GUIDELINE

G1139

THE TECHNICAL SPECIFICATION OF VDES

Edition 3

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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
December 2018	All chapters updated to reflect technical developments related to VDES. Replaced Annex C (link layer) with new Link Layer proposed in China 2018 Intersessional.	Council 68
June 2019	Clarifications and corrections to: Annex A: min. Power for shore stations, all Link ID Tables, CRC Annex B: Table 18, User ID and Message ID size, Annex C: NAK, default channel width, Annex D: spreading sequence, propagation.	Council 69

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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.

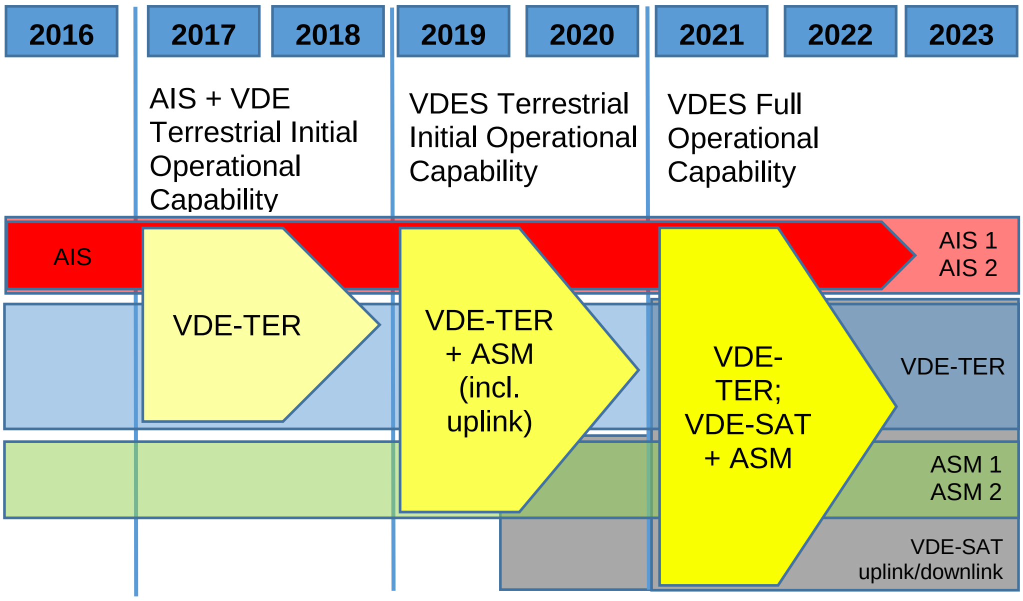

Figure 1 - Implementation of VDES

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.

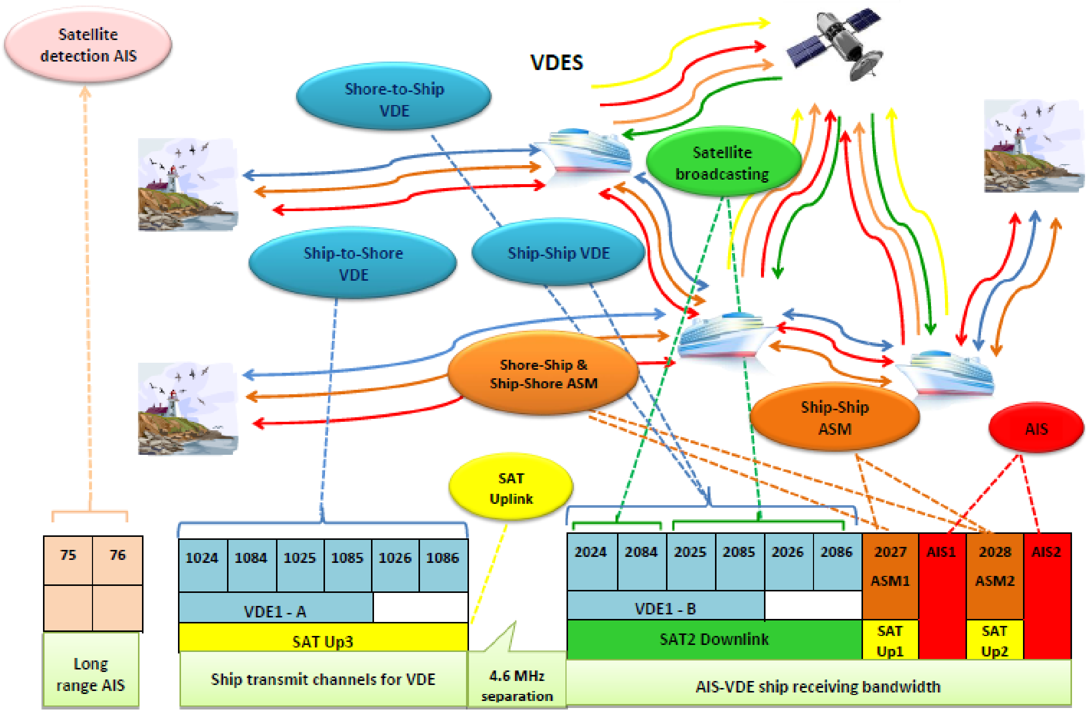

Figure 2 - VDES functions and frequency use – full system

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 center 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	161.950
2028 (ASM 2)	162.000	162.000
VDE SAT	157.2875	161.8625 160.9625
VDE TER (100KHz BW channel)	157.2375	161.8375
VDE1 TER (50KHz BW channel)	157.2125	161.8125
VDE2 TER (50KHz BW channel)	157.2625	161.8625
VDE1 TER (25KHz BW channel)	157.200	161.800
VDE2 TER (25KHz BW channel)	157.225	161.825
VDE3 TER (25KHz BW channel)	157.250	161.850
VDE4 TER (25KHz BW channel)	157.275	161.875

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.

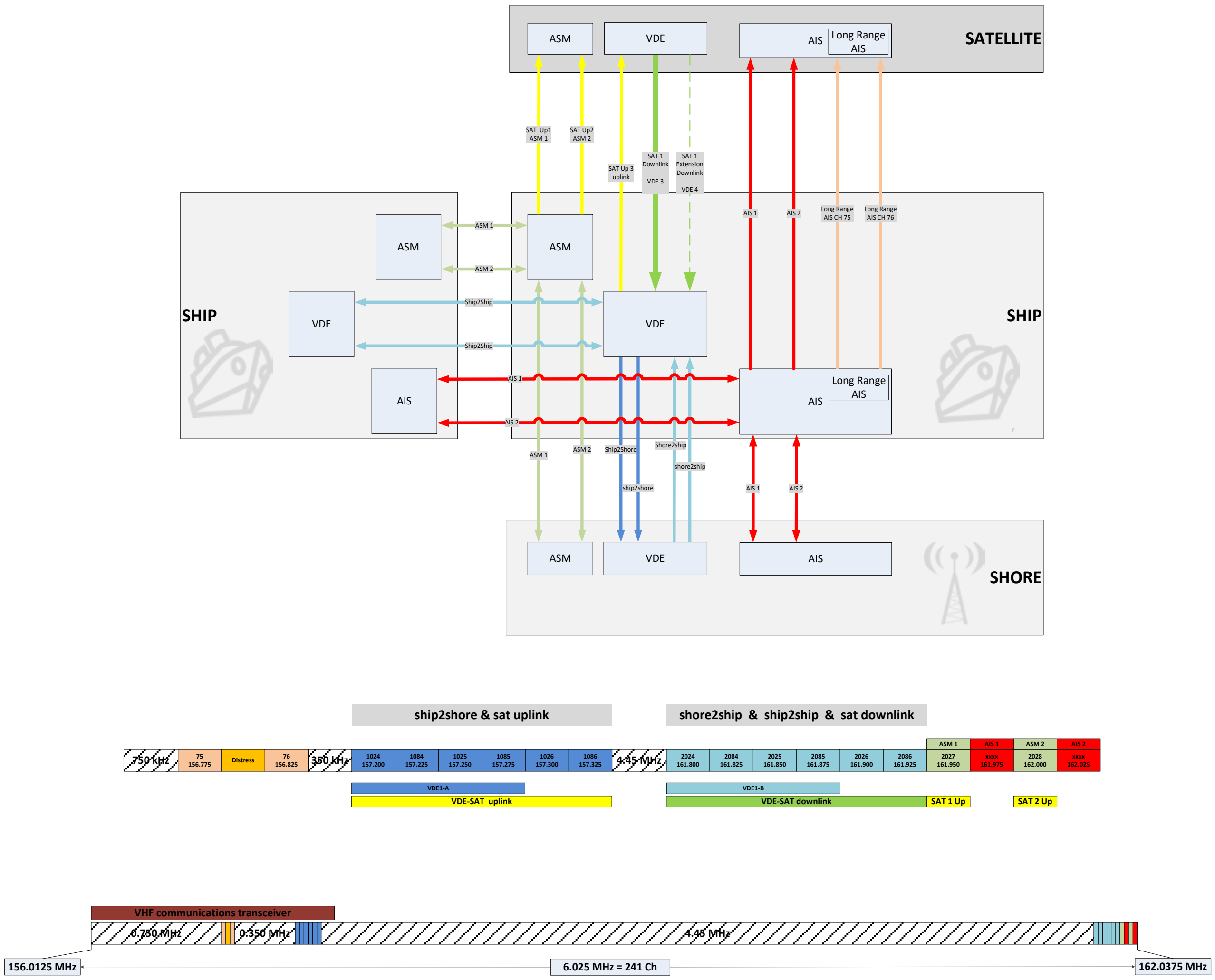

Figure 3 - VHF data exchange system functions and frequency usage engineer's perspective

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.

7.1 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 H.222.0 : Information technology - Generic coding of moving pictures and associated audio information: Systems.

[RD-6] European Standard ETSI EN 301 545-2 – Digital Video Broadcasting (DVB); Second Generation DVB – Interactive Satellite System (DVB-RCS2); Part 2: Lower Layers for Satellite standard.

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.

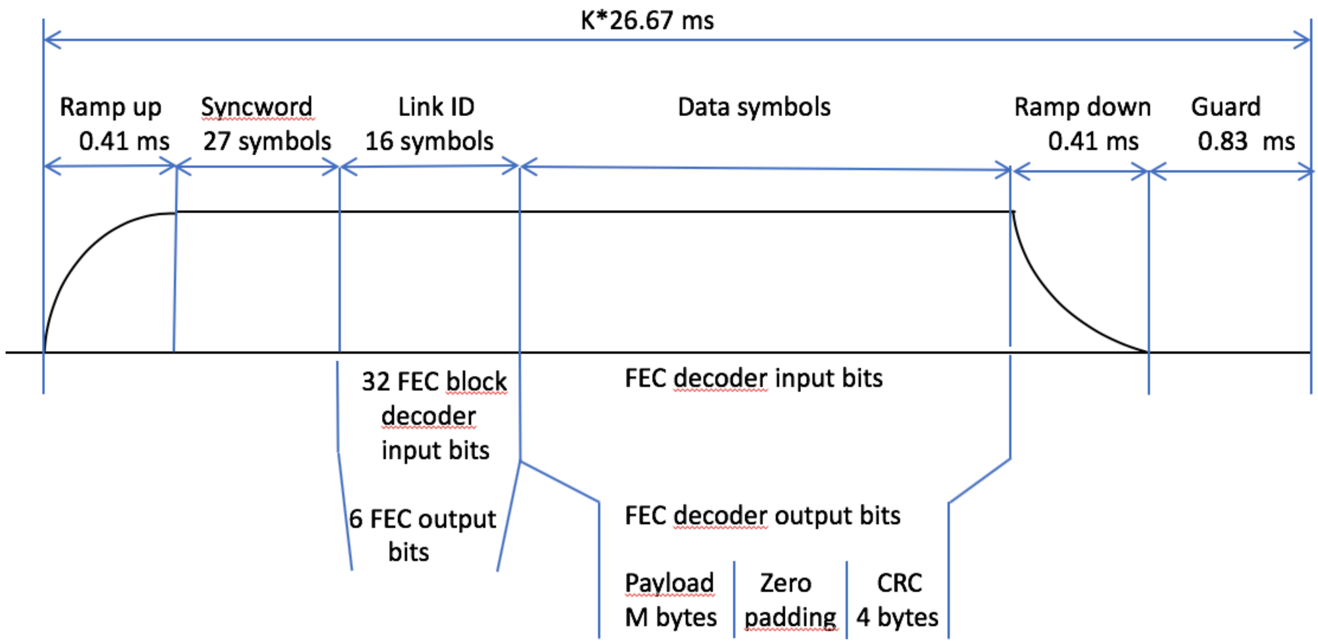

Figure 5 - ASM-TER and VDE-TER General Packet Format

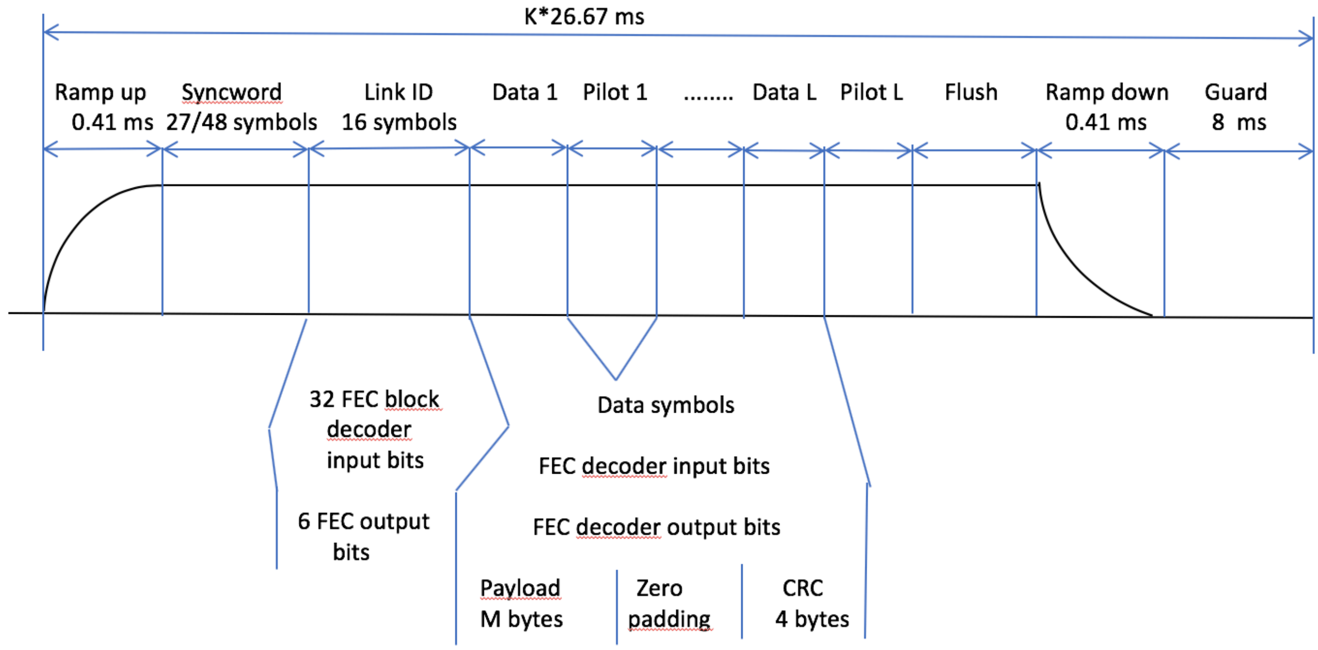

Figure 6 - ASM-SAT and VDE-SAT General Packet Format

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

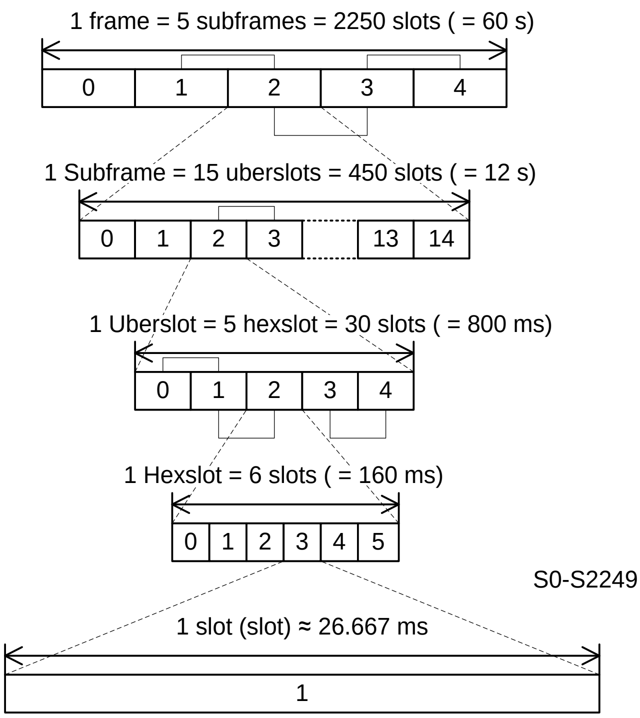

Figure 7 - Frame Hierarchy for shared frequency

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 modulation during ramp up is not specified.

A 1.2.3.2 Training sequence

Table 2 shows the syncwords used for VDES.

Table 2 – 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.
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

For training the 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 ID

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

The Link ID follows the training sequence for transmissions, see Figure 5 and Figure 6, and uses $\pi/4$ QPSK bit mapping, see A 1.2.8.

The Link ID consists of 6 bits (D0, D1, D2, D3, D4, D5) encoded into a sequence of 32 bits using biorthogonal (32,6) code. The code is a first order Reed-Muller code with generator matrix:

The code shall be bit scrambled using the scrambling word 11000010111000101000111001001111. This results in the Link ID coding of Table 3.

Table 3 - Link ID code words for VDES

Link Conf ID	Bit-scrambled code word	Link Conf ID	Bit-scrambled code word
0	11 00 00 10 11 10 00 10 10 00 11 10 01 00 11 11	32	01 00 00 00 00 00 10 11 01 10 01 11 11 01 10 01
1	11 00 01 10 11 10 00 10 11 11 00 01 10 11 00 00	33	01 00 01 00 00 00 10 11 00 01 10 00 00 10 01 10
2	11 00 10 10 10 01 11 01 10 00 11 10 10 11 00 00	34	01 00 10 00 01 11 01 00 01 10 01 11 00 10 01 10
3	11 00 11 10 10 01 11 01 11 11 00 01 01 00 11 11	35	01 00 11 00 01 11 01 00 00 01 10 00 11 01 10 01
4	11 01 00 01 11 10 11 01 00 00 00 01 01 00 00 00	36	01 01 00 11 00 00 01 00 11 10 10 00 11 01 01 10
5	11 01 01 01 11 10 11 01 01 11 11 10 10 11 11 11	37	01 01 01 11 00 00 01 00 10 01 01 11 00 10 10 01
6	11 01 10 01 10 01 00 10 00 00 00 01 10 11 11 11	38	01 01 10 11 01 11 10 11 11 10 10 00 00 10 10 01
7	11 01 11 01 10 01 00 10 01 11 11 10 01 00 00 00	39	01 01 11 11 01 11 10 11 10 01 01 11 11 01 01 10
8	11 10 00 01 01 01 00 01 10 11 11 01 01 11 11 00	40	01 10 00 11 10 11 10 00 01 01 01 00 11 10 10 10
9	11 10 01 01 01 01 00 01 11 00 00 10 10 00 00 11	41	01 10 01 11 10 11 10 00 00 10 10 11 00 01 01 01
10	11 10 10 01 00 10 11 10 10 11 11 01 10 00 00 11	42	01 10 10 11 11 00 01 11 01 01 01 00 00 01 01 01
11	11 10 11 01 00 10 11 10 11 00 00 10 01 11 11 00	43	01 10 11 11 11 00 01 11 00 10 10 11 11 10 10 10

12	11 11 00 10 01 01 11 10 00 11 00 10 01 11 00 11	44	01 11 00 00 10 11 01 11 11 01 10 11 11 10 01 01
13	11 11 01 10 01 01 11 10 01 00 11 01 10 00 11 00	45	01 11 01 00 10 11 01 11 10 10 01 00 00 01 10 10
14	11 11 10 10 00 10 00 01 00 11 00 10 10 00 11 00	46	01 11 10 00 11 00 10 00 11 01 10 11 00 01 10 10
15	11 11 11 10 00 10 00 01 01 00 11 01 01 11 00 11	47	01 11 11 00 11 00 10 00 10 10 01 00 11 10 01 01
16	10 00 00 11 00 11 01 11 01 01 10 11 00 01 10 10	48	00 00 00 01 11 01 11 10 10 11 00 10 10 00 11 00
17	10 00 01 11 00 11 01 11 00 10 01 00 11 10 01 01	49	00 00 01 01 11 01 11 10 11 00 11 01 01 11 00 11
18	10 00 10 11 01 00 10 00 01 01 10 11 11 10 01 01	50	00 00 10 01 10 10 00 01 10 11 00 10 01 11 00 11
19	10 00 11 11 01 00 10 00 00 10 01 00 00 01 10 10	51	00 00 11 01 10 10 00 01 11 00 11 01 10 00 11 00
20	10 01 00 00 00 11 10 00 11 01 01 00 00 01 01 01	52	00 01 00 10 11 01 00 01 00 11 11 01 10 00 00 11
21	10 01 01 00 00 11 10 00 10 10 10 11 11 10 10 10	53	00 01 01 10 11 01 00 01 01 00 00 10 01 11 11 00
22	10 01 10 00 01 00 01 11 11 01 01 00 11 10 10 10	54	00 01 10 10 10 10 11 10 00 11 11 01 01 11 11 00
23	10 01 11 00 01 00 01 11 10 10 10 11 00 01 01 01	55	00 01 11 10 10 10 11 10 01 00 00 10 10 00 00 11
24	10 10 00 00 10 00 01 00 01 10 10 00 00 10 10 01	56	00 10 00 10 01 10 11 01 10 00 00 01 10 11 11 11
25	10 10 01 00 10 00 01 00 00 01 01 11 11 01 01 10	57	00 10 01 10 01 10 11 01 11 11 11 10 01 00 00 00
26	10 10 10 00 11 11 10 11 01 10 10 00 11 01 01 10	58	00 10 10 10 00 01 00 10 10 00 00 01 01 00 00 00
27	10 10 11 00 11 11 10 11 00 01 01 11 00 10 10 01	59	00 10 11 10 00 01 00 10 11 11 11 10 10 11 11 11
28	10 11 00 11 10 00 10 11 11 10 01 11 00 10 01 10	60	00 11 00 01 01 10 00 10 00 00 11 10 10 11 00 00
29	10 11 01 11 10 00 10 11 10 01 10 00 11 01 10 01	61	00 11 01 01 01 10 00 10 01 11 00 01 01 00 11 11
30	10 11 10 11 11 11 01 00 11 10 01 11 11 01 10 01	62	00 11 10 01 00 01 11 01 00 00 11 10 01 00 11 11
31	10 11 11 11 11 11 01 00 10 01 10 00 00 10 01 10	63	00 11 11 01 00 01 11 01 01 11 00 01 10 11 00 00

The Link ID is not used by the SAT link.

A 1.2.3.5 Data with CRC

The data payload with its appended CRC 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.

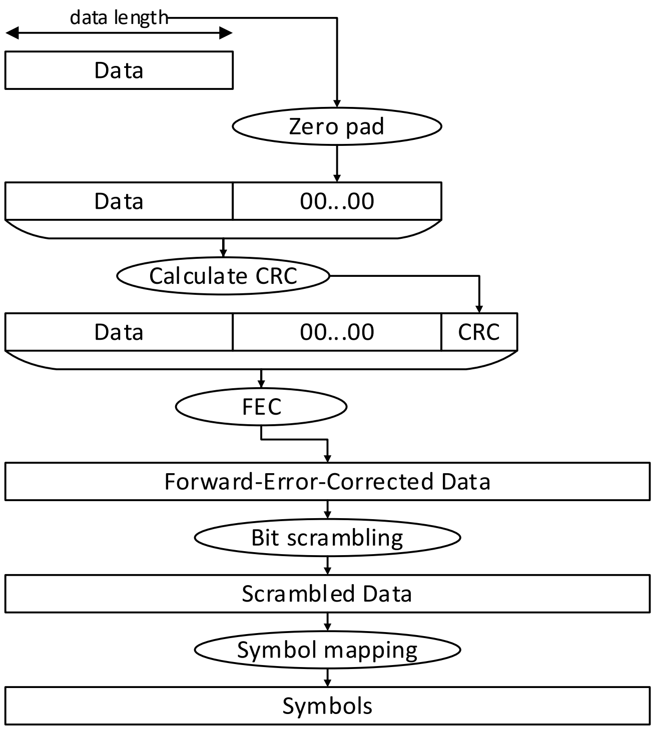

Figure 8 - Order of operations for TDMA; if CR=1 FEC is not applied

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 ….

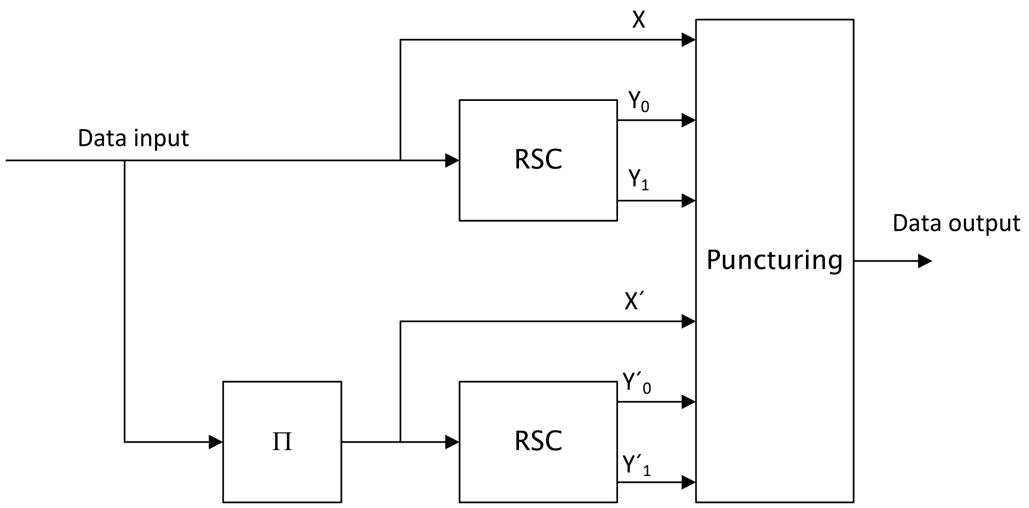

Figure 9 - Turbo encoder structure (high-level)

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.

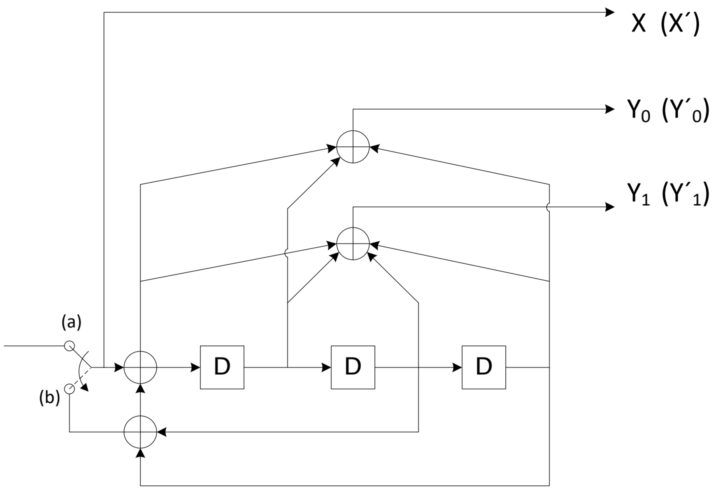

Figure 10 - RSC code encoder

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	k1|k2	p1|p2|p3| p4| p5| p6| p7| p8	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	47|17|233|127|239|139|199|163	8	8
6	3/4	672	2|336	37|101|191|149|79|131|229|31	8	8
7	3/4	1056	4|264	23|31|167|223|59|113|47|211	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	1872	6|312	211|61|227|239|181|79|73|193	6	6a
18	3/4	4032	4|1008	31|37|43|47|53|59|61|67	8	8
19	3/4	5616	16|351	137|101|223|41|67|131|61|47	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	16|195	89|47|239|17|127|59|43|31	7a	7b
23	2/3	4544	4|1136	31|37|43|47|53|59|61|67	7b	7b

24	5/6	3788*2	4|947	127|251|227|173|139|149|101|7	9	9
25	1/2	4776	12|398	31|37|43|47|53|59|61|67	6	6a
26	1/4	5456*7	16|341	37|41|43|47|53|59|61|67	2	2a
27	1/2	6032*19	16|377	31|37|43|47|53|59|61|67	6	6b
28	1/4	5280*4	16|330	31|37|43|47|53|59|61|67	2	2b
29	1/4	5552*6	16|347	31|37|43|47|53|59|61|67	2	2c
30	1/4	5320*13	14|380	31|37|43|47|53|59|61|67	2	2c
31	1/4	5328*22	16|333	31|41|43|47|53|59|61|67	2	2d
32	1/4	312	2|156	37|79|29|139|151|97|181|157	2	2e
33	1/3	4280	8|535	59|37|157|167|239|83|163|29	4	4a
34	1/3	4160*2	16|260	163|157|149|137|197|47|241|251	4	**

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

**) No tail bits.

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 $\pi(s)$:

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

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

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

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

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

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

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

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; Y0; Y1; X'; Y'0; Y'1 | X; Y0; Y1; 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
7b	2/3	1;0;0;0;0;0 | 1;1;0;0;0;0 | 1;0;0;0;0;0 | 1;0;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; Y0; Y1; X'; Y'0; Y'1 | X; Y0; Y1; 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
2b	1/4	1;1;1;0;0;0 | 1;1;1;0;0;0 | 1;1;0;0;0;0 | 0;0;0;1;1;1 | 0;0;0;1;1;1 | 0;0;0;1;1;0
2c	1/4	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
2d	1/4	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
2e	1/4	2;1;1;0;0;0 | 2;1;1;0;0;0 | 2;1;0;0;0;0 | 0;0;0;2;1;1 | 0;0;0;2;1;1 | 0;0;0;2;0;0
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
4a	1/3	2;1;0;0;0;0 | 2;1;0;0;0;0 | 2;0;0;0;0;0 | 0;0;0;2;1;0 | 0;0;0;2;1;0 | 0;0;0;0;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
6a	1/2	1;1;0;0;0;0 | 1;1;0;0;0;0 | 1;0;0;0;0;0 | 0;0;0;1;1;0 | 0;0;0;1;1;0 | 0;0;0;1;0;0
6b	1/2	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
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;0
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

A generated CRC check sequence is appended to the last segment of the datagram. A 32 bits CRC-32 check sequence is applied for all waveforms except for the satellite waveform SAT-MCS-1.50-2 (Link Config ID 20) which applies a 16 bits CRC-16 check sequence. The CRC-32 is calculated with the generator polynomial

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

and the CRC-16 with the generator polynomial $x^{16} + x^{15} + x^2 + 1$. CRC check sequence generation shall be equivalent to that defined in ITU-T H.222.0, Annex A [RD-5] for CRC-32 and ETSI EN 301 545-2 [RD-6] for CRC-16. The CRC check sequence is the remainder of the division of the initial value+datagram by the generator polynomial and can be effectively calculated by applying a linear feedback shift register. The 32 bits shift register for generating CRC-32 must be set to the initial value 0xFFFF FFFF, and the 16 bits shift register for generating CRC-16 to the initial value 0x0000 (all zero).

The CRC check sequence is calculated over all fragments of the datagram (including any zero padding) with MSB of each byte processed first, and the resulting CRC check sequence is appended MSB first. In the receiver, the CRC check sequence can be verified by obtaining an all zero result in the linear feedback shift register after processing over the entire data+padding+CRC datagram.

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 Figure 11. For each transmitted packet, the bit scrambler is re-initialized. The MSB shall be the first output bit.

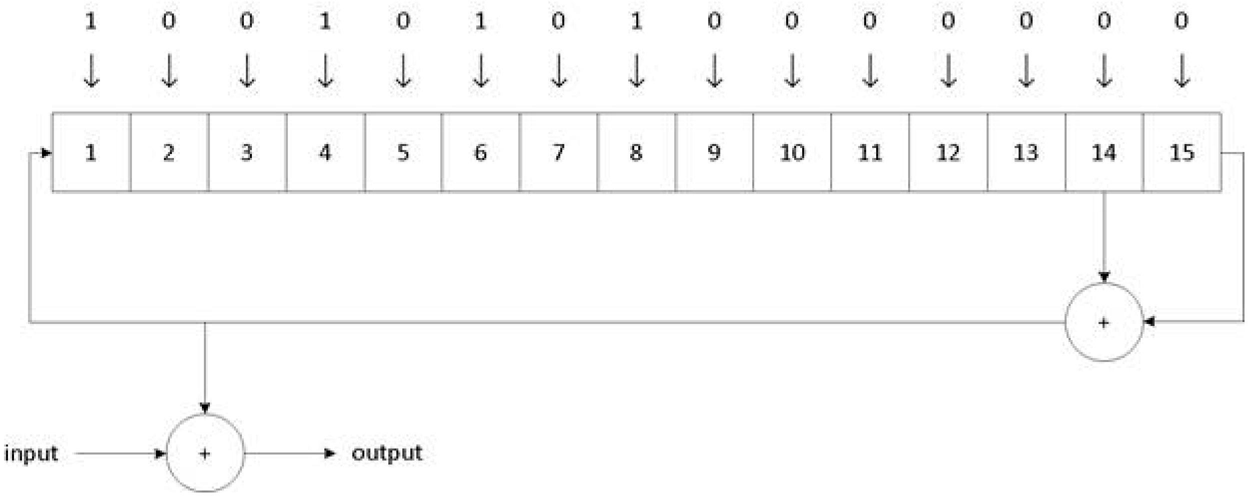

Figure 11 - Bit scrambling

A 1.2.7. MODULATION CODING SCHEMES

All MCS formats are defined in the Link ID in Table 7, Table 8,

Table 9, Table 10 and Table 11 (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 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				
Link Config ID	1	2	3	4 (SAT)	5	6	7				
Channel BW	16										kHz
Roll off filtering[1]	0,35										
Signal BW	13,0										kHz
Symbol rate	9,6										ksps
PAPR (example)	3.35										dB
Minimum high output average power	12.5										Watt
Burst size	1	2	3	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				ms
Symbols/ burst	248	504	760	691	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				symbols
Channel bits	394	906	1418	1280	394	906	1418				bits
Padding+FEC tail***	10+0			0+11	0+10						bits
FEC decoder input symbols	192	448	704	634.5	192	448	704				symbols
FEC decoder input bits	384	896	1408	1269	384	896	1408				bits
FEC output bits	384	896	1408	952	288	672	1056				bits
FEC output bytes	48	112	176	119	36	84	132				bytes
Modul.	PI/4 QPSK										
Bits / symbol	2										
FEC rate	1			3/4							
E_s/N_0 on AWGN	11,0	11,0	11,0	4,5	5,3	5	4,8				dB
$C/(N_0+I_0)$ threshold	50,8	50,8	50,8	44,3	45,1	44,8	44,6				dBHz
Minimum CQI value[2]	71	71	71	61	63	62	61	71			

***) Given as padding + FEC tail bits, where the tail bits are according to Table 6, refer to C 4.6 Data Structures.

[2] See definition of CQI in C 4.8. Minimum CQI is defined at PER = 1% + 0.5 dB margin for synchronization and implementation losses.

1 The baseband shall employ a root raised cosine filter

Table 8 - VDE-TER Link 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
PAPR (example)	3.82	4.4	6.7	3.82	4.4	6.7	3.82	4.4	6.7	dB
Minimum high output average power	12.5	11	6.5	12.5	11	6.5	12.5	11	6.5	Watt
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 + FEC tail***	10+0	3+12	8+12	30+12	51+12	72+12	0+10	243+12	8+12	bits
FEC decoder input symbols	432			896			1872	1792	1872	symbols
FEC decoder input bits	864	1296	1728	1792	2688	3584	3744	5376	7488	bits
FEC output bits	432	972	1296	896	2016	2688	1872	4032	5616	bits
FEC output bytes	54	122	162	112	252	336	234	504	702	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]						48		84	dBHz

*) this link configuration is defined for future use. It is optional and not subject to testing.

***) Given as padding + FEC tail bits, where the tail bits are according to Table 6, refer to C 4.6 Data Structures.

Table 9 - VDE-SAT UpLink 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
PAPR (example)	0	4.35		4.9	7.1	dB
Minimum high output average power	12.5	11		10	6	Watt
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 ID size	0	16 (32,6 block code)				symbols
Link ID modulation	NA	PI/4 QPSK				
Pilot symbol distance	17	NA		33		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 + FEC tail***	0+18	0+8	4+12	3+12	2*(0+8)	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
FEC subblock	1	1		1	2	
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	37	59	56	71	90	

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

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

***) Given as padding + FEC tail bits, where the tail bits are according to Table 6, refer to C 4.6 Data Structures.

****) this link configuration is defined for future use. It is optional and not subject to testing.

Table 10 – VDE-SAT DownLink 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			2				chips
Symbol rate	4,2	33,6		36,0	56,4	116,4	196,8	ksps
Burst size	90							slots
Guard time	8							ms
Burst duration	2392,0							ms
Symbols/burst	10046	80371		86112	134908	278428	470745	symbols
Ramp-up/down	14/14			30/30	47/47	96/96	162/162	symbols / chips
Ramp-up/down	0.41/0.41							ms
Syncword size	48	27		48				symbols
Number of syncwords	10	35		32				
Total syncword symbols	480	945		1536				symbols
Syncword distance	1004	2268		2690	4214	8697	14705	symbols
Syncword modulation	BPSK/ CDMA	PI/4 QPSK (00 /11)		BPSK/CDMA				
Link Config ID	0 (not used)							symbols
Link Config ID modulation	BPSK/ CDMA	PI/4 QPSK		BPSK/CDMA				
Pilot distance		27						symbols
Total pilots symbols		2940						symbols
Net symbols/burst	9562	76458	76458	84546	133325	276796	469047	symbols
Burst stuffing bits	0	1	6	2	5	0	7	bits
Channel bits	9562	152915	229368	84544	133320	276796	469040	bits
Padding + FEC tail***	0+10	7*(3+18)	(0+8)*19	4*(0+16)	6*(0+12)	13*(0+12)	22*(0+8)	bits
FEC decoder input symbols	9552	76384	76406	84480	133248	276640	468864	symbols
FEC decoder input bits*	9552	152768	229216	84480	133248	276640	468864	bits
FEC output bits	4776	7*5456	19*6032	4*5280	6*5552	13*5320	22*5328	bits
FEC output	597	7*682	19*754	4*660	6*694	13*665	22*666	bytes
FEC sub-blocks	1	7	19	4	6	13	22	
Modulation	BPSK/ CDMA	PI/4 QPSK	8PSK	BPSK/CDMA				
FEC rate	1/2	1/4	1/2	1/4				
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	35	32	60	20				

***) Given as padding + FEC tail bits, where the tail bits are according to Table 6, refer to C 4.6 Data Structures.

Table 11 - VDE-SAT DownLink ID Parameters (continued)

PL format	SAT-MCS-0.50-2	SAT-MCS-0.50-3	SAT-MCS-1.50-2	
Link Config ID	32	33	34	
Channel BW	50			kHz
Roll off filtering	0,25			
Signal BW	42,0			kHz
CDMA chiprate	33,6			kcps
Codelength	8			chips
Symbol rate	4,2	33,6		ksps
Burst size	15			slots
Guard time	8			ms
Burst duration	392,0			ms
Symbols/burst	1646	13171		symbols
Ramp-up/down	14/14			symbols/chips
Ramp-up/down	0.41/0.41			ms
Syncword size	48	48	27	symbols
Number of syncwords	4	6	6	symbols
Total syncword symbols	192	288	162	symbols
Syncword distance	531	2619	2619	symbols
Syncword modulation	BPSK / CDMA	BPSK	PI/4-QPSK (00 /11)	
Link Config ID	(32,6) block-code will not work for downlink $C/(N_0+I_0)$ (E_s/N_0) thresholds			symbols
Pilot distance	8		27	symbols
Total pilots symbols	180		480	symbols
Burst symbol duration*	1641	13143	13122	symbols
Net symbols/burst	1269	12855	12480	symbols
Channel bits	1269	12855	24960	bits
Padding + FEC tail ***	0+21	0+15	0+0	bits
FEC decoder input symbols	1248	12840	12480	symbols
FEC decoder input bits	1248	12840	2*12480	bits
FEC output bits	312	4280	2*4160	bits
FEC output	39	535	1040	bytes
Modulation	BPSK/ CDMA	BPSK	PI/4 QPSK	
FEC rate	1/4	1/3	1/3	
E_s/N_0 on AWGN	-4,5	-3,6	-0,6	dB
$C/(N_0+I_0)$ threshold	31,6	41,7	44,7	dBHz
Minimum CQI value	21	24	36	

*) Burst symbol duration is number of symbols from syncword preamble to syncword postamble, disregarding ramping symbols
***) Given as padding + FEC tail bits, where the tail bits are according to Table 6, refer to C 4.6 Data Structures.

A 1.2.8. BIT MAPPING

The bit mappings used throughout the Annexes are shown in Figure 13, Figure 14, Figure 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 13); the next symbol is mapped to the constellation defined by points $\{1+0j, 0+j, -1+0j, 0-j\}$ (shown in purple in Figure 13); the third symbol is mapped to the same constellation as the first symbol; and so on.

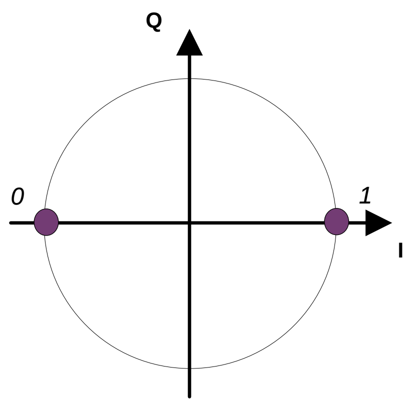

Figure 12 – Bit Mapping for BPSK

The modulation accuracy requirements for π/4 QPSK are:

(1) The RMS error vector in any burst shall be less than 0.1

(2) The peak error vector magnitude shall be less than 0.3 for any symbol

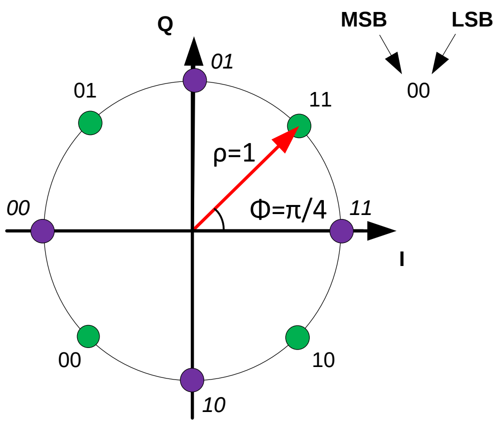

Figure 13 - Bit Mapping for π/4 QPSK

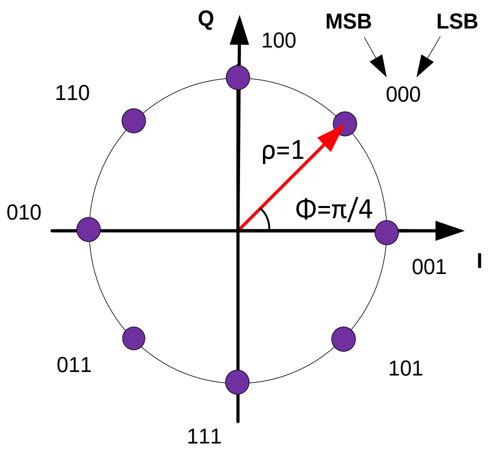

Figure 14 - 8PSK symbol to bit mapping

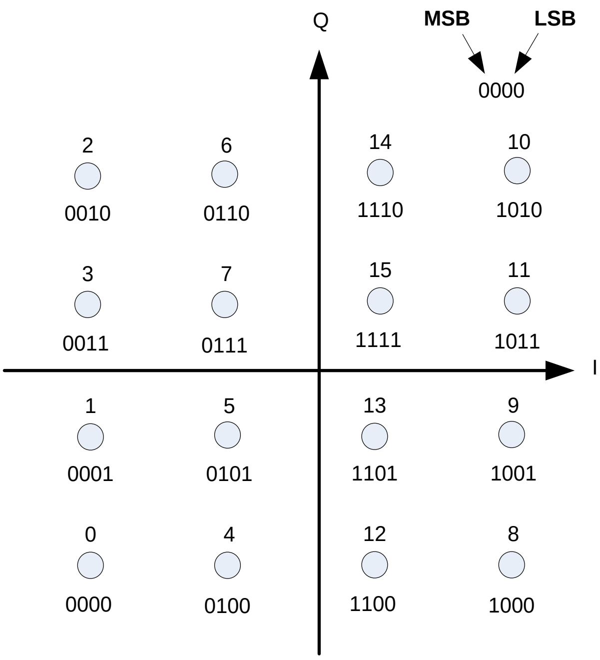

Figure 15 - Bit Mapping for 16QAM

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 12 presents representative values for the receiver noise figure.

Table 12 - 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 13Table 13 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 13 - Transmitter parameters

Transmitter parameters	Requirements	Condition
Frequency error	1.5 ppm	normal
Frequency error	3 ppm	extreme
Maximum transmit power capability	The minimum average power should be according to Table 7, Table 8, Table 9. The power tolerance is ±1.5 dB in normal, +2/−6 dB in extreme conditions.	Conducted
Maximum adjacent power levels for 25 kHz channel	Δfc < ±12.5 kHz: 0 dBc[2] ±12.5 kHz < Δfc < ±25 kHz: below the straight line between −25 dBc at ±12.5 kHz and –70 dBc at ±25 kHz ±25 kHz < Δfc < ±62.5 kHz: −70 dBc	
Maximum adjacent power levels for 50 kHz channel	Δfc < ±25 kHz: 0 dBc ±25 kHz < Δfc < ±37.5 kHz: below the straight line between −25 dBc at ±25 kHz and –70 dBc at ±37.5 kHz ±37.5 kHz < Δfc < ±125 kHz: −70 dBc	
Maximum adjacent power levels for 100 kHz channel	Δfc < ±50 kHz: 0 dBc ±50 kHz < Δfc < ±62.5 kHz: below the straight line between −25 dBc at ±50 kHz and –70 dBc at ±62.5 kHz ±62.5 kHz < Δfc < ±250 kHz: −70 dBc	
Spurious emissions	−36 dBm −30 dBm	9 kHz to 1 GHz 1 GHz to 4 GHz

2 where 0 dBc is average.

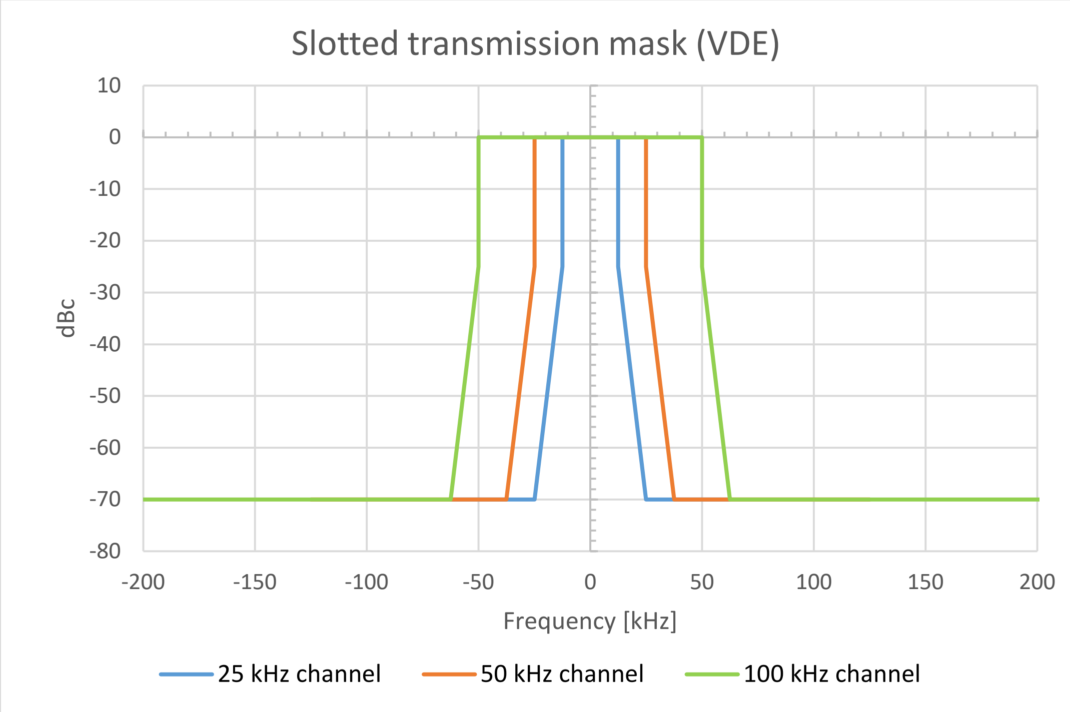

Figure 16 - Slotted Transmission Mask (VDE)

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 14 is based on a linear transmitter meeting the maximum Adjacent Channel Interference levels defined in Table 13. For saturated operation, the e.i.r.p. shall be 3 dB higher.

Table 14 - 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 between ships, ship and shore, and ship and satellite. This layer will further be responsible for packing data into messages and providing access to the data transfer medium using TDMA techniques.

A 1.3.1. TDMA SYNCHRONIZATION

TDMA synchronization is achieved using an algorithm as described below.

The TDMA receiving process should not depend on slot boundaries.

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

A 1.3.2. COORDINATED UNIVERSAL TIME DIRECT

A station, which may acquire timing directly from coordinated universal time (UTC) source having the required accuracy.

A 1.3.3. COORDINATED UNIVERSAL TIME INDIRECT

A station, which is unable to get direct access to UTC, but has access to the AIS system timing, should get its synchronization from the AIS system.

A 1.4. 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 1.4.1. 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 1.4.2. 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 1.4.3. 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 1.4.4. 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 1.4.5. MOBILITY MANAGEMENT

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

A 1.4.6. 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 15 - 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 16 and Figure 17. The resolution bandwidth for the mask measurement is 300Hz.

Table 16 - Minimum required time division multiple access transmitter characteristics

	Requirements
Carrier power error	±1.5 dB
Carrier frequency error (normal)	1.5 ppm
Carrier frequency error (extreme)	3.0 ppm
Slotted modulation mask	Δfc < ±8 kHz: 0 dBc[3] ±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

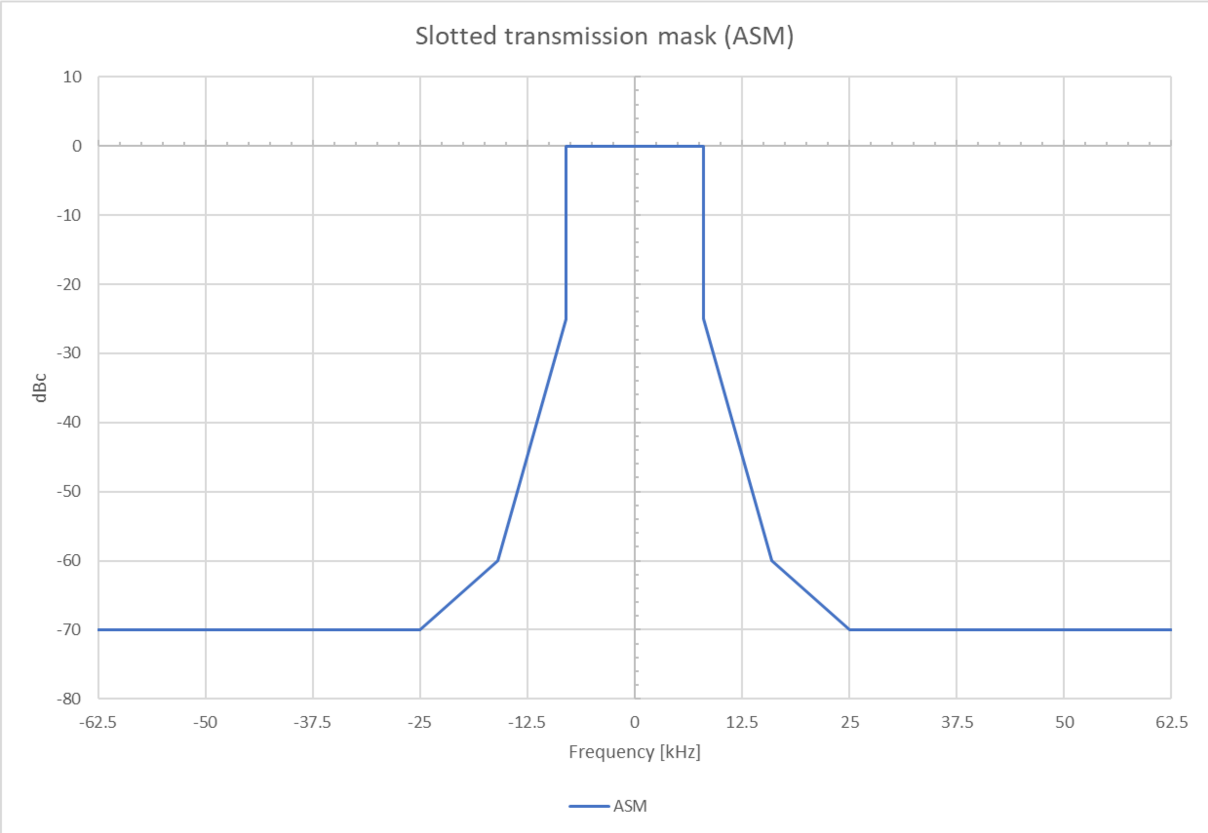

Figure 17 - ASM Slotted modulation mask

3 where 0 dBc is 12.5W average power for higher power and 1W average power for low power.

Table 17 - 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 ID, see Table 7.

For the modulation bit mapping, see Annex A.

B 2.4. DATA TRANSMISSION BIT RATE

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

B 2.5. FRAME STRUCTURE

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

B 2.6. SIGNAL INFORMATION

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

B 2.7. 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 2.8. 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 2.9. 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 (average power) 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 as described in section A 1.3.1.

B 3.3. 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***:
  - not allocated externally on AIS and ASM channels
  - no addressed message to own station expected on VDE channel
- ***Available***:
  - externally allocated by an AIS which may be considered as a candidate slot. 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.

- ***Unavailable***:
  - internal allocation by own station for the purpose of own transmission
  - 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
  - externally allocated by an ASM station on the intended ASM channel
  - externally allocated by an ASM station on the other ASM channel for an addressed message to own station.
  - slots allocated to own station for VDE reception

B 3.4. 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 being used to synchronize the VDES receiver.

B 3.6.2.2 Summary of the transmission packet

The data packet is defined in

Table 18.

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

Table 18 - Packet symbol structure for π/4 QPSK modulation scheme

	symbols	Description
Ramp up	4	
Training sequence	27	Necessary for synchronization
Link ID	16	Decoded from (32,6) biorthogonal code; ASM channel configurations as defined in Link ID table; Note that the Link ID will identify how many slots make up the message.
Data	1 slot: 176 2 slot: 432 3 slot: 688 SAT: 616	The symbol count and the information bits varies according to coding rate as defined by the Link ID field
CRC	16	The CRC only includes the data field
FEC termination bits	6	Set to zero when not used
Ramp Down	4	Distance delay and jitter
Guard Time	TER: 7 SAT: 79	Distance delay and jitter
Total	1 slot: 256 2 slot: 512 3 slot: 768	

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 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 ID see Table 7.

B 3.5. 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 235 slots.

The selection process uses received data from AIS, ASM and VDE where these functions are co-located. Functions not part of a co-located station are not considered by the candidate slot selection process of the station.

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

- Rule 1: The candidate slots are primarily selected from slots that are Free.

If the candidate slot set contains less than eight slots, additional candidate slots can be obtained by using the following rules and order (rule 2 followed by rule 3):

- Rule 2: Available slot on one AIS channel and Free on the other channels.
- Rule 3: Available slot on both AIS channels (AIS1 and AIS2) and Free on the other 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 a 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.

Figure 18 shows a flowchart representation of the selection algorithm.

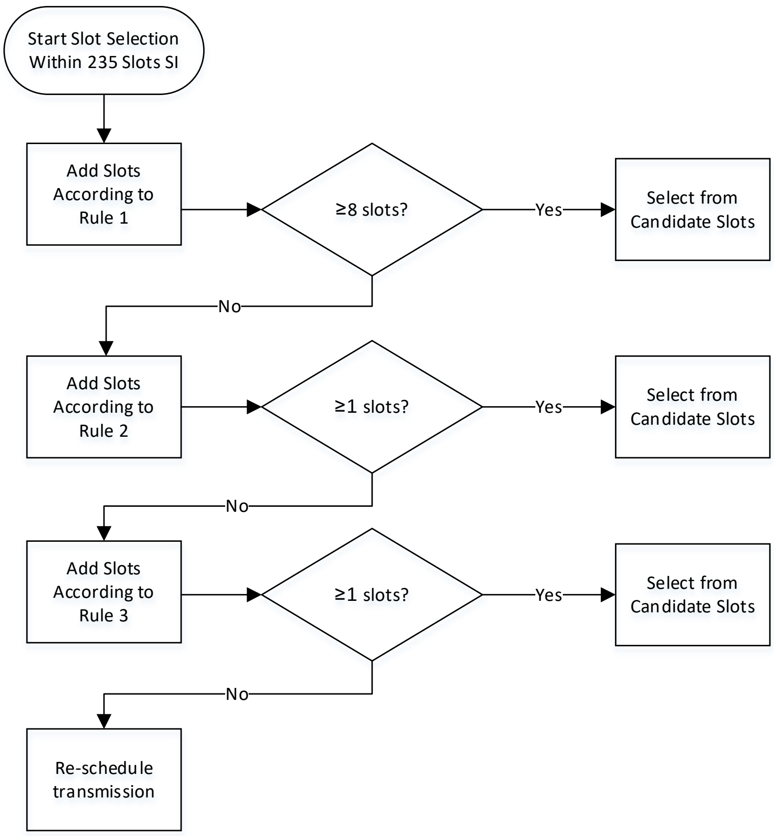

Figure 18 – ASM candidate slot selection algorithm

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 (MITDMA)

MITDMA is a method of chaining slot allocations together for the purpose of transmitting messages. The first transmission within a MITDMA chain will be a single slot transmission using RATDMA access. Further transmissions will be allocated by 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. See section B5.4.

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 225 time slots, which is equivalent to 6 s. The candidate slot set should be chosen within the SI, so that the transmission occurs within 6 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 parameters (Table 19) are used to control the RATDMA scheduling:

Table 19 - 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 6 or more (see § 3.3.1.2). However, during the cycle of the p-persistent algorithm the value may be reduced below 6	1	225
RTES	End Slot	Defined as the slot number of the last slot in the initial SI, which is 133 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 6 or more initially. Therefore LME.RTPS has a maximum value of −16 (100/6)	0	16
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	224
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	16

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 19. 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.

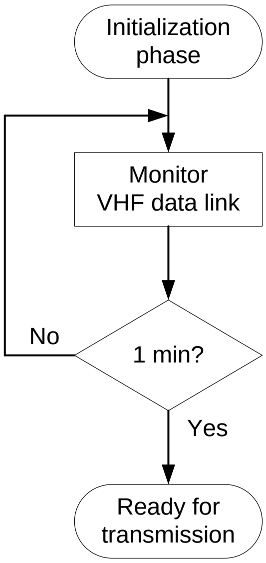

Figure 19 - Network Access for MITDMA and RATDMA

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 20 inside the data portion of a data packet.

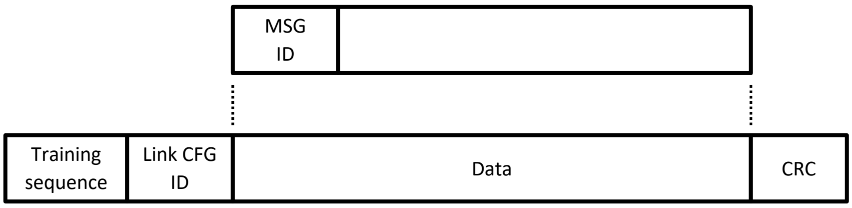

Figure 20 - Message Structure

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 – 15. 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 32 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 21.

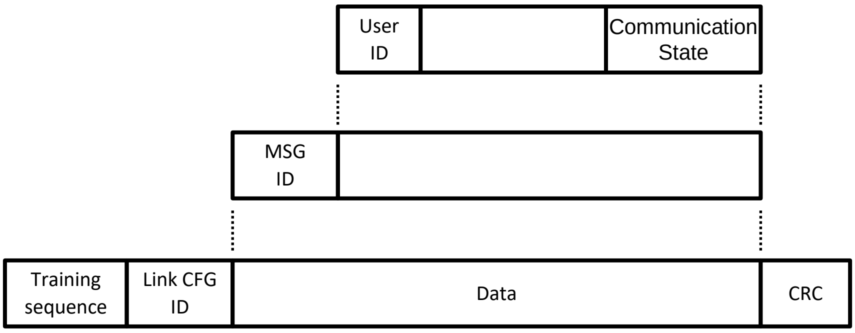

Figure 21 - MITDMA Message Structure

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 20.

Table 20 - 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 13500*
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	38			
*) When combining Slot Increment 1 and Slot Increment 2 as a 16 bit field. This value should not exceed 6 frames. The combining of these values should only be done for recurring period broadcast transmissions.				

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 21).

Table 21 - 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 22)

Table 22 - 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 up to 3 times.

B 5.3.2 BROADCAST MESSAGES

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

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 22. 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.

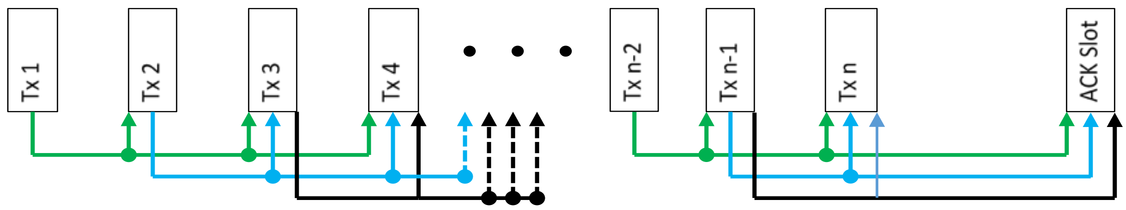

Figure 22 - MITDMA Access Example

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 23.

Table 23 - General packet structure

Parameter	Number of bits	Descriptions
Ramp up	8 bits	417 us
Training sequence	54 bits	Necessary for synchronization
Link ID	32 bits	Six information bits decoded from (32,6) biorthogonal code ASM channel configurations as defined in Link ID, see Table A1-6 Note that the Link ID will identify how many slots make up the message.
Message	1 slot: 352 2 slot: 864 3 slot: 1376 SAT : 1232	The symbol count and the information bits varies according to coding rate as defined by the Link 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 158 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 24.

Table 24 – 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

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 25.

Table 25 - Scheduled broadcast message

Parameter	Number of bits	Description
Message ID	4	1 - Broadcast message with MITDMA communication state
Retransmit flag	1	0 (reserved for future use)
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	38	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 – 248 2 slot – 760 3 slot – 1272 SAT – 1128	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 26.

Table 26 - Broadcast Message

Parameter	Number of bits	Description
Message ID	4	2 - Broadcast message with no communication state
Retransmit flag	1	0 (reserved for future use)
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 cout
Spare bits	6	Spare Bits – reserved for the future
Binary Data	1 slot – 280 2 slot – 792 3 slot – 1304 SAT – 1160	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 27.

Table 27 - 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	38	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 – 216 2 slot – 728 3 slot – 1240 SAT – 1096	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 28.

Table 28 - 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
Spare Bits	6	Spare bits – reserved for future use
Binary Data	1 slot – 248 2 slot – 760 3 slot – 1272 SAT – 1128	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 ID of 5 (3/4 coding rate). Acknowledgement message is defined in Table 29.

Table 29 - Acknowledgment message

Parameter	Number of bits	Description
Message ID	4	5 – Multiple acknowledgment message with no communication state
Retransmit flag	1	0 (reserved for future use)
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 (reserved for future use)
Signal Quality Indicator	8	Received C/N0 in dBHz
Zero padding	1 slot – 255 SAT – 1135 As required	Padding bits are added as required to complete the block size. These bits are not available for future use.

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 30.

Table 30 - 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 – 1096	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 A 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 31.

Table 31 - 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 A 1.2.7. 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. TDMA HIERARCHY

TDMA hierarchy describes the use of slots in a time interleaved pattern, thus non-continuous in time. Figure 23 details the TDMA layout. Note that the numbers inside each block indicate the slot number. Time runs from top to bottom from left to right.

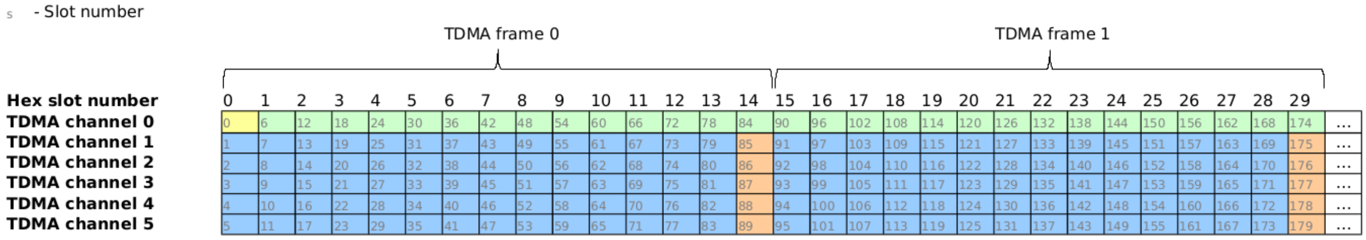

Figure 23 - TDMA hierarchy

C 4.1.1. TDMA CHANNEL

A TDMA channel refers to all the slots with the same offset in a hexslot. Every 6th slot is part of the same TDMA channel. 6 TDMA channels are defined. 0 shows each TDMA channel as a horizontal line of slots.

C 4.1.2. TDMA FRAME

A TDMA channel is divided into TDMA frames. The duration of a TDMA frame is defined as 15 slots within a TDMA channel. TDMA frames are numbered from 0 to 24.

The functionality to configure a TDMA frame length by a shore station exists, but is reserved for future use.

C 4.1.3. TDMA SLOT

A TDMA slot defines the slot number within a TDMA frame. With the TDMA frame length of 15 slots, the TDMA slots will be cyclically numbered from 0 to 14.

C 4.2. LINK LAYER DEFINITIONS

C 4.2.1. LOGICAL CHANNEL

Logical Channels define functions for a set of continuous slots within a TDMA channel and may repeat in a TDMA channel. See C 4.14.

C 4.2.2. VDE SLOTMAP

Each Physical Channel is associated with one VDE slotmap to map Logical Channels to slots for one frame.

C 4.2.3. BULLETIN BOARD

The bulletin board message is sent by the control station to define the Physical Channels with their VDE Slotmap for a control station service area. See C 4.15.

C 4.2.4. SHORT DATA MESSAGE

The short data message refers to the data transfer protocol used for transmission of payload in one slot only.

C 4.2.5. DATA SESSION

A data session refers to the data transfer protocol used for transmission of payload in a TDMA frame. See C 4.20.

C 4.2.6. MULTISESSION DATA TRANSFER

Multisession data transfer, refers to multiple data sessions chained together to be able to transmit arbitrary payloads. See C 4.20C 4.20.

C 4.2.7. DATA FRAGMENT

During a data session, the data may be broken into multiple data fragments to be transmitted in separate slots. The data fragments refer to the Start Fragment, Continuation Fragment and End Fragment VDE messages. See C 4.20.

C 4.3. CONTROL STATION SERVICE AREA

Control stations may transmit a bulletin board message with its control station service area. The bulletin board content only applies to vessels inside the control station service area. While vessels are inside a control station service area, all data session transmissions between ships should take place via the control station.

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

A ship inside the control station service area, may not communicate with a ship outside the control station service area.

C 4.4. RESOURCE MANAGEMENT

The connection between ship and shore is session oriented with a Logical Channel being reserved for a particular ship for a given time.

Ship originated short data 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, modify the maximum allowed number of ship originated short data messages or only allow traffic with high priority levels.

C 4.5. ENDIANNESS

The same endianness is used as in AIS. See ITU-R.M1371-5 Annex 1 3.3.7.

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. Each byte should be output with least significant bit first. Multi-byte words are transmitted least significant byte first.

C 4.6. DATA STRUCTURES

VDE packet transmissions shall always fit into one slot. The number of bits transmitted per VDE packet shall be fixed, depending on the Link ID used. A packet shall consist of one or multiple VDE messages, zero padding and a CRC.

An example is shown in Figure 24.

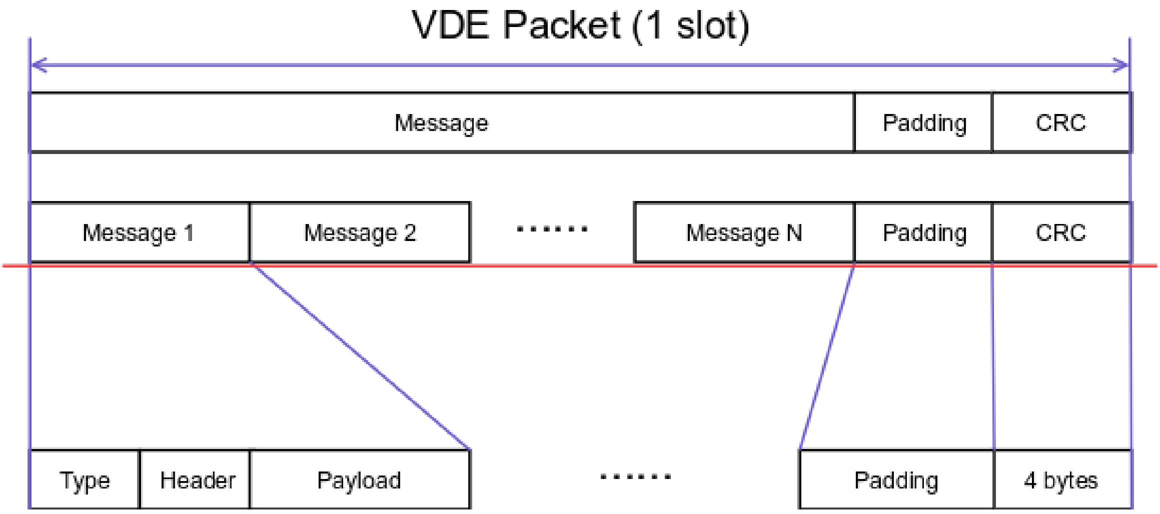

Figure 24 - Single/Multiple Message, zero padding and CRC-32 structure

Note that the padding is defined as a separate message. The CRC is always at the end of the packet. Preamble and FEC tail bits are not shown.

C 4.7. SESSION ASSIGNMENT

The session ID is reserved for future use. [A session ID is assigned to every new data session by the data receiving station. The first data fragment will announce the total number of fragments to be transmitted. A session ID is valid until all the data session fragments have been transmitted and successfully acknowledged, or negatively acknowledged. To avoid the generation of duplicate session IDs and causing conflicting data sessions near each other, the following resource allocating algorithm is proposed:

The first session ID generated after a station's power up, should start at zero and be incremented by one for every session ID generation request, independent of station requesting the session ID.]

C 4.8. ADAPTIVE CODING AND MODULATION/RATE ADAPTION

The signal and interference environment are 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 Link ID to maximize throughput. The physical channel may not be changed dynamically according to the environment, thus the physical channel in use determines the Link ID's available for selection as determined by the physical channel bandwidth.

The Link ID is not allowed to be changed by a control station on failure of reception of data fragments. This is because the overall data payload is fragmented based on the Link ID used during a data transfer and the fragmentation cannot be re-adjusted for individual fragments in a data transfer.

The control station is only allowed to change the Link ID after all the fragments in a session have been successfully received. If the channel deteriorates to the extent that further communication at the current Link ID is not possible, then the complete data session will fail and may be retransmitted at a more robust Link ID by the application layer.

A ship will report a Channel Quality Indicator (CQI) to the control station which may adjust the Link ID for the next session. The ship terminal receiver shall estimate the CQI parameters based on a signal to noise plus interference ratio estimate, SNIR, given in dB. The SNIR is equivalent to E_s/N_0 on AWGN, when no interference. The CQI parameter is a positive integer value that occupies one byte, ranging from 0 to 255. The relationship between the estimated SNIR and the CQI is given by

$$CQI = 4\cdot(10+SNIR) = 40+4\cdot SNIR$$

The SNIR estimate and hence the CQI parameter is independent of the channel BW, and the carrier to noise plus interference ratio estimate, $C/(N_0+I_0)$, as given in Annex A, is related to SNIR by

$$C/(N_0+I_0)=SNIR+10\cdot\log_{10}(R_s)$$

where R_s denotes the symbol rate. An estimated SNIR value less than -10.0dB shall result in a minimum CQI value of 0, and a SNIR larger 53.75dB shall result in CQI=255. The precision of the CQI parameter is 0.25dB, but the actual accuracy is also dependent on the variance of the SNIR estimate. The CQI accuracy will thus depend on the SNIR working point, the length of the burst waveform, type of modulation and estimation method.

The SNIR can be estimated based on averaging the noise power of demodulated symbol, found by squaring the deviating distance from nominal symbol locations. The signal power is known in advance, provided that an automatic gain control loop is implemented. Such an estimation approach can be performed on known symbols (syncwords and pilot symbols), but also on unknown symbols based on symbol location decision. Another possible method for estimating the SNIR can be based on BER, counting the error corrected by the FEC Turbo coder.

During ship-to-ship communication outside of control station service area, the Link ID can be controlled by the resource allocating ship. The details for rate adaptation are not defined in this document.

The Link Adaption Model has not been defined and will be defined for future use.

C 4.9. SLOT FUNCTIONS

C 4.9.1. BULLETIN BOARD SIGNALLING CHANNEL

Bulletin board signalling channel (BBSC) slots are reserved for bulletin board message transmissions. All transactions in the BBSC shall use link ID 11.

C 4.9.2. RANDOM ACCESS CHANNEL

Random access channel (RAC) slots are reserved for requests, resource allocations or short data message transmissions by mobile stations. All transactions in the BBSC shall use link ID 11.

C 4.9.3. ANNOUNCEMENT SIGNALLING CHANNEL

Announcement signalling channel (ASC) slots are reserved for requests, assignments or ad-hoc one-slot data transmissions by the control station. All transactions in the BBSC shall use link ID 11.

C 4.9.4. DATA CHANNEL

Data channel (DC) slots are reserved for data transmission messages. The link ID used in the DC is defined by message 4, Resource allocation and may be changed with message 13, ACK/NACK.

C 4.9.5. DATA SIGNALLING CHANNEL

Data signalling channel (DSCH) slots are reserved for acknowledgements, resource allocation and resource de-allocations for the DC within the same TDMA channel. The link ID used in the DSCH is defined by message 4, Resource allocation and may be changed with message 13, ACK/NACK.

C 4.9.6. VDE-TER DEFAULT SLOT FUNCTIONS

The default slot functions are defined in Figure 25 and Figure 26.

BB	Bulletin Board Signalling Channel
RA	Random Access Signalling Channel
AS	Announcement Signalling Channel
DS	Data Signalling Channel
	Data Channel
s	Slot number

TDMA 0		0 BB	6 BB	12 BB	18 RA	24 RA	30 RA	36 RA	42 RA	48 RA	54 RA	60 RA	66 RA	72 RA	78 RA	84 RA	
TDMA 1		1	7	13	19	25	31	37	43	49	55	61	67	73	79	85 DS	
TDMA 2		2	8	14	20	26	32	38	44	50	56	62	68	74	80	86 DS	
TDMA 3		3	9	15	21	27	33	39	45	51	57	63	69	75	81	87 DS	
TDMA 4		4	10	16	22	28	34	40	46	52	58	64	70	76	82	88 DS	
TDMA 5		5	11	17	23	29	35	41	47	53	59	65	71	77	83	89 DS	
TDMA 0		90 RA	96 RA	102 RA	108 RA	114 RA	120 RA	126 RA	132 RA	138 RA	144 RA	150 RA	156 RA	162 RA	168 RA	174 RA	...
TDMA 1		91	97	103	109	115	121	127	133	139	145	151	157	163	169	175 DS	...
TDMA 2		92	98	104	110	116	122	128	134	140	146	152	158	164	170	176 DS	...
TDMA 3		93	99	105	111	117	123	129	135	141	147	153	159	165	171	177 DS	...
TDMA 4		94	100	106	112	118	124	130	136	142	148	154	160	166	172	178 DS	...
TDMA 5		95	101	107	113	119	125	131	137	143	149	155	161	167	173	179 DS	...
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
TDMA 0	...	2160 RA	2166 RA	2172 RA	2178 RA	2184 RA	2190 RA	2196 RA	2202 RA	2208 RA	2214 RA	2220 RA	2226 RA	2232 RA	2238 RA	2244 RA	
TDMA 1	...	2161	2167	2173	2179	2185	2191	2197	2203	2209	2215	2221	2227	2233	2239	2245 DS	
TDMA 2	...	2162	2168	2174	2180	2186	2192	2198	2204	2210	2216	2222	2228	2234	2240	2246 DS	
TDMA 3	...	2163	2169	2175	2181	2187	2193	2199	2205	2211	2217	2223	2229	2235	2241	2247 DS	
TDMA 4	...	2164	2170	2176	2182	2188	2194	2200	2206	2212	2218	2224	2230	2236	2242	2248 DS	
TDMA 5	...	2165	2171	2177	2183	2189	2195	2201	2207	2213	2219	2225	2231	2237	2243	2249 DS	

Figure 25 - VDE-TER Ship to Shore default slot functions (lower leg)

BB	Bulletin Board Signalling Channel
RA	Random Access Signalling Channel
AS	Announcement Signalling Channel
DS	Data Signalling Channel
	Data Channel
s	Slot number

TDMA 0		0 BB	6 BB	12 BB	18 RA	24 AS	30 RA	36 AS	42 RA	48 AS	54 RA	60 AS	66 RA	72 AS	78 RA	84 AS	
TDMA 1		1	7	13	19	25	31	37	43	49	55	61	67	73	79	85 DS	
TDMA 2		2	8	14	20	26	32	38	44	50	56	62	68	74	80	86 DS	
TDMA 3		3	9	15	21	27	33	39	45	51	57	63	69	75	81	87 DS	
TDMA 4		4	10	16	22	28	34	40	46	52	58	64	70	76	82	88 DS	
TDMA 5		5	11	17	23	29	35	41	47	53	59	65	71	77	83	89 DS	
TDMA 0		90 RA	96 AS	102 RA	108 AS	114 RA	120 AS	126 RA	132 AS	138 RA	144 AS	150 RA	156 AS	162 RA	168 AS	174 RA	...
TDMA 1		91	97	103	109	115	121	127	133	139	145	151	157	163	169	175 DS	...
TDMA 2		92	98	104	110	116	122	128	134	140	146	152	158	164	170	176 DS	...
TDMA 3		93	99	105	111	117	123	129	135	141	147	153	159	165	171	177 DS	...
TDMA 4		94	100	106	112	118	124	130	136	142	148	154	160	166	172	178 DS	...
TDMA 5		95	101	107	113	119	125	131	137	143	149	155	161	167	173	179 DS	...
	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
TDMA 0	...	2166 AS	2166 RA	2172 AS	2178 RA	2184 AS	2190 RA	2196 AS	2202 RA	2208 AS	2214 RA	2220 AS	2226 RA	2232 AS	2238 RA	2244 AS	
TDMA 1	...	2161	2167	2173	2179	2185	2191	2197	2203	2209	2215	2221	2227	2233	2239	2245 DS	
TDMA 2	...	2162	2168	2174	2180	2186	2192	2198	2204	2210	2216	2222	2228	2234	2240	2246 DS	
TDMA 3	...	2163	2169	2175	2181	2187	2193	2199	2205	2211	2217	2223	2229	2235	2241	2247 DS	
TDMA 4	...	2164	2170	2176	2182	2188	2194	2200	2206	2212	2218	2224	2230	2236	2242	2248 DS	
TDMA 5	...	2165	2171	2177	2183	2189	2195	2201	2207	2213	2219	2225	2231	2237	2243	2249 DS	

Figure 26 - VDE-TER Ship to Ship and Shore to Ship default slot functions (upper leg)

C 4.10. VDE MESSAGE SUMMARY

Table 32 – VDE Message Summary

Type	Name	Description	Slot Function
0	Media access control	Changes random access selection interval.	BB, AC
4	Resource allocation	Allocated LC resource to data session.	AC, RAC, DSCH
13	ACK/NACK	Acknowledgement or negative-acknowledgement.	AC, RAC, DSCH
14	Very short ACK/ACM (satellite Link ID 20 only)	Acknowledgement or negative-acknowledgment.	RAC
20	Bulletin board message start fragment	Start fragment of bulletin board message used for control station service area configuration.	BB
21	Bulletin board message continuation fragment	Middle fragment of bulletin board message used for control station service area configuration.	BB
22	Bulletin board message end fragment	Last fragment of bulletin board message used for control station service area configuration.	BB
41-56	Very short RA message from ship (satellite Link ID 20 only)	Very short 3 bytes data message. ACK is required.	RAC
58-73	Very short RA message from ship (satellite Link ID 20 only)	Very short 3 bytes data message. ACK is not required.	RAC
74	Start fragment	Start data fragment of data session.	DC
75	Continuation fragment	Middle data fragment of data session.	DC
76	End fragment	Last data fragment of data session.	DC
81	Padding byte	Byte used for padding.	BB, AC, RAC, DSCH
90	Resource request/ Transmission announcement	Request resource from station or announce transmission to follow.	AC, RAC

C 4.11. VDE MESSAGE DESCRIPTIONS

C 4.11.1. MEDIA ACCESS CONTROL

Table 33 – Media Access Control

Media access control				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	000	1	Type	
2	0 to 2^{16}-1	2	Length	8: Total size in bytes, fixed at 8 bytes
3	0-255	1	Media Access priority level	Reserved for future use. Always 0.
4	0-511	2	Random access selection interval	The Random Access scheme selection interval in hexslots. 0 – Default selection interval applies
5	0-127	1	Short data message limit	Maximum allowed number of Short Data Message transmissions on the RACH during a frame.
6	0-255	1	System status	0: Normal 10: Busy 20: Temporarily out of service 30: Scheduled out of service

Note:
Provides methods for granting data transfer access.
When a mobile station receives a MAC message, this message takes preference over the BB message parameters and the mobile station should apply the random access selection interval for a duration selected randomly between 4 and 8 minutes. After the expiry of the duration, the random access selection interval should revert back to the parameters specified by the BB. Similar as behaviour specified in ITU-R.M1371-5 3.14.
If the random access selection interval is set to 0, then the BB random access selection interval applies.

C 4.11.2. RESOURCE ALLOCATION

Table 34 – Resource Allocation

Resource allocation				
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	Source ID	Source MMSI number.
4	0 to 2^{32}-1	4	Destination ID	MMSI number of ship being assigned a logical channel.
5	0-255	1	Logical Channel Tx	Logical channel assigned to the session for transmission. Transmission only applies to data slots.(1) LC of 255 indicates no resource.
6	0-255	1	Logical Channel Rx	Logical channel assigned to the session for reception. Reception only applies to data signalling slots.(1) LC of 255 indicates no resource.
7	0-255	1	Link ID	The link ID that must be used in the TDMA channel. This will apply to Messages 74, 75, 76 and 13.
8	0-255	1	TDMA frame delay	The number of TDMA frames to delay before the resource may be used. Default 0. (2)
9(4)	0-255	1	Session ID	Session ID. The session is uniquely identified by the combination of the session ID, transmitting station MMSI, receiving station MMSI and channel.
10	0-255	1	CQI	Received C/N_0 in dBHz

Notes:

(1) The resource allocation message will always be sent on the signalling channel when being sent in response to a Resource Request (#90) message and will always be sent in the assigned TDMA channel when sent in response to a Continuation Fragment (#75). When the Resource Allocation message is being sent in the assigned TDMA channel, then the message must be transmitted in the same VDE packet as the Ack (#13) message. See Fragment Continuation for more details.
(2) When assigning a Logical Channel, then both the Logical Channel Tx and the Logical Channel Rx must have identical TDMA channel numbers. The assigned LCs may have the same Physical Channels for simplex communication and different Physical Channels for duplex communication.
(3) The TDMA frame delay allows for the efficient transferral of Logical Channels from one vessel to another with as little as possible wasting of slots.
(4)The Session ID is reserved for future use.

C 4.11.3. ACK/NACK

Table 35 – ACK/NACK

ACK/NACK				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	013	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes.
3	0 to 2^{32}-1	4	Source ID	Source MMSI.
4	0 to 2^{32}-1	4	Destination ID	Destination MMSI.
5(1)	0-255	1	Session ID	Session ID of data session.
6	0 to 2^{16}-1	2	ACK/NACK mask 0	When a packet was not received, then its corresponding bit must be set to one to Not Acknowledge the packet. Each NACK mask corresponds to a data transfer session that started with a Start Fragment and ended with a Continuation Fragment. If the Start Fragment is not received, then the least significant bit is set. The first Continuation Fragment corresponds with the next bit, and so on, with the End Fragment being represented by the last bit. If there were 10 fragments and the End Fragment was not received, then the NACK mask must be or-ed with 0x0200. NACK mask 2 represents the latest session received directly before this message response. NACK mask 1 represents the second to last session received. NACK mask 0 represents the third to last session received.
7	0 to 2^{16}-1	2	NACK mask 1	
8	0 to 2^{16}-1	2	NACK mask 2	
9	0-255	1	CQI	Received C/N_0 in dBHz
10	0-255	1	ACM or EDN	0: Maintain Link ID. 1: Increment Link ID (higher rate) 2: Decrease Link ID. 3: End Delivery Notification The Link ID may only be changed if all the fragments have been successfully received and the ACK/NACK mask is set to 0. Changing the Link ID must not change the channel bandwidth.
11	0-255	1	Power setting	0: Maintain Power Level 1: Increase Power Level (Reserved for future use). 2: Decrease Power Level (Reserved for future use).

Notes:
The ACK/NACK message will be transmitted in the Data Signalling Channels on the same Logical Channel as defined by the "Logical Channel Rx" assigned by the Resource Allocation (#4).
During short addressed message transmissions, the ACK/NACK message will be transmitted on the RAC.
(1) Session ID is reserved for future use.

C 4.11.4. Very short Ack/Acm – satellite Link ID 20 only

Table 36 – Very Short ACK/ACM – Satellite Link ID 20 Only

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	Source ID	Source MMSI
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. The MSB is set for fragment 16 and the LSB for fragment 1. For example, 0x0005 to indicate fragment 1 and fragment 3.
5	0-255	1	CQI	Received C/N_0 in dBHz
6	0 to 2^{16}-1	2	CRC-2	16 bit CRC used

C 4.11.5. Resource request/Transmission announcement

Table 37 – Resource Request / Transmission Announcