

B 2.5. DATA TRANSMISSION BIT RATE

The transmission bit rate should be 19.2 kbit/s ±10 ppm for π/4 QPSK.

B 2.6. FRAME STRUCTURE

For the generic definition of the frame structure, see Annex A.

B 2.7. SIGNAL INFORMATION

Signal information selects the modulation scheme and coding according to the Link Configuration Id defined in Table 7.

B 2.8. FORWARD ERROR CORRECTION AND BIT SCRAMBLING

When forward error correction is used, it will be used as defined in Annex A. Interleaving and bit scrambling are used, as defined by the FEC designated in the signal information. In the event of no FEC, bit scrambling according to Annex A shall be implemented.

B 2.9. TRANSMITTER TRANSIENT RESPONSE

The time taken to switch from transmit to receive conditions, and receive to transmit conditions, should not exceed the transmit ramp up and ramp down, see Annex A 1.2.3.1. It should be possible to receive a message from the slot directly after or before own transmission.

The equipment should not be able to transmit during channel switching operation.

B 2.10. TRANSMITTER POWER

The power level is determined by the link management entity (LME) of the link layer.

Provision should be made for two levels of nominal power (high power, low power) as required by some applications. The default operation of the ASM station should be on the high nominal power level.

The nominal levels for the two power settings should be 1 W (PEP) and 12.5 W (average power); tolerance should be within ±1.5 dB.

B 3. LINK LAYER

The link layer specifies how data is packaged in order to apply error detection and correction to the data transfer. The link layer is divided into three sub-layers.

B 3.1. SUB-LAYER 1 – MEDIUM ACCESS CONTROL

The medium access control (MAC) sub layer provides a method for granting access to the data transfer medium, i.e. the VHF data link. The access scheme is TDMA using a common time reference.

B 3.2. TDMA SYNCHRONIZATION

TDMA synchronization is achieved using an algorithm based on a synchronization state as described below. The sync state flag within the MITDMA communication state indicates the synchronization state of a station.

The TDMA receiving process should not depend on slot boundaries.

Synchronization other than UTC direct may be provided by the AIS system.

B 3.3. COORDINATED UNIVERSAL TIME DIRECT

A station, which has direct access to coordinated universal time (UTC) timing, with the required accuracy, should indicate this by setting its synchronization state to UTC direct.

B 3.4. COORDINATED UNIVERSAL TIME INDIRECT

A station, which is unable to get direct access to UTC, but has access to the AIS system, may get its synchronization from the AIS system. It should then change its synchronization state to indicate the type of synchronization which is being provided by the AIS system.

B 3.5. TIME DIVISION

The slot and frame are as defined in Annex A. Access to the data link is, by default, given at the start of a slot. The frame start and stop coincide with the UTC minute, when UTC is unavailable the AIS system may provide the frame synchronization.

B 3.5.1 SLOT PHASE AND FRAME SYNCHRONIZATION

Slot phase synchronization and frame synchronization is done by using information from UTC or from the AIS system.

B 3.5.1.1 Slot phase synchronization

Slot phase synchronization is the method whereby the slot boundary is synchronized with a high level of synchronization stability, thereby ensuring no message boundary overlapping or corruption of messages.

B 3.5.1.2 Frame synchronization

Frame synchronization is the method whereby the current slot number for the frame is known.

B 3.5.2 SLOT IDENTIFICATION

Each slot is identified by its index (0-2249). Slot zero (0) should be defined as the start of the frame.

B 3.5.3 SLOT ACCESS

The transmitter should begin transmission by turning on the RF power at slot start.

The transmitter should be turned off after the last bit of the transmission packet has left the transmitting unit. This event must occur within the slots allocated for own transmission. The slot access is performed as described in Annex A 1.2.2.

B 3.5.4 SLOT STATE

Each slot on an ASM channel can be in one of the following states:

- Free: meaning that the slot is unused on the channel within the receiving range of the own station for AIS/ASM/VDE
- Internal allocation allocated by own station for the purpose of AIS/ASM/VDE/long range transmission
- AIS Available –externally allocated by an AIS which may be considered as a candidate slot
- AIS Unavailable –externally allocated by an AIS which should not be considered as a candidate slot for the following reasons:
  - SOTDMA slot timeout = 0
  - FATDMA allocated slot
- ASM Unavailable – Externally allocated by an ASM station within the receiving range of the own station
- VDE Unavailable – slots allocated to own station for VDE reception

B 3.6. SUB LAYER 2 – DATA LINK SERVICE

The data link service (DLS) sub layer provides methods for:

- data link activation and release;
- data transfer; or
- error detection, correction and control.

B 3.6.1 DATA LINK ACTIVATION AND RELEASE

Based on the MAC sub layer the DLS will listen, activate or release the data link. A slot, marked as free or externally allocated, indicates that own equipment should be in receive mode and listen for other data link users.

B 3.6.2 DATA TRANSFER

Data transfer should use a bit-oriented protocol and should be in accordance with this standard.

B 3.6.2.1 Packet format

Data is transferred using the generic transmission packet as defined in Annex A, Figure 5 and Figure 6.

The packet should be sent from left to right. The training sequence is be used to synchronize the VDES receiver.

B 3.6.2.2 Summary of the transmission packet

The data packet is defined in Table 25.

The ASM channel configurations are defined by Link Configuration Id table, Table 7.

Table 25 - Packet symbol structure for π/4 QPSK modulation scheme

		Description
Ramp up	4 symbols	
Training sequence	27 symbols	Necessary for synchronization
Link configuration id	16 symbols	Decoded from (32,6) biorthogonal code ASM channel configurations as defined in Link Configuration Id table
Data	1 slot: 176 2 slot: 432 3 slot: 688 symbols	The symbol count and the information bits varies according to coding rate as defined by the link configuration id field
CRC	16 symbols	The CRC only includes the data field
Ramp Down	4 symbols	Distance delay and jitter
Guard Time	13 symbols	Distance delay and jitter
Total	1 slot: 256 2 slot: 512 3 slot: 768 symbols	

B 3.6.2.3 Transmission timing

The modulation may be applied during the ramp up period, but it shall not be considered as part of the training sequence

B 3.6.2.4 Long transmission packets

A station may occupy a maximum of 3 consecutive slots, as defined by the Link Configuration id, for one (1) continuous transmission. Only a single application of the overhead (ramp up, training sequence, flags, CRC, guard time) is required for a long transmission packet.

B 3.6.3 ERROR DETECTION AND CONTROL

Error detection is accomplished using a CRC polynomial as described in Annex A.

B 3.6.4 FORWARD ERROR CORRECTION

Forward error correction should be handled as described in Annex A, and specified by the Link Configuration Id see Table 7.

B 3.7. SUB LAYER 3 – LINK MANAGEMENT ENTITY

The LME controls the operation of the DLS, MAC and the physical layer.

B 3.7.1 ACCESS TO THE DATA LINK

There should be different access schemes for controlling access to the data transfer medium. The application and mode of operation determine the access scheme to be used.

The access schemes are MITDMA, RATDMA, and FATDMA.

B 3.7.1.1 Cooperation on the data link

The access schemes operate continuously, and in parallel, on the same physical data link. They all conform to the rules set up by the TDMA. The ASM system must give priority to the AIS system when accessing the physical data link.

B 3.7.1.2 Candidate slots

Slots, used for transmission, are selected from *candidate slots* in the selection interval (SI) which is defined as 300 slots.

The selection process uses received data from AIS, ASM and VDE.

There should be, at minimum, a set of eight candidate slots to choose from.

The candidate slots are primarily selected from slots that are free on AIS, ASM and VDE.

The available AIS slots are as defined in Recommendation ITU-R M.1371 and must only be taken from the most distant station(s) within the SI.

If the candidate slot set contains less than eight slots, additional candidate slots can be obtained by using the following rules and order (rule 1 followed by rule 2):

- Rule 1: available slot on one AIS channel and free on the other AIS and free on the ASM and VDE channels
- Rule 2: available slot on both AIS channels (AIS1 and AIS2) and free on all ASM and VDE channels.

When selecting candidates for messages longer than one (1) slot, a candidate slot should be the first slot in a consecutive block of slots that conform to the selection criteria stated above.

If the station cannot find sufficient number of candidate slots, the station should not transmit and should re-schedule the transmission.

The candidate slot selection process also has to consider time periods reserved for the reception of the bulletin board.

The purpose of maintaining a minimum of eight candidate slots within the same probability of being used for transmission is to provide high probability of access to the link.

Note that the AIS and VDE channels need only to be considered when ASM and the other system share the same antenna. Or when there is not sufficient isolation to support independent operations such that the AIS station will still meet its receiver performance requirements.

B 3.7.2 MODES OF OPERATION

There should be two modes of operation, autonomous and assigned. The default mode should be autonomous.

B 3.7.2.1 Autonomous

A station operating autonomously should determine its own schedule for transmission. The station should automatically resolve scheduling conflicts with other stations.

B 3.7.2.2 Assigned

A station operating in the assigned mode takes into account the transmission schedule of the assigning message when determining when it should transmit.

B 3.7.3 CHANNEL ACCESS SCHEMES

The access schemes, as defined below, should coexist and operate simultaneously on the TDMA channel. The access scheme FATDMA is as defined in Recommendation ITU-R M.1371.

B 3.7.3.1 Multiple incremental time division multiple access (MITDMA)

The MITDMA access schemes allows a station to pre-announce transmission slots that the station will use in the future. A single MITDMA transmission may be used to schedule up to three future transmissions with each transmission occupying up to 3 slots.

B 3.7.3.2 Multiple incremental time division multiple access algorithm

The first transmission within a MITDMA chain will be a single slot transmission using RATDMA access. Prior to the first transmission the station will randomly select up to three additional transmission slots. The offset from the first transmission to the first future transmission is calculated and provided in the MITDMA communication state. If a second future transmission is desired, then the offset from the first future transmission to the second future transmission is provided in the MITDMA communication states. If a third future allocation is desired, then the offset from the second future transmission to the third future transmission is provided in the MITDMA communication state.

Receiving stations should mark these slot allocations as unavailable.

MITDMA may chain up to 15 transmissions together in a single frame.

B 3.7.3.3 Random access time division multiple access (RATDMA)

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 MITDMA chain, or for messages of a non-repeatable character.

B 3.7.3.4 Random access time division multiple access algorithm

The RATDMA access scheme should use a probability persistent (p-persistent) algorithm as described in this paragraph (see Table 26).

When a candidate slot is selected, the station randomly selects a probability value (LME.RTP1) between 0 and 100. This value should be compared with the current probability for transmission (LME.RTP2). If LME.RTP1 is equal to, or less than LME.RTP2, transmission should occur in the candidate slot. If not, LME.RTP2 should be incremented with a probability increment (LME.RTPI) and the station should wait for the next candidate slot in the frame.

The SI for RATDMA should be 300 time slots, which is equivalent to 8 s. The candidate slot set should be chosen within the SI, so that the transmission occurs within 8 s.

Each time that a candidate slot is entered, the p-persistent algorithm is applied. If the algorithm determines that a transmission shall be inhibited, then the parameter LME.RTCSC is decremented by one and LME.RTA is incremented by one.

LME.RTCSC can also be decremented as a result of another station allocating a slot in the candidate set. If LME.RTCSC + LME.RTA < 8 then the candidate set shall be complemented with a new slot within the range of the current slot and LME.RTES following the slot selection criteria.

B 3.7.3.5 Random access time division multiple access parameters

The following parameter are used to control the RATDMA scheduling:

Table 26 - RATDMA Parameters

Symbol	Name	Description	Minimum	Maximum
RTCSC	Candidate slot counter	The number of slots currently available in the candidate set. NOTE 1 – The initial value is always 8 or more (see § 3.3.1.2). However, during the cycle of the p-persistent algorithm the value may be reduced below 8	1	300
RTES	End Slot	Defined as the slot number of the last slot in the initial SI, which is 150 slots ahead	0	2249
RTPS	Start probability	Each time a new message is due for transmission, LME.RTP2 should be set equal to LME.RTPS. LME.RTPS shall be equal to 100/LME.RTCSC. NOTE 2 – LME.RTCSC is set to 8 or more initially. Therefore LME.RTPS has a maximum value of −25 (100/8)	0	25
RTP1	Derived probability	Calculated probability for transmission in the next candidate slot. It should be less than or equal to LME.RTP2 for transmission to occur, and it should be randomly selected for each transmission attempt	0	100
RTP2	Current probability	The current probability that a transmission will occur in the next candidate slot	RTPS	100
RTA	Number of attempts	Initial value set to 0. This value is incremented by one each time the p-persistent algorithm determines that a transmission shall not occur	0	149
RTPI	Probability Increment	Each time the algorithm determines that transmission should not occur, LME.RTP2 should be incremented with LME.RTPI. LME.RTPI shall be equal to(100 – LME.RTP2)/LME.RTCSC	1	25

B 3.7.3.6 Network access and entry of a new data stream

At power on, a station should monitor the TDMA channels for one (1) minute to determine channel activity, other participating member IDs, current slot assignments and reported positions of other users, and possible existence of base stations, as shown in Figure 33. During this time, a dynamic directory of all members operating in the system should be established. A frame map should be constructed, which reflects TDMA channel activity. After one (1) minute has elapsed, the station may be available to transmit ASM messages according to its own schedule.

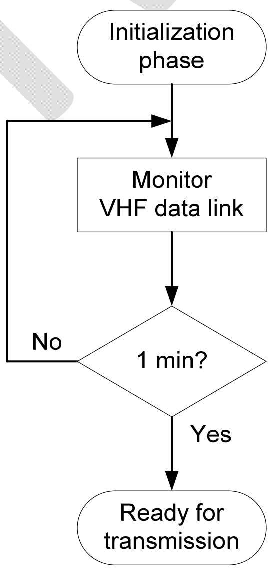

Figure 33. Network Access for MITDMA and RATDMA

B 3.7.3.7 RATDMA channel access

When the ASM station needs to transmit a single ASM message which is not repeated periodically, it should use RATDMA access.

B 3.7.3.8 MITDMA channel access

When the ASM station needs to transmit a block of ASM messages, or if it needs to transmit ASM message periodically, it should use MITDMA access.

B 3.7.9 MESSAGE STRUCTURE

The messages should have the following structure shown in Figure 34 inside the data portion of a data packet.

Figure 34. Message Structure

Each message is described using a table with parameter fields listed from top to bottom. Each parameter field is defined with the most significant bit first.

Parameter fields containing sub-fields (e.g. communication state) are defined in separate tables with sub-fields listed top to bottom, with the most significant bit first within each sub-field.

B 3.7.9.1 Message identification

The message ID should be 4 bits long and should have a range of 0 – 16. The message ID should identify the message type.

B 3.7.9.2 User identification

The user ID should be a unique identifier and is 30 bits long. All ASM messages will contain the user identifier to identify the source of the transmission.

B 3.7.9.3 Incremental time division multiple access message structure

The MITDMA message structure is shown in Figure 35.

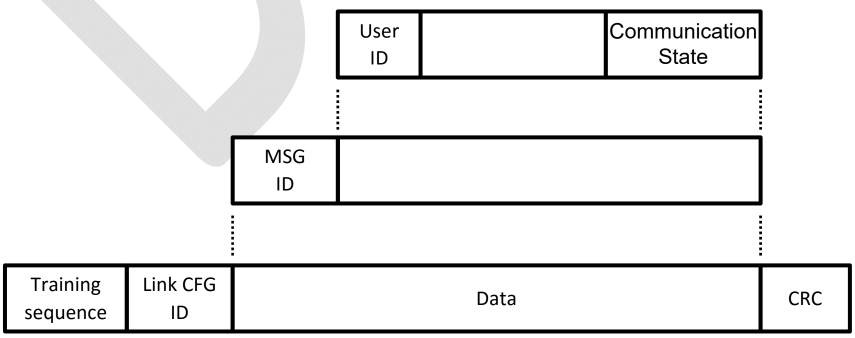

Figure 35. ATDMA Message Structure

B 3.7.9.4 Multiple Incremental time division multiple access communication state

The communication state provides the information used by the slot allocation algorithm in the MITDMA concept.

The MITDMA communication state is structured as shown in Table 27.

Table 27 - MITDMA communication state parameters

Parameter	Number of bits	Description	Minimum	Maximum
Transmit block counter	4	A decrementing counter used to indicate how many transmissions are left to transmit within the chain A value of 1 indicates this is the last transmission within the chain A value of 0 indicates a recurring transmission.	0	15
Block Identifier	4	This identifier uniquely identifies the block of data within the transmit chain. This identifier also maps to the acknowledgment for addressed messages.	0	15
Slot Increment 1	8	Offset to the next slot to be used, referenced to the current transmission start slot. A value of 0 indicates no additional slot allocations	20	255
Number of Slots 1	2	Indicates the number of consecutive slots, which are allocated, starting at the slot increment A value of 0 indicates the 8 bits from Slot Increment 1 become the MSB for the Slot Increment 2	0	3
Slot Increment 2	8	Offset to the next slot to be used, referenced to the slot specified by slot increment 1 (or current transmission slot if the Number of Slots 1 is set to 0) A value of 0 indicates no additional slot allocations	20	255 45001
Number of Slots 2	2	Indicates the number of consecutive slots, which are allocated, starting at the slot increment	1	3
Slot Increment 3	8	Offset to the next slot to be used, referenced to the slot specified by Slot Increment 2	20	255
Number of Slots 3	2	Indicates the number of consecutive slots, which are allocated, starting at the slot increment	1	3
Total bits	37			
Note 1: When combining Slot Increment 1 and Slot Increment 2 as a 16 bit field. This value should not exceed 2 frames.				

B 4. NETWORK LAYER

The network layer should be used for:

- Establishing and maintaining channel connections
- Management and priority assignments of messages
- Distribution of transmission packets between channels
- Data link congestion resolution.

B 4.1. MULTI-CHANNEL OPERATIONS

Two frequencies have been designated in RR Appendix 18 for ASM transmissions. These frequencies are:

- ASM1 (Channel 2027, 161.950 MHz)
- ASM2 (Channel 2028, 162.000 MHz)

Channel access is performed independently on each of the two channels. Generally, ASM transmission should alternate between the two channels when available.

Terrestrial transmissions of acknowledgements to addressed messages should be done on the channel as the initial message was received.

Chained transmissions using MITDMA shall all be done on the same channel.

B 4.2. MANAGEMENT OF PRIORITY ASSIGNMENT FOR MESSAGES

ASM messages support message priority. The priority of the message is determined by the PI interface. The messages are serviced in order of priority. Messages with the same priority are dealt with in a FIFO order.

B 4.3. DATA LINK CONGESTION RESOLUTION

As the data link becomes loaded, the availability of transmission slots will reduce. When the data link is loaded to such a level as reception of ASM message`s is jeopardized, measures should be taken to reduce the loading.

ASM channel loading shall be measured independently per channel over a window of the past 2250 slots (1 Minute).

The amount of ASM transmissions on a specific channel shall be adopted to the channel loading on that channel.

The maximum number of slots allocated by one station on one channel shall not exceed 50 slots over a period of one minute (2.2% duty cycle).

B 4.3.1 MANDATORY QUIET TIMES

After the completion of a singular Non-MITDMA ASM channel transmission or a complete MITDMA transmission block chain, the ASM station shall wait for a specific time before additional transmission can be scheduled. This time is referred to as Quiet Time. The Selection Interval for finding candidate transmission slots starts after the Quiet Time.

For a singular transmission, Quiet Time shall per default be one second per timeslot.

For an MITDMA linked transmission chain, the Quiet Time is a function of the number of transmission slots within that chain. The Quiet Time shall be increased by one second per time slot used in the transmission chain.

The Quiet Time shall be increased with a multiplier, depending on channel load (Table 28).

Table 28 - Quiet Time Multiplier

Channel load	<10%	10%-30%	30%<
Multiplier	1	2	3
Quiet Time [seconds] = Transmission slots * Multiplier			

B 5. TRANSPORT LAYER

The transport layer is responsible for:

- converting data into transmission packets of correct size;
- sequencing of data packets;
- interfacing protocol to upper layers.

B 5.1. DEFINITION OF TRANSMISSION PACKET

A transmission packet is an internal representation of some information which can ultimately be communicated to external systems. The transmission packet is dimensioned so that it conforms to the rules of data transfer. Transmission packets are fixed block sizes on slot boundaries with a maximum of 3 consecutive slots. When data does completely fill the block, then padding bits with the value of 0 should be added to completely required block size.

B 5.2. ASM IDENTIFIER

Addressed and broadcast binary messages should contain a 16-bit application identifier (Table 29)

Table 29 - ASM identifier parameters

Bit	Description
15-6	Designated area code (DAC). This code is based on the maritime identification digits (MID). Exceptions are 0 (test) and 1 (international). Although the length is 10 bits, the DAC codes equal to or above 1 000 are reserved for future use
5-0	Function identifier. The meaning should be determined by the authority which is responsible for the area given in the designated area code

Whereas the application identifier allows for regional applications, the application identifier should have the following special values for international compatibility.

B 5.3. TRANSMISSION PACKETS

B 5.3.1 ADDRESSED MESSAGES

Addressed messages are point to point communications between VDES stations. Addressed messages may require an acknowledgment. When an acknowledgement is required and not received, the VDES stations may retransmit the message.

B 5.3.2 BROADCAST MESSAGES

A broadcast message lacks a destination identifier ID. Therefore, receiving stations should not acknowledge a broadcast message up to 3 times.

B 5.3.4 CONVERSION TO PRESENTATION INTERFACE MESSAGES

Each received transmission packet should be converted to a corresponding presentation interface message and presented in the order they were received regardless of message category. Applications utilizing the presentation interface should be responsible for their own sequencing numbering scheme, as required. For a mobile station, addressed messages should not be output to the presentation interface, if Destination ID (unique identifier) is different to the ID of own station (own unique identifier).

B 5.3.5 CONVERSION OF DATA INTO TRANSMISSION PACKETS

The transport layer should convert data, received from the presentation interface into transmission packets. If the data exceeds the maximum limit, then a negative acknowledgement should be returned on the PI

B 5.4. MITDMA ACCESS

When the length of the data requires more than 3 consecutive slots, then the data should be divided up into sub-groups of 3 slot packets and MITDMA should be used to chain the transmissions together. A total of 15 MITDMA transmissions may be chained together. If the data provided by the PI exceeds this limit, a negative acknowledgment should be provided on the PI.

If data transmissions are repetitive in nature, and have a transmit interval less than 2 frames (4 500 slots), then MITDMA should be used to maintain the link.

If multiple messages are queued for transmission, then MITDMA should be used to allocate slots for the additional messages.

When using MITDMA for addressed messages, the MITDMA will provide the return slot for the message acknowledgment as specified in Slot Increment 3 during block identifier 2, 1 or 0.

B 5.4.1 MITDMA ACCESS EXAMPLE

An MITDMA access example is shown in Figure 36. The first transmission (Tx 1) of a MITDMA chain is always a single slot transmission.

Determine the candidate slots for the Tx 1. Apply the RATDMA algorithm until the transmit criteria is meet.

Before transmitting at Tx 1, determine the candidate slots for up to three additional transmissions. Randomly select the transmit slots from the candidate slot lists. Calculate the offsets for these future transmissions. This information is provided in the MITDMA communication state. Slot Increment 1 reserves Tx 2, Slot Increment 2 reserves Tx 3, and Slot Increment 3 reserves Tx 4.

Before transmitting at Tx 2, determine the candidate slots for the next transmission, e.g. Tx 5. Randomly select a transmit slot from the candidate slot list. This information is provided in the MITDMA communication state. Slot Increment 1 reserves Tx 3, Slot Increment 2 reserves Tx 4, and Slot Increment 3 reserves Tx 5.

If this is a broadcast message, then starting at Tx n-2, the unused Slot Increments are set to 0. If this is an addressed message, then the following process happens.

At Tx n-2, determine the candidate slots for the acknowledgment message. Randomly select the acknowledgment slot from the candidate slot list. Calculate the offset for the ACK Slot. This information is provided in the MITDMA communication state. Slot Increment 1 reserves the Tx n-1, Slot Increment 2 reserves the Tx n, and Slot Increment 3 reserves the ACK Slot.

At Tx n-1 a new offset is calculated for the ACK Slot. This information is provided in the MITDMA communication state. Slot Increment 1 reserves the Tx n, Slot Increment 2 reserves the ACK Slot, and Slot Increment 3 is set to 0.

At Tx n a new offset is calculated for the ACK Slot. This information is provided in the MITDMA communication state. Slot Increment 1 reserves the ACK Slot, Slot Increment 2 and 3 are set to 0.

At the ACK Slot, the receiving station transmits the acknowledgment message.

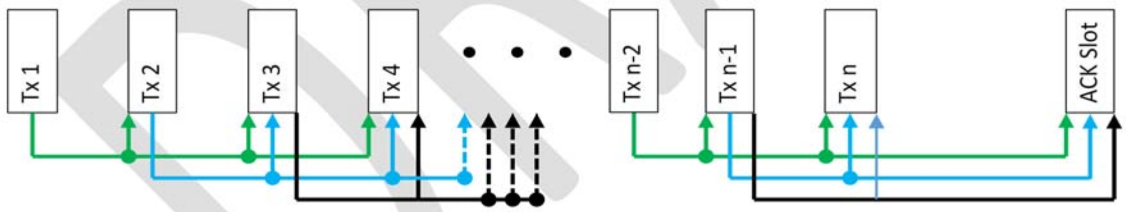

Figure 36. MITDMA Access Example

B 6. PACKET STRUCTURE

The ASM transmission packets are used to transport data from one ASM station to another. There are multiple types of packet definitions which use different address modes and channel access schemes. The packet structures are defined by the message identifier.

B 6.1. GENERAL PACKET STRUCTURE

The generic data packet is defined in Table 30.

Table 30 - General packet structure

Parameter	Number of bits	Descriptions
Ramp up	8 bits	417 us
Training sequence	54 bits	Necessary for synchronization
Link configuration id	32 bits	Six information bits decoded from (32,6) biorthogonal code ASM channel configurations as defined in Link Configuration Id, see Table A1-6 Note that the Link Configuration Id will identifiy how many slots make up the message.
Message	1 slot: 352 2 slot: 864 3 slot: 1376 SAT : 1236	The symbol count and the information bits varies according to coding rate as defined by the link configuration id field
CRC	32 bits	The CRC only includes the data field
FEC termination bits	12 bits	Set to zero when not used
Ramp Down	8 bits	417 us
Guard Time	14 bits TER 154 bits SAT	Distance delay TER 729 us Distance delay SAT 8.02 ms
Total	1 slot: 512 2 slot: 1024 3 slot: 1536	

B 6.2. MESSAGE SUMMARY

The defined message types are summarized Table 31.

Table 31 – Message Summary

Message ID	Name	Description	Access scheme	Communication State
1	Scheduled Broadcast Message	Broadcast data using communication state	FATDMA RATDMA MITDMA	MITDMA
2	Broadcast Message	Broadcast data with no communication state	FATDMA RATDMA	none
3	Scheduled Individual Addressed Message	Individual addressed data with communication state. Requires acknowledgement	FATDMA RATDMA MITDMA	MITDMA
4	Individual Addressed Message	Individual addressed data with no communication state. Requires acknowledgement	FATDMA RATDMA	none
5	Acknowledgment Message	This message is used to provide and acknowledgment for one or more addressed messages	FATMDA RATDMA MITDMA	none
6	Geographical Multicast Message	Addressed to a group of stations defined by their geographical location with no communication state. No acknowledgment required.	FATDMA RATDMA	none
7	Group Multicast Message	Address to a group of stations defined by the group address identifier	FATDMA RATDMA	none

B 6.3. MESSAGE 1: SCHEDULED BROADCAST MESSAGE

This ASM message is used to broadcast data to all targets, and utilizes MITDMA communication state. Multiple messages, or periodically broadcasted messages may be chained together using the MITDMA communication state. The first transmission in the chain will use RATDMA to access the link, and all additional transmission will use slots allocated by the MITDMA communication state. Scheduled broadcast message is defined in Table 32.

Table 32 - Scheduled broadcast message

Parameter	Number of bits	Description
Message ID	4	1 - Broadcast message with MITDMA communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Communication State	37	MITDMA communication state as described in section 3.3.3.1
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
ASM identifier	16	Application identifier and described in section 5.2
Data Count	11	1 – Max data count
Binary Data	1 slot – 245 2 slot – 757 3 slot – 1269 SAT – 1129	Application data as specified by the ASM Identifier. The available length of the binary data is specified by the LinkConfigId. Unused payload data is zero-filled

B 6.4. MESSAGE 2: BROADCAST MESSAGE

This ASM message is used to broadcast data to all targets, and does not contain a communication state. These broadcast messages are used for non-periodic transmission of data, and access the link using RATDMA. Broadcast message is defined in Table 33.

Table 33 - Broadcast Message

Parameter	Number of bits	Description
Message ID	4	2 - Broadcast message with no communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
ASM identifier	16	Application identifier and described in section 5.2
Data Count	11	1 – Max data count
Binary Data	1 slot – 286 2 slot – 798 3 slot – 1310 SAT – 1170	Application data as specified by the ASM Identifier. The available length of the binary data is specified by the LinkConfigId.

B 6.5. MESSAGE 3: SCHEDULED ADDRESSED MESSAGE

This ASM message is used to send data to an individual target, and utilizes MITDMA communication state. Multiple transmission of messages, or periodically transmissions of messages may be chained together using the MITDMA communication state. The first transmission in the chain will use RATDMA access the link, and all additional transmission will use slots allocated by the MITDMA communication state.

These transmissions require the destination station to return a message acknowledgment (Message 5). This addressed message supplies the return slot for the message acknowledgment. Scheduled addressed message is defined in Table 34.

Table 34 - Scheduled addressed message

Parameter	Number of bits	Description
Message ID	4	3 – Individually addressed message with MITDMA communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Communication State	37	MITDMA communication state as described in section 3.3.3.1
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
Destination ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
ASM identifier	16	Application identifier and described in section 5.2
Data Count	11	1 – Max data count
Binary Data	1 slot – 213 2 slot – 725 3 slot – 1237 SAT – 1097	Application data as specified by the ASM Identifier. The available length of the binary data is specified by the LinkConfigId.

B 6.6. MESSAGE 4: ADDRESSED MESSAGE

This ASM message is used to send data to an individual target, and does not contain a communication state. This message is used for non-periodic transmission of data, and access the link using RATDMA.

These transmissions require the destination station to return a message acknowledgment (Message 5). The destination station will use RATDMA to send the message acknowledgment. Addressed message is defined in Table 35.

Table 35 - Addressed message

Parameter	Number of bits	Description
Message ID	4	4 – Individually addressed message with no communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
Destination ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
ASM identifier	16	Application identifier and described in section 5.2
Data Count	11	1 – Max data count
Binary Data	1 slot – 254 2 slot – 766 3 slot – 1278 SAT – 1138	Application data as specified by the ASM Identifier. The available length of the binary data is specified by the LinkConfigId.

B 6.7. MESSAGE 5: ACKNOWLEDGMENT MESSAGE

This ASM message is used to return message acknowledgments to one or more addressed messages. Note that this message should always use Link Configuration Id of 8 (1/2 coding rate). Acknowledgement message is defined in Table 36.

Table 36 - Acknowledgment message

Parameter	Number of bits	Description
Message ID	4	5 – Multiple acknowledgment message with no communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
Destination ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
ACK/NACK Mask	16	Specifies which MITDMA block ids failed. Bit map field with the LSB representing Block id 1, the MSB representing Block Id 16. “1” indicates a packet failed “0” indicates the packet was received ok
Coding rate adaption request	2	0: Maintain MCS 1: Increment MCS (higher rate) 2: Decrease MCS 3: Reserved for future uses
Signal Quality Indicator	8	Received C/N0 in dBHz
Zero padding	As required	Padding bits are added as require to complete the block size.

B 6.8. MESSAGE 6: GEOGRAPHICAL MULTICAST MESSAGE

This ASM message is used to broadcast data to a group of stations as defined by the specified geographical area. The broadcast message does not contain a communication state. These broadcast messages are used for non-periodic transmission of data, and access the link using RATDMA. Geographical multicast message is defined in Table 37.

Table 37 - Geographical multicast message

Parameter	Number of bits	Description
Message ID	4	6 – Geographical addressed message with no communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
Longitude 1	18	Longitude of area to which the group assignment applies; upper right corner (north-east); in 1/10 min (±180°, East = positive, West = negative)
Latitude 1	17	Latitude of area to which the group assignment applies; upper right corner (north-east); in 1/10 min (±90°, North = positive, South = negative)
Longitude 2	18	Longitude of area to which the group assignment applies; lower left corner (south-west); in 1/10 min (±180°, East = positive, West = negative)
Latitude 2	17	Latitude of area to which the group assignment applies; lower left corner (south-west); in 1/10 min (±90°, North = positive, South = negative)
ASM identifier	16	Application identifier and described in section 5.2
Data Count	11	1 – Max data count
Binary Data	1 slot – 216 2 slot – 728 3 slot – 1240 SAT – 1100	Application data as specified by the ASM Identifier. The available length of the binary data is specified by the LinkConfigId.

B 6.9. MESSAGE 7: GROUP MULTICAST MESSAGE

This ASM message is used to broadcast data to a group of stations as defined by the specified geographical area. The broadcast message does not contain a communication state. These broadcast messages are used for non-periodic transmission of data, and access the link using RATDMA. Group multicast message is defined in Table 38.

Table 38 - Group multicast message

Parameter	Number of bits	Description
Message ID	4	7 – Group addressed message with no communication state
Retransmit flag	1	Indicates that this is a retransmission of data
Repeat Indicator	2	Used by the repeater to indicate how many times a message has been repeated. 0 - 3; 0 = default; 3 = do not repeat any more
Source ID	32	The Unique Identifier of the transmitting station as described in Annex 1 section 3.2
Group Destination ID	32	The Unique Identifier of a group of receiving
ASM identifier	16	Application identifier and described in section 5.2
Data Count	11	1 – Max data count
Binary Data	1 slot – 254 2 slot – 766 3 slot – 1278 SAT – 1138	Application data as specified by the ASM Identifier. The available length of the binary data is specified by the LinkConfigId.

ANNEX C TECHNICAL CHARACTERISTICS OF VDE-TERRESTRIAL IN THE MARITIME MOBILE BAND

C 1 INTRODUCTION

This section describes those elements of the VDE-TER that are unique to VDE-TER operation. For those elements that are common, the cross reference into Annex 1 is provided. It contains a description of the different protocols according to the OSI layer model and recommends implementation details for each layer.

Data transmission is made in the VHF maritime mobile band. Data transmissions are made within the spectrum allocated for the VDE1-A and VDE1- B. The spectrum may be used as 25 kHz, 50 kHz or 100 kHz channels.

The system should use TDMA techniques in a synchronized manner.

C 2 OSI LAYER

Refer to Annex A.

C 3 PHYSICAL LAYER

C 3.1. RANGE

The communication range of terrestrial VDE is typically 20−50 NM.

C 3.2. TRANSMITTER PARAMETER SETTINGS

Refer to Annex A for transmitter parameter settings for mobile stations.

C 3.3. ANTENNA

Terrestrial VDE may share the same antenna(s) with the other subsystems AIS, ASM,

Refer to Annex A.

C 3.4. MODULATION

C 3.4.1. WAVEFORMS

The waveforms are defined in Annex A, Modulation and Coding Schemes.

C 3.4.2. BIT MAPPING

For bit mappings, see Annex A.

C 3.5. SENSITIVITY AND INTERFERENCE

VDE uses adaptive modulation and coding to maximise spectral efficiency and throughput. Sensitivity and interference levels for the supported modulation methods are given in Table 39.

Table 39 - Sensitivity and Carrier to Interference Ratios

Modulation Coding Scheme	25 kHz		50 kHz		100 kHz	
	Sensitivity (dBm)	CIR (dB)	Sensitivity (dBm)	CIR (dB)	Sensitivity (dBm)	CIR (dB)
MCS-1*	−110	8	−107	8	−104	8
MCS-3*	−104	14	−101	14	−98	14
MCS-5*	−102	16	−99	16	−96	16

* Modulation Coding Schemes, see Table . This table assumes a BER of 1e-6.

C 3.6. SYMBOL TIMING ACCURACY

Refer to Annex A.

C 3.7. TRANSMITTER TIMING JITTER

Refer to Annex A.

C 3.8. SLOT TRANSMISSION ACCURACY AT THE OUTPUT

Refer to Annex A.

C 3.9. FRAME STRUCTURE

Refer to Annex A.

C 4 LINK LAYER

C 4.1. ACCESS SCHEMES

The VDE terrestrial system should support the following TDMA access schemes:

- FATDMA;
- ATDMA.

C 4.2. DATA ENCAPSULATION

Refer to Annex A.

C 4.3. CYCLIC REDUNDANCY CHECK

Refer to Annex A.

C 4.4. AUTOMATIC REPEAT REQUEST (ARQ)

Refer to Annex A.

C 4.5. ACKNOWLEDGEMENT (ACK)

Refer to Annex A.

C 4.6. END DELIVERY NOTIFICATION (EDN)

Refer to Annex A.

C 4.7. END DELIVERY FAILURE (EDF)

Refer to Annex A.

C 4.8. FRAME HIERARCHY

Refer to Annex A.

C 4.9. CHANNEL RESOURCE AND MEDIA ACCESS CONTROL FOR VDE TERRESTRIAL

VDE spectrum (and logical channel) resources are allocated by the reception of shore (or satellite-based) media access control messaging (for example, shore stations perform this operation using the bulletin board service). In the event of vessel reception of, both satellite and shore-based stations, the shore-based resource allocations should take precedence.

Duplexing modes are a function of the resource allocation above, as well as the operational mode.

C 4.9.1. SIMPLEX MODES

- Ship-to-ship

Same channel resource is used for both directions of communications.

C 4.9.2. DUPLEX MODES

- Shore-to-ship
- Ship-to-shore

Upper and lower spectrum are used for ship to shore or shore to ship respectively, only one side transmits at one time.

Refer to Annex A for details of frequency allocations.

C 4.10. PHYSICAL AND LOGICAL CHANNELS

VDES uses several channels to carry data. These channels are separated into Physical and Logical channels. A bulletin board may prescribe this channel usage.

Lacking bulletin board information, ship borne stations should employ a default channel configuration of 100 kHz channels on the terrestrial VDES (channel 2024, 2084, 2025 and 2085 combined) operating in a simplex ad-hoc access scheme. The simplex ad-hoc access scheme for ship-to-ship communications should be ATDMA.

C 4.11. PHYSICAL CHANNELS

The physical channels (PC) are determined by the centre frequency and bandwidth.

C 4.12. LOGICAL CHANNELS

The logical channels (LC) are divided into signalling and traffic channels. These are described below. Logical channel definitions can be defined based on the physical channel and message time information (frame hierarchy, start time, etc.).

C 4.12.1. SIGNALLING CHANNELS:

- Terrestrial Bulletin Board (TBB), see C 4.12.2.1
- Announcement, see C 4.12.2.2
- Random access, see C 4.12.2.5.

All signalling channels use the most robust modulation and coding scheme.

C 4.12.2. TRAFFIC CHANNELS:

- Multicast, see C 4.12.2.3
- Unicast, see C 4.12.2.4

- Random access, see C 4.12.2.5

Traffic channels may use a combination of robust and higher bitrate modulation and coding schemes.

C 4.12.2.1. Terrestrial bulletin board (TBB) signalling channel

Each VDE shore station should employ a fixed logical channel for the TBB. All TBB logical channels will be based on one of a number of predefined structures of the frame hierarchy 50 kHz shore to ship physical channel (2024 and 2084 combined). These are defined to occupy only a portion of the frame (60 seconds, 2 250 slots) to permit possible spectrum and temporal sharing with satellites, see Annex E.

The TBB defines the network configuration parameters such as signalling channels (control channels) and data channel(s), protocol versions and future network configuration. The TBB takes precedence in the allocation of spectrum (logical channel) resources. This may be co-ordinated with the satellite bulletin board signalling channel to facilitate sharing of mutual spectrum resources.

The logical channels are normally repeated based on the VDES frame hierarchy.

The VDE terrestrial channel usage for the service area of VDE shore station is defined by the TBB, see Annex A.

The TBB information includes the area of applicability. The TBB does not change often and should be transmitted in regular intervals.

C 4.12.2.2. Announcement signalling channel (ASC)

This channel(s) will normally carry announcements, MAC information, VDE forward and return resource allocation, CQIs, ARQs, and ACKs. Announcements also include the co-ordination of uni-cast and multi-cast (broadcast) datagrams.

The MAC information includes changes to network version, congestion control (randomization interval (hold-off) and minimum priority level). Some of these parameters will be reflected in the TBB on periodic basis.

The ASC logical channels will be assigned in the TBB and consist of a number of defined structures of the frame hierarchy 50 kHz shore to ship physical channel (2024 and 2084 combined). These are defined to occupy only a portion of the frame (60 seconds, 2 250 slots) to permit possible spectrum and temporal sharing with satellites, see Annex A.

The ASC defines the physical channel usage (logical channel, i.e. frequency and slot) to an individual ship following a resource request. The VDE shore station uses CQI information from the ship terminal to select the highest throughput format with adequate link margin.

C 4.12.2.3. Multicast data channel (MDC)

This traffic channel(s) is utilized to send messages to be received by a large number of ships. By default, multicast messages are addressed to all stations (i.e. broadcast).

C 4.12.2.4. Unicast data channel (UDC)

This traffic channel is allocated a specific ship for the duration of a unicast datagram.

This channel is set up after a ship responds to an announcement, and the response includes received channel quality information (CQI) allowing the shore station to maximise throughput.

C 4.12.2.5. Random access channel (RAC)

This channel has the characteristics of a slotted Aloha channel, uses a random access scheme and will be selected from a predefined list of logical channels.

C4.12.2.5.1 For ship-to-shore, and shore-to-ship communications

A ship station uses this channel to access the network or send a short message.

C4.12.2.5.2 For ship-to-ship when ships are within control area of a VDE shore station

A ship station uses this channel to communicate directly with other ships. This logical channel is allocated by shore station via TBB or ASC.

C4.12.2.5.3 For ship-to-ship when outside the control area of a shore VDE station

A ship station uses these channels to communicate with other ship stations directly via short message, and will also use these random access channels to co-ordinate communication with other ships for larger messages. These logical channels will be based on a number of predefined structures of the frame hierarchy of the ship-to-ship physical channels (2024, 2084, 2025 and 2085 combined). Ship-to-ship random access channels should have fixed physical channel assignments and use the most robust modulation and coding scheme. These logic channels are distinct from the TBB logical channels.

C 5 NETWORK LAYER

Refer to Annex A, assuming “Control Station” refers to a shore station.

C 6 TRANSPORT LAYER

Refer to Annex A.

ANNEX D TECHNICAL CHARACTERISTICS OF VDE-SAT SERVICE IN THE VHF MARITIME MOBILE BAND

D 1 INTRODUCTION

This section describes those elements of the VDE-SAT that are unique to VDE-SAT operation. For those elements that are common, the cross reference into Annex 1 is provided. In this context, the following types of functionality are envisaged:

- VDE-SAT allows two-way communications and transmit-only:
  - Shore initiated polling of information from ships (satellite-ship-satellite)
  - Ship initiated enquiry for information from shore (ship-satellite-ship)
  - Ship initiated data transfer to shore (ship-satellite)
  - Collection of information from transmit-only VDES terminals (ship-satellite). This could be either event driven or periodic. The slot and frequency band for this service should be assigned by the bulletin board and announcement signalling channels.
  - Downlink multicast multi-packet data transfer (satellite-ship)
  - Shore originated unicast multi-packet data transfer via satellite (satellite ship)

In this annex low earth orbit (LEO) satellites with 600 km altitude are considered to present typical examples of VDE satellite solutions. It should be noted that other orbital selections are also possible according to the overall system design consideration.

The focus of this annex is to describe the physical layer of the OSI model as defined in Annex A. The overall description of the link, network and the transport layers is provided in Annex A.

D 2 VDE-SAT PHYSICAL LAYER

D 2.1. VDE-SAT UPLINK KEY PARAMETERS

This section outlines assumptions regarding the VDE-SAT system parameters that are used as representative examples in this annex.

D 2.1.1. SATELLITE TO SURFACE DISTANCE RANGE

The orbit height determines the satellite range variations. For example, for a 600 km LEO the maximum range is 2 830 km. For timing purposes, a maximum range of 3 000 km will be used.

The minimum range is equal to the orbit height. For a LEO satellite at 600 km altitude the minimum range will be 600 km. This value is used to determine the minimum propagation delay time. Considering these exemplary values for the minimum and maximum ranges, the path delay will vary from 2 ms to 10 ms, a variation of 8 ms as shown in Figure 37 and Figure 38.

For the VDE-SAT downlink, in addition to the relative delays between signal receptions at a vessel from different satellites, there could be absolute delay due to other sources such as signal processing delay. The satellite service provider should pre-compensate for absolute delay.

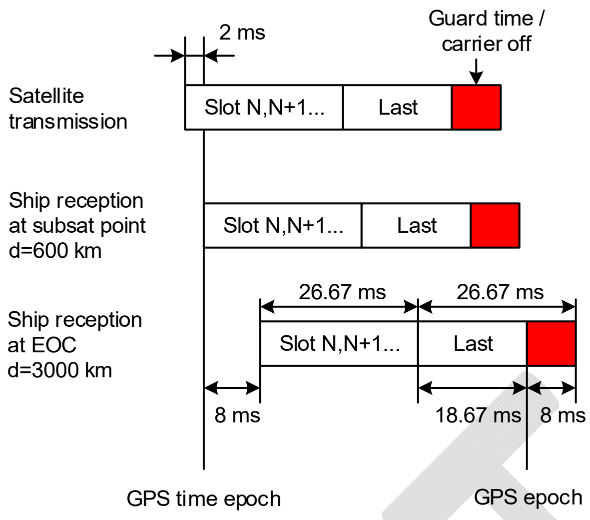

Figure 37. *VDE-SAT downlink timing*

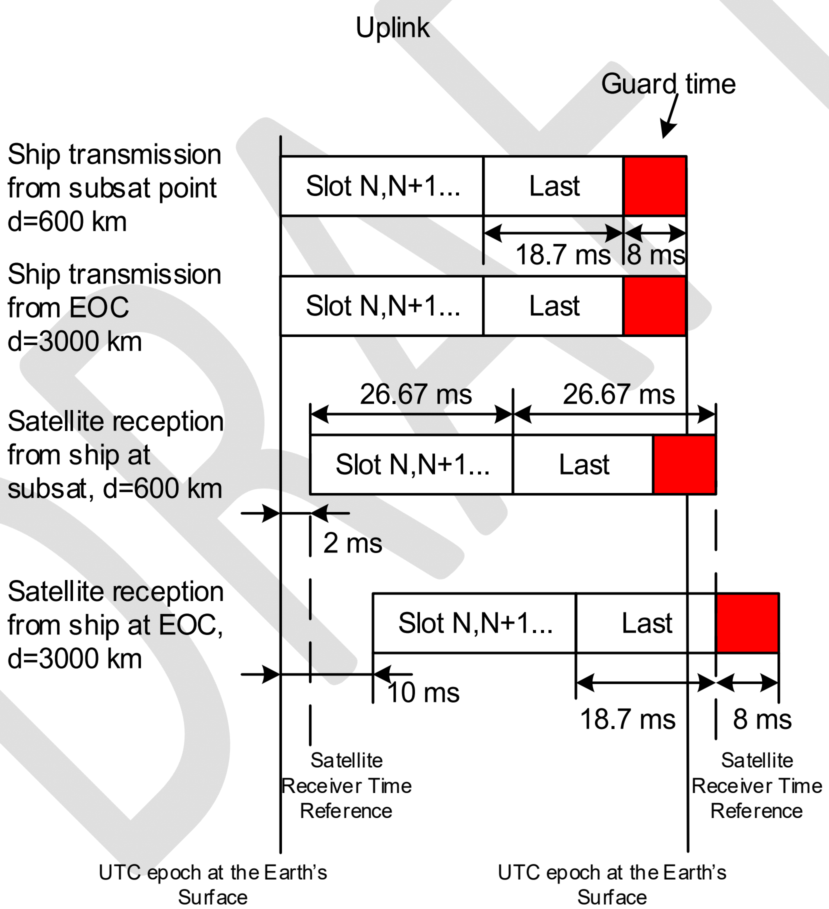

Figure 38. *VDE-SAT Uplink timing*

D 2.1.2. SATELLITE TRANSMISSION CARRIER FREQUENCY ERROR

The satellite transmission carrier frequency error is the sum of the satellite transmission frequency error and Doppler, and the frequency uncertainty at the receiver. The transmit frequency error at the satellite shall be less than 1 ppm, i.e. ±160 Hz.

A LEO satellite will move at a speed of about 8 km/s and this will cause a maximum Doppler of ±4 kHz at VHF.

D 2.1.3. SHIP STATION TRANSMITTER REQUIREMENTS

For ship station transmitter requirements, see Annex A.

D 2.1.4. SHIP STATION ANTENNA GAIN

For ship station antenna gain, see Annex A.

D 2.1.5. SHIP STATION NOISE PLUS INTERFERENCE LEVEL

For noise plus interference level of ship station, see Annex A.

D 2.2. LINK BUDGET ANALYSIS

The link C/N_0 is determined by the transmitted e.i.r.p., path losses, propagation losses, receiver sensitivity/figure of merit and local interference levels.

D 2.2.1. VDE-SAT DOWNLINK LINK BUDGET

Examples of link budgets for the VDE-SAT downlink are provided in the following sections.

D 2.2.1.1. Satellite downlink e.i.r.p.

The e.i.r.p. can be derived from PFD mask given in Table 40.

Table 40 - Proposed power spectral and PFD mask

$$\theta° = earth - satellite\ elevation\ angle$$

$$PFD(\theta°)_{(\text{dBW}/(\text{m}^2 * 4\ \text{kHz}))} = \begin{cases} -149 + 0.16 * \theta° & 0° \leq \theta < 45°; \\ -142 + 0.53 * (\theta° - 45°) & 45° \leq \theta < 60°; \\ -134 + 0.1 * (\theta° - 60°) & 60° \leq \theta \leq 90°. \end{cases}$$

Table 41 shows the theoretical maximum satellite e.i.r.p. as a function of elevation angles for this mask.

Table 41 - Satellite maximum e.i.r.p. vs. elevation angle

Ship Elevation angle θ (degrees)	Powerflux density on ground (dBW/m²/4 kHz)	Satellite range (km)	Maximum downlink satellite e.i.r.p. (dBW in 25 kHz)
0	−149.0	2 831	−1.0
10	−147.4	1 932	−2.7
20	−145.8	1 392	−4.0
30	−144.2	1 075	−4.6
40	−142.6	882	−4.7
50	−139.4	761	−2.8
60	−134.0	683	1.6
70	−133.0	635	2.0
80	−132.0	608	2.6
90	−131.0	600	3.5

D 2.2.1.2. Satellite e.i.r.p. vs. elevation

Most of the satellite coverage area and visibility time will be at low elevation angles, and high elevation angle coverage may be sacrificed without significant system capacity loss.

The following two satellite antennas have been analysed and are acceptable.

1) Yagi Antenna: For this antenna, the link budget is optimised for 0 degrees ship elevation angle using a three element Yagi antenna with the satellite pointed at the horizon is given in Table A4-3. Assuming a peak antenna gain of 8 dBi, a transmit RF power of −12.4 dBW in 25 kHz will ensure compliance with the PFD limit. Satellite e.i.r.p. vs. ship elevation is shown in Table 42.

Table 42 - Satellite e.i.r.p. vs. elevation using a Yagi antenna

Ship elevation angle (degrees)	Nadir offset angle (degrees)	Boresight offset (degrees)	Satellite antenna gain (dBi)	Satellite e.i.r.p. in circular polarization (dBW)	Satellite range (km)	PFD dBW/m²/4 (kHz)	Table A4-1 PFD limit dBW/m²/ (4 kHz)	PFD margin (dB)
0	66.1	0	8	−4.4	2 830	−152.4	−149.0	3.4
10	64.2	1.9	8	−4.4	1 932	−149.1	−147.4	1.7
20	59.2	6.9	8	−4.4	1 392	−146.2	−145.8	0.4
30	52.3	13.8	7.8	−4.6	1 075	−144.2	−144.2	0.0
40	44.4	21.7	6.9	−5.5	882	−143.4	−142.6	0.8
50	36	30.1	5.5	−6.9	761	−143.5	−139.4	4.1
60	27.2	38.9	3.6	−8.8	683	−144.5	−134.0	10.5
70	18.2	47.9	0.7	−11.7	635	−146.7	−133.0	13.7
80	9.1	57	−2.2	−14.6	608	−149.2	−132.0	17.2
90	0	66.1	−5.5	−17.9	600	−152.4	−131.0	21.4

2) Isoflux antenna: This antenna is designed to point at the nadir direction providing a symmetric radiation pattern around the pointing direction. Assuming a peak antenna gain of 2 dBi, a transmit RF power of −5 dBW in 25 kHz will ensure compliance with the PFD limit. Satellite e.i.r.p. vs. ship elevation is shown in Table 43.

Table 43 - Satellite e.i.r.p vs. elevation using an isoflux antenna

Ship elevation angle (degrees)	Nadir offset angle (degrees)	Boresight offset (degrees)	Satellite antenna (gain dBi)	Satellite e.i.r.p. in circular polarization (dBW)	Satellite range (km)	PFD dBW/m²/4 (kHz)	Table A4-1 PFD limit dBW/m²/4 (kHz)	PFD margin (dB)
0	66.1	0	2	−3.0	2 830	−151.0	−149.0	2.0
10	64.2	1.9	1.5	−3.5	1 932	−148.2	−147.4	0.8
20	59.2	6.9	1	−4.0	1 392	−145.8	−145.8	0.0
30	52.3	13.8	−0.5	−5.5	1 075	−145.1	−144.2	0.9
40	44.4	21.7	−2	−7.0	882	−144.9	−142.6	2.3
50	36	30.1	−4	−9.0	761	−145.6	−139.4	6.2
60	27.2	38.9	−5	−10.0	683	−145.7	−134.0	11.7
70	18.2	47.9	−7	−12.0	635	−147.0	−133.0	14.0
80	9.1	57	−8	−13.0	608	−147.6	−132.0	15.6
90	0	66.1	−8.5	−13.5	600	−148.0	−131.0	17.0

D 2.2.1.3. Link $C/(N_0+I_0)$

The nominal signal level and $C/(N_0+I_0)$ vs. elevation for a 25 kHz channel are provided in Table 42 and Table 43 for Yagi and Isoflux on-board antennas. The assumed ship antenna gain is 3 dBi and the system noise temperature is 30.2 dBK as shown in Table 11.

Because the downlink is PFD limited, increasing the channel bandwidth to 50 kHz or 100 kHz will increase the signal level and $C/(N_0+I_0)$ by 3 and 6 dB respectively. Limiting the service area to ship elevation angles between 10 and 55 degrees also improves the link margin by 3 dB.

The Isoflux antenna improves the link budget at low elevation angles and provides a wider symmetrical coverage area, but requires a 5 times larger transmitter power on the satellite.

The link budget results with a satellite Yagi antenna is shown in Table 44. Isoflux antenna is shown in Table 45.

It should be noted that the analyses based on single satellite visibility.

Table 44 - Link budget with satellite Yagi antenna (transmit RF power = −12.4 dBW/25 kHz)

Ship elevation angle (degrees)	Satellite EIRP in circular polarization (dBW)	Satellite range (km)	Path loss (dB)	Polarization loss (dB)	Ship antenna gain (dBi)	Antenna signal level (dBm)	C/N_0 (dBHz)	Noise level in 25 kHz BW (dBm)	$C/(N_0+I_0)$ (dBHz)
0	−4.4	2 830	145.6	3	3	−120.0	48.4	−116	40.0
10	−4.4	1 932	142.2	3	3	−116.7	51.7	−116	43.3
20	−4.4	1 392	139.4	3	2.5	−114.3	54.1	−116	45.7
30	−4.6	1 075	137.2	3	1	−113.8	54.6	−116	46.2
40	−5.5	882	135.4	3	0	−114.0	54.4	−116	46.0
50	−6.9	761	134.2	3	−1.5	−115.6	52.8	−116	44.4
60	−8.8	683	133.2	3	−3	−118.0	50.4	−116	41.9
70	−11.7	635	132.6	3	−4	−121.3	47.1	−116	38.7
80	−14.6	608	132.2	3	−10	−129.8	38.6	−116	30.2
90	−17.9	600	132.1	3	−20	−143.0	25.4	−116	17.0

Table 45 - Link budget using Isoflux antenna (transmit RF power = −5.0 dBW/25 kHz)

Ship elevation angle (deg)	Sat. EIRP (dBW)	Path loss (dB)	Pol. loss (dB)	Ship antenna gain (dBi)	Ship G/T (dB/K)	C/N_0 no interference (dBHz)	Antenna level (dBm)	Noise level in 25 kHz (dBm)	$C/(N_0+I_0)$ (dBHz)
0	−3.0	145.6	3	3	−27.2	49.8	−118.6	−116	41.4
10	−3.5	142.2	3	3	−27.2	52.7	−115.7	−116	44.2
20	−4.0	139.4	3	2.5	−27.7	54.5	−113.9	−116	46.1
30	−5.5	137.2	3	1	−29.2	53.7	−114.7	−116	45.3
40	−7.0	135.4	3	0	−30.2	53.0	−115.4	−116	44.5
50	−9.0	134.2	3	−1.5	−31.7	50.7	−117.7	−116	42.3
60	−10.0	133.2	3	−3	−33.2	49.2	−119.2	−116	40.8
70	−12.0	132.6	3	−4	−34.2	46.8	−121.6	−116	38.4
80	−13.0	132.2	3	−10	−40.2	40.2	−128.2	−116	31.8
90	−13.5	132.1	3	−20	−50.2	29.8	−138.6	−116	21.4

D 2.2.2. VDE-SAT UPLINK LINK BUDGET

Examples of link budgets for the VDE-SAT uplink are provided in the following sections.

D 2.2.2.1. Ship station e.i.r.p. vs. elevation angle

For ship station e.i.r.p vs elevation angle, see Annex A.

D 2.2.2.2. Satellite antenna gain

Table 46 presents the gain of a 3-element Yagi satellite antenna with a peak gain of 8 dBi as a function of elevation angle.

Table 46 - Satellite antenna gain vs. ship elevation angle

Ship elevation angle (deg)	Nadir offset angle (deg)	Boresight offset angle (deg)	Satellite antenna gain (dBi)
0	66.1	0	8
10	64.2	1.9	8
20	59.2	6.9	8
30	52.3	13.8	7.8
40	44.4	21.7	6.9
50	36	30.1	5.5
60	27.2	38.9	3.6
70	18.2	47.9	0.7
80	9.1	57	−2.2
90	0	66.1	−5.5

D 2.2.2.3. Satellite system noise temperature

The satellite noise level at the receiver input is shown in Table 47. Without external interference, the system noise temperature is 25.7 dBK.

Table 47 - Satellite receiver system noise temperature

Antenna noise temperature	200.0	ºK
Feed losses	1.0	dB
LNA noise figure	2.0	dB
LNA noise temperature	159.7	ºK
Feedloss noise temp. at LNA	56.1	ºK
Antenna noise temp. at LNA	158.9	ºK
System noise temp. at LNA	374.7	ºK
System noise temp. at LNA	25.7	dBK

D 2.2.2.4. Uplink C/N_0

The baseline uplink link budget is given in Table 48. It is optimised for 0 degree ship elevation angles.

It can be seen from Table 48 that the C/N_0 is better than 74 dBHz for ship elevation angles between 0 and 65 degrees.

Table 48 - VDE-SAT Uplink link budget, 6 W ship transmit power

Ship elevation angle (deg)	Ship antenna gain (dBi)	Ship e.i.r.p. (dBW)	Polarization loss (dB)	Range (km)	Path loss (dB)	Satellite antenna gain (dBi)	Satellite G/T (dB/K)	C/N_0 (dBHz)
0	3	10.8	3	2 830	145.56	8	−17.6	73.2
10	3	10.8	3	1 932	142.25	8	−17.6	76.5
20	2.5	10.3	3	1 392	139.40	8	−17.6	78.9
30	1	8.8	3	1 075	137.16	7.8	−17.8	79.4
40	0	7.8	3	882	135.44	6.9	−18.7	79.2
50	−1.5	6.3	3	761	134.16	5.5	−20.1	77.6
60	−3	4.8	3	683	133.22	3.6	−22	75.2
70	−4	3.8	3	635	132.58	0.7	−24.9	71.9
80	−10	−2.2	3	608	132.21	-2.2	−27.8	63.4
90	−20	−12.2	3	600	132.09	-5.5	−31.1	50.2

D 2.2.3. PROPAGATION EFFECTS

The received signal level on-board a ship will vary due to a number of factors as shown in Table . A Rice distribution with a carrier to multipath (*C/M*) ratio of 10 dB and fading bandwidth of 3 Hz is assumed (see Figure 39), however the system shall be adaptable to handle significantly worse and better propagation conditions. Mid-latitude fade depths due to ionospheric scintillation are shown in Table 50.

Table 49 - Ionospheric effects for elevation angles of about 30° one-way traversal (derived from Recommendation ITU-R P.531)

Effect	Frequency dependence	0.1 GHz	0.25 GHz	1 GHz
Faraday rotation	$1/f^2$	30 rotations	4.8 rotations	108°
Propagation delay	$1/f^2$	25 µs	4 µs	0.25 µs
Refraction	$1/f^2$	< 1°	< 0.16°	< 0.6′
Variation in the direction of arrival (r.m.s.)	$1/f^2$	20′	3.2′	12″
Absorption (auroral and/or polar cap)	$\approx 1/f^2$	5 dB	0.8 dB	0.05 dB
Absorption (mid-latitude)	$1/f^2$	< 1 dB	< 0.16 dB	< 0.01 dB
Dispersion	$1/f^3$	0.4 ps/Hz	0.026 ps/Hz	0.0004 ps/Hz
Scintillation (1)	See Rec. ITU-R.P.531	See Rec. ITU-R P.531	See Rec. ITU-R P.531	> 20 dB peak-to-peak

* This estimate is based on a TEC of 1 018 electrons/m², which is a high value of TEC encountered at low latitudes in day-time with high solar activity.

(1) Values observed near the geomagnetic equator during the early night-time hours (local time) at equinox under conditions of high sunspot number.

Table 50 - Mid-latitude fade depths due to ionospheric scintillation (dB)

Percentage of time (%)	Frequency (GHz)			
	0.1	0.2	0.5	1
1.0	5.9	1.5	0.2	0.1
0.5	9.3	2.3	0.4	0.1
0.2	16.6	4.2	0.7	0.2
0.1	25.0	6.2	1.0	0.3

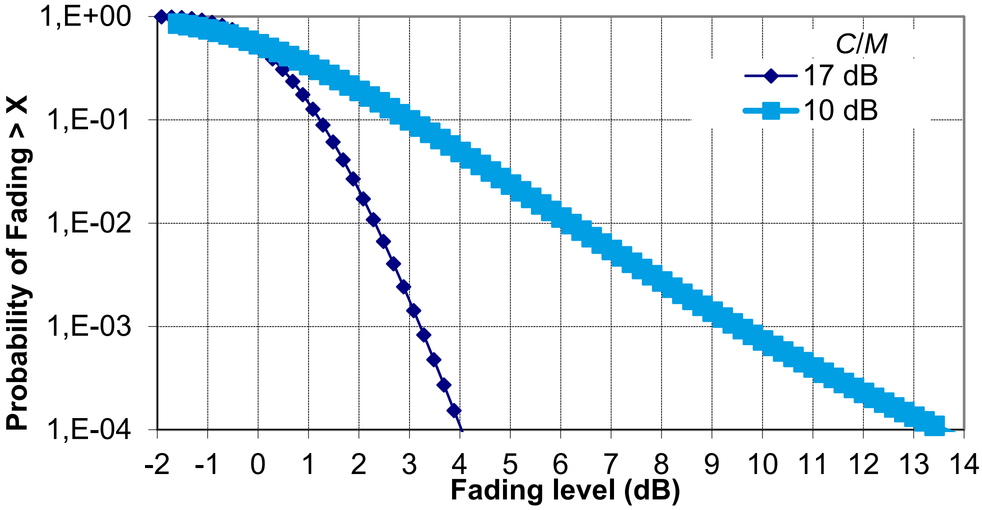

Figure 39. Ricean fade depth probability

D 2.3. PROTECTION OF THE RADIO ASTRONOMY SERVICE IN THE 150.05-153 MHZ BAND FROM HARMFUL INTERFERENCE FROM THE VDE-SAT DOWNLINK

An appropriate protection limit for Radio Astronomy service in the 150.05-153.0 MHz band would be −238 dBW/m^2 in a 2.95 MHz bandwidth centred around 152 MHz. Accordingly, the maximum VDE-SAT downlink emission in the 150.05-153 MHz band should be below values shown in Table 51.

Table 51 - Maximum satellite unwanted emissions in the 150.05-153 MHz band

Ship elevation angle (deg)	RAS limit (W/m^2/ 2.95 MHz)	Range (km)	Sat. max. interference e.i.r.p.		
			(W)	(dBW)	(dBW/Hz)
0	1.58E-24	2830	1.60E-10	−97.97	−162.67
10	1.58E-24	1932	7.43E-11	−101.29	−165.99
20	1.58E-24	1392	3.86E-11	−104.14	−168.83
30	1.58E-24	1075	2.30E-11	−106.38	−171.08
40	1.58E-24	882	1.55E-11	−108.10	−172.80
50	1.58E-24	761	1.15E-11	−109.38	−174.08
60	1.58E-24	683	9.29E-12	−110.32	−175.02
70	1.58E-24	635	8.03E-12	−110.95	−175.65
80	1.58E-24	608	7.36E-12	−111.33	−176.03
90	1.58E-24	600	7.17E-12	−111.44	−176.14

D 2.4. BIT MAPPING

For bit mappings, see Annex A.

D 2.5. SPREAD SPECTRUM WITH CONSTANT ENVELOPE

Direct sequence spreading with constant envelope can be implemented according to the spreading strategy [RD-3]. This provides a way to generate constant envelope signals whilst allowing the use of linear modulations (i.e. BPSK, or QPSK for data modulation). In this approach, the CPM spreading sequences are selected such that the spread symbols maintain quasi continuous phase even at the transition from one symbol to the next. The CPM spreading principle is provided in Figure 40.

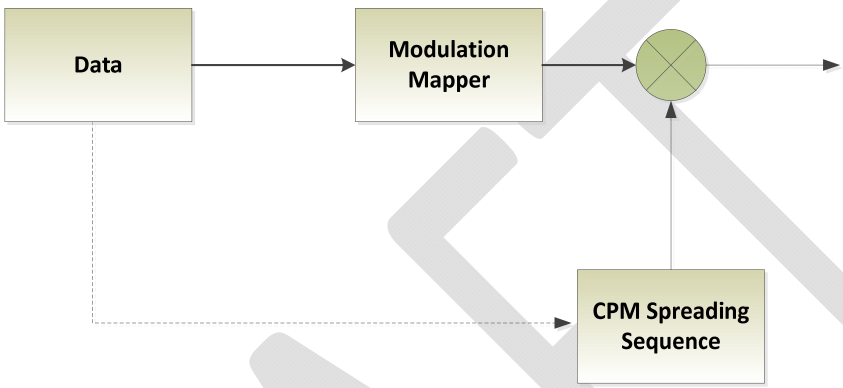

Figure 40. CPM Spreading Principle

In order to avoid phase discontinuity at the data symbol transitions, the proposed solution is to adapt the spreading sequence to the modulation data. In other words, the CPM spreading sequence at the edge of each symbol is adapted according to the new input modulation symbol value to avoid any phase discontinuity. Such a solution produces a small loss at the receiver as the receiver does not know the edge symbol part of the used CPM spreading sequence. For a spreading factor of 16 or higher, the resulting correlation loss experienced by the receiver due to this issue is less than 0.25 dB. Performance losses with respect to conventional spreading is thus quite negligible provided that SF = 16 or larger is used.

The CPM spreading sequences are computed and optimized off-line and then stored in the memory of the terminals and receivers. A single spreading code is sufficient for all the users in the system. There is thus no need for storing multiple spreading sequences but just a single spreading sequence.

The stored spreading sequence is then applied starting from the preamble and continuing in the data part (as shown in Figure 41). It should be noted that the actual spreading sequence is actually partly dependent on the modulation symbols in order to ensure continuity of the signal phase when the modulation symbol changes (Figure 40). The spread samples are computed on the basis of the current modulation symbol and previous modulation symbol. For QPSK modulation there are 4 possible values for the phase difference of these two symbols. An index from 0 to 3 can point to the possible phase differences and is used to address which of 4 possible spreading sequences is actually used for computing the output signal. Figure 42 illustrates the power spectral properties of the proposed modulation scheme (with spreading factor 16). Due to its constant envelope properties, this modulation scheme can operate with a transmit power amplifier operating close to saturation while maintaining a low power leakage to adjacent channels.

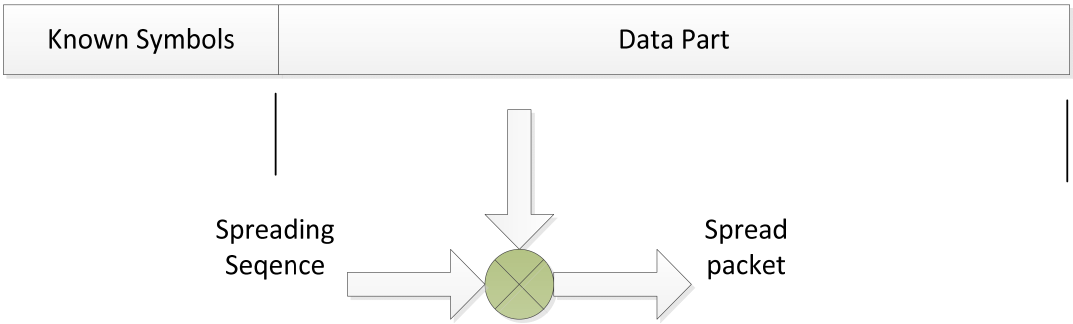

Figure 41. Proposed Spreading in the CPM

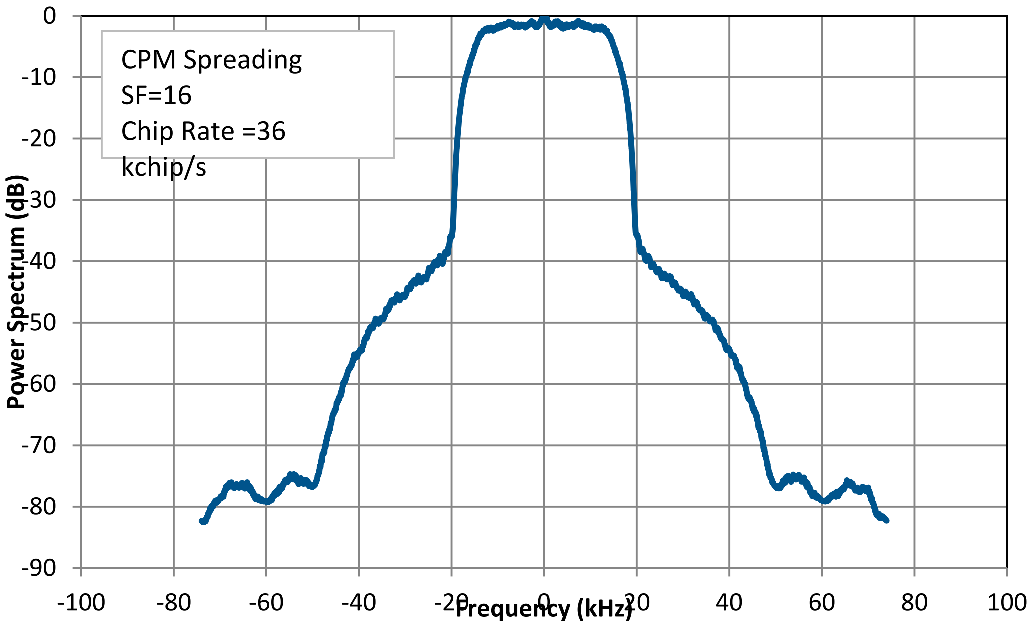

Figure 42. Power spectral properties of spread spectrum with constant envelope

D 2.6. BASEBAND SHAPING AND QUADRATURE MODULATION

For baseband shaping of symbols, see Annex A.

D 2.7. TRANSMISSION TIMING ACCURACY

For transmission accuracy figures, see Annex A.

D 2.8. HALF DUPLEX AND FULL DUPLEX SATELLITES

The system can be configured for both half and full duplex satellites as shown in Figure 43.

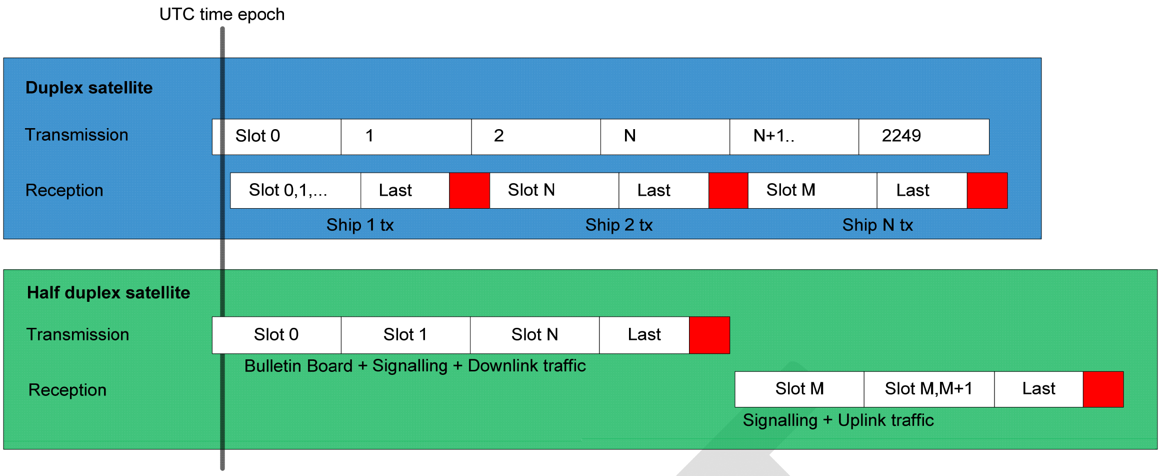

Figure 43. Half-duplex and full duplex satellite operation

D 2.9. FRAME STRUCTURE

For frame and transmission burst structure, see Annex A.

D 2.10. FORWARD ERROR CORRECTION AND INTERLEAVING

For forward error correction and interleaving, see Annex A.

D 2.11. VDE-SAT LINK CONFIGURATION FORMATS

For link configurations available for the VDE-SAT uplink and downlink, see Annex A.

D 2.12. VDE-SAT DOWNLINK BLOCK CHANNEL INTERLEAVER

A block channel interleaver is considered on the VDE-SAT downlink in order to reduce the impact of the channel short blockage (for example due to the AIS transmission from the vessel or fast fading events). The channel interleaver is applied to the code-words at the output of the encoder.

The interleaver can be applied on data blocks by column permutation (as long as the number of columns can be made as an integer power of 2). The interleaver memory in this case (from the point of view of the transmitter) is written by row and read by columns after having applied an inter-column permutation. The proposed column permutation is resulting from reading the column index in the reverse order (bit shuffling), i.e. the column with index i5 i4, i3 i2, i1, i0 become the column i0, i1,i2, i3, i4, i5, where i0, i1 i2 i3 i4 and i5 are the bits representing a given number.

In more general cases (where the number of columns is not an integer power of 2), the interleaver index can be made available as table-lookup.

D 3 VDE-SAT LINK LAYER

For description of the link layer, see Annex A.

D 4 NETWORK LAYER

For description of the network layer, see Annex A.

D 5 TRANSPORT LAYER

For description of the transport layer, see Annex A.

ANNEX E RESOURCE SHARING METHOD FOR VDES TERRESTRIAL AND SATELLITE SERVICES

E 1 INTRODUCTION

This annex describes how resource sharing (i.e. in time and frequency) for utilizing the VHF spectrum available between different VDES services and stations should be accomplished.

A ship may be within range of multiple controlling shore stations. This annex describes a method for coordinating time and frequency resources between multiple controlling shore stations, particularly the use of bulletin boards and announcement signalling channels, as defined in Annexes A and C.

The VDE-SAT is an effective means to extend the VDES to areas outside of coastal VHF coverage. However, due to the large footprint of satellite, the VDE-SAT downlink signal may interfere with VDE-TER in the coastal areas when satellite is in visibility. Similarly, the terrestrial ship-to-shore VDE signals can interfere with the satellite reception of VDE-SAT uplink when a VDE Satellite is in the field of view. The method described in this annex for resource sharing is derived based on the characteristics of VDE-TER and VDE-SAT, particularly the use of bulletin board and announcement signalling channels, as defined in Annexes A, B and C.

The channels 24, 84, 25, 85, 26 and 86 are allocated for VDE, with the lower leg frequencies used for ship-to-shore and the upper leg frequencies used for shore-to-ship and ship-to-ship. The channels 2027 (ASM 1) and 2028 (ASM 2) are allocated for ASM. Currently, 2 alternative frequency utilization plans for VDES are under consideration. They describe how resources are allocated and shared between VDE-TER, VDE-SAT and ASM. These 2 alternative frequency utilization plans are illustrated in Figure 44, and described further in this section.

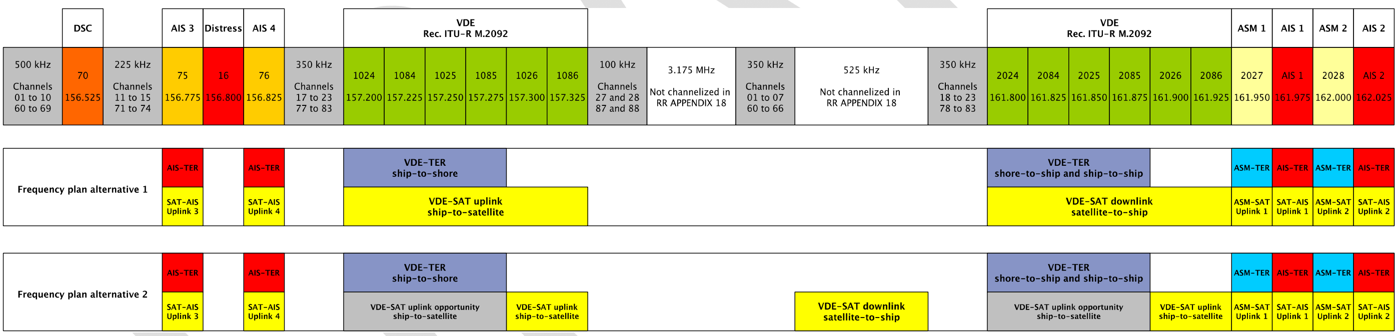

Figure 44 - RR APPENDIX 18 and VDES frequency utilization plans

E 1.1 FREQUENCY PLAN ALTERNATIVE 1

Frequency plan alternative 1 allow for utilization of the channels 24, 84, 25, 85, 26 and 86 in a shared manner between VDE-TER and VDE-SAT.

- The four channels 1024, 1084, 1025 and 1085 are shared between ship-to-shore and ship-to-satellite (VDE-SAT uplink) services
- The two channels 1026 and 1086 are exclusively reserved for ship-to-satellite (VDE-SAT uplink) services
- The four channels 2024, 2084, 2025 and 2085 are shared among shore-to-ship, ship-to-ship and satellite-to-ship (VDE-SAT downlink) services
- The two channels 2026 and 2086 are exclusively reserved for satellite-to-ship (VDE-SAT downlink) services.
- Two channels 2027(ASM 1) and 2028 (ASM 2) are shared between ship-to-shore, ship-to-ship, shore-to-ship and ship-to-satellite services

E 1.2 FREQUENCY PLAN ALTERNATIVE 2

Frequency plan alternative 2 allow for utilization of channels 24, 84, 25 and 85 primarily for VDE-TER, while channels 26 and 86 exclusively reserved for VDE-SAT uplink. VDE-SAT uplink is also possible in channels 24, 84, 25 and 85, but the VDE-SAT uplink in these channels do not impose constraints on VDE-TER. Frequencies are exclusively reserved for VDE-SAT downlink within the frequency range 160.9625 MHz to 161.4875 MHz, which is not channelized in RR Appendix 18.

- The four channels 1024, 1084, 1025 and 1085 are reserved for ship-to-shore services, but ship-to-satellite (VDE-SAT uplink) services are possible without imposing constraints on ship-to-shore services
- The four channels 2024, 2084, 2025 and 2085 are reserved for shore-to-ship and ship-to-ship services, but ship-to-satellite (VDE-SAT uplink) services are possible without imposing constraints on shore-to-ship and ship-to-ship services
- The four channels 1026, 1086, 2026 and 2086 are exclusively reserved for ship-to-satellite (VDE-SAT uplink) services.
- Frequencies are exclusively reserved for satellite-to-ship (VDE-SAT downlink) services within the frequency range 160.9625 MHz to 161.4875 MHz, which is not channelized in RR Appendix 18
- Two channels 2027(ASM 1) and 2028 (ASM 2) are shared between ship-to-shore, ship-to-ship, shore-to-ship and ship-to-satellite services

E 2 VDES RESOURCE SHARING PRINCIPLES

E 2.1 AIS PRIORITY

Understanding that when transmissions occurs a VDES mobile station with a single antenna will suffer decreased receiver sensitivity, care must be taken to respect the AIS transmission and reception as the highest priority.

E 2.2 COORDINATION BETWEEN ASM AND VDE

VDE ship transmissions should be coordinated with transmissions on the ASM channels to ensure that ASM messages with new safety and navigational related information can be received.

E 2.3 SHORE STATION VDES CONTROL AREA

The VDES resource assignments in the proximity of a shore station is monitored and controlled by a shore station. Shore stations utilize terrestrial bulletin board (TBB) and announcement signalling channels (ASC) to coordinate the resource assignment within the control area. The shore station may incorporate information regarding VDE satellite communications within the TBB and ASC. The shore station may acquire the VDE satellite information directly from the VDE-Satellite downlink (the satellite bulletin board and ASC) or in coordination with the satellite service providers.

There are dedicated slots and frequency bands for TBB and ASC that are reserved to communicate the required information to each vessel in the control area of a shore station. The default (or initial) assignment are described in Annex E 4.

E 2.4 VDE-SAT RESOURCE ASSIGNMENT

Each satellite should use bulletin board and announcement channels (as defined in Annexes A and C) to communicate the VDE-SAT resource assignments (both downlink and uplink) to vessels in the coverage area.

There are dedicated slots and frequency bands for the satellite bulletin board and announcement channels that are reserved to communicate the required information to each vessel in the field of view of a satellite.

Since the satellite coverage may include several shore station control areas, the VDE-SAT resource assignment should respect all requirements of shore control areas that are within the field of view at any given time. Within each satellite orbit the information regarding the resource assignment should be updated according to the shore station control areas in the satellite field of view.

A default (or initial) VDE-SAT resource allocation is defined Annex E 4 to serve as the starting point for the resource sharing.

E 3 VDE-TER RESOURCE SHARING BETWEEN MULTIPLE CONTROLLING SHORE STATIONS

The allocation of frequency and time slots used for the bulletin board announcement must be coordinated between controlling stations. Other resource assignments are managed based on the content of the bulletin board and announcement signalling channels. The assignment may change dynamically (according to temporal demands).

There are dedicated resources in channel 2024 and 2084 that are assigned to the terrestrial bulletin board and announcement channels, as described in Annexes A and C.

Channels 2024, 2084, 2025 and 2085 are shared between multiple controlling stations. The resource sharing must be coordinated between shore station operators. This coordination can be done either directly between the operators or rely on the bulletin board and announcement channels of the shore stations, depending on the shore control areas, the resource assignment may vary. As an initial configuration for resource sharing, the controlling shore stations should adopt a static assignment in time and frequency.

E 4 VDE-TER AND VDE-SAT DOWNLINK RESOURCE SHARING

E 4.1 RESOURCE SHARING WITH FREQUENCY PLAN ALTERNATIVE 1

With frequency plan alternative 1, the channels 2026 and 2086 are dedicated to VDE-SAT downlink. Within these exclusive VDE-SAT channels, there are dedicated time slots that are assigned to the satellite bulletin board and announcement signalling channels as described in Annexes A and C. Other slot assignments in the exclusive VDE-SAT frequency bands are managed based on the content of the bulletin board and announcement signalling channels. The assignment may change dynamically (according to the satellite coverage or temporal demands).

Channels 2024, 2084, 2025 and 2085 are shared between VDE-SAT Downlink and VDE-TER. Depending on the satellite coverage area and the shore control areas, the resource assignment may vary.

There are dedicated time slots in channel 2024 and 2084 that are assigned to the terrestrial signalling channel and terrestrial bulletin board, as described in Annexes A and C. These slots should not be used by VDE-SAT downlink when a VDE shore station is within the satellite coverage area.

A shore station may assign the full resources of channels 2024, 2084, 2025 and 2085 for terrestrial services when there is no transmitting VDE satellite in the field of view.

When a transmitting VDE satellite is in the field of view the resource sharing between VDE-SAT downlink and VDE shore-to-ship and ship-to-ship must be coordinated between the shore operator and the satellite operator. This coordination can be done either directly between the operators or rely on the bulletin board and announcement channels of the satellite and shore stations. As an initial configuration for resource sharing, a static assignment in time and frequency should be adopted by the terrestrial and satellite entities.

- Channels 2024 and 2084 are exclusively used for terrestrial VDE, maintaining the original signalling assignment that was described above
- Channels 2026 and 2086 are exclusively used for VDE-SAT downlink, maintaining the original signalling assignment that was described above

- Channels 2025 and 2085 are time-shared between VDE-SAT downlink and VDE terrestrial services. The time sharing is based on time intervals of 2.4 s (90 slots) that are assigned periodically to VDE-SAT and VDE terrestrial services

As the starting point of VDES resource sharing or in the absence of coordination between the shore and satellite operation, this resource sharing method should be used.

Coordination of resource sharing between VDE ship-to-ship and VDE-SAT downlink for areas not controlled by a VDE shore station is managed by the VDE-SAT bulletin board, as described in Annex D. As a starting point for this resource sharing or in the absence of any VDE-SAT bulletin board, the resource sharing method described above should be used.

E 4.2 RESOURCE SHARING WITH FREQUENCY PLAN ALTERNATIVE 2

With frequency plan alternative 2, the frequency band from 160.9625 MHz to 161.4875 MHz is dedicated to VDE-SAT downlink. The frequencies in this band are not channelized in RR APPENDIX 18. Within this exclusive VDE-SAT band, there are dedicated channels and time slots that are assigned to the satellite bulletin board and announcement signalling channels as described in Annexes A and D. Other slot assignments in this exclusive VDE-SAT frequency band are managed based on the content of the bulletin board and announcement signalling channels. The assignment may change dynamically (according to the satellite coverage or temporal demands).

E 5 SHARING BETWEEN DIFFERENT VDE SATELLITE SYSTEMS

The sharing between two or more satellite systems is coordinated between the satellite operators and organized through the bulletin board, delivered by satellites in VDE-SAT downlink band, as described in Annexes A and D. Ships use the satellite bulletin boards for channel and resource configuration.

The waveform used for the bulletin board should allow for detection of overlapping signals received from multiple satellites. The use of direct sequence spreading as defined in Annex D, allows for detection of up to 8 overlapping satellite signals.

E 6 VDE-TER AND VDE-SAT UPLINK RESOURCE SHARING

E 6.1 RESOURCE SHARING WITH FREQUENCY PLAN ALTERNATIVE 1

With frequency plan alternative 1, the lower frequency bands, channel 1026 and 1086 are dedicated to VDE-SAT uplink while channels 1024, 1084, 1025 and 1085 are shared between VDE-TER and VDE-SAT.

The exclusive VDE-SAT uplink channels may be used for dedicated (demand assigned) or random access to satellite. Since there is no VDE terrestrial interference on these two channels, these channels should be used for higher priority message (safety, distress, acknowledgement, etc.).

Through the bulletin board, a shore station may assign the full resources of channels 1024, 1084, 1025 and 1085 for terrestrial services when there is no receiving VDE satellite in the field of view.

When a transmitting VDE satellite is in the field of view the resource sharing between VDE-SAT uplink and VDE-TER ship-to-shore must be coordinated between the shore operator and the satellite operator. This coordination can be done either directly between the operators or rely on the bulletin board and announcement channels of the satellite and shore stations. As an initial configuration for resource sharing, a static assignment in time and frequency should be adopted by the terrestrial and satellite entities.

- Channels 1024 and 1084 are exclusively used for VDE-TER ship-to-shore
- Channels 1026 and 1086 are exclusively used for VDE-SAT uplink (ship-to-satellite)
- Channels 1025 and 1085 are time-shared between the VDE-SAT uplink and VDE-TER services. The time-sharing is based on time intervals of 1 hexslot (6 slots) that are assigned alternately to VDE-SAT and VDE-TER services

As the starting point of VDES resource sharing or in the absence of coordination between the shore and satellite operation, this resource sharing method should be used.

E 6.2 RESOURCE SHARING WITH FREQUENCY PLAN ALTERNATIVE 2

With frequency plan alternative 2, the utilization of channels 24, 84, 25 and 85 is primarily for VDE-TER. VDE-SAT uplink is also possible in channels 24, 84, 25 and 85, but the VDE-SAT uplink in these channels do not impose constraints on VDE-TER and should only use resources not reserved by VDE-TER.

Channels 26 and 86 exclusively reserved for VDE-SAT uplink. Therefore, on these channels no resources are shared and no sharing scheme is required.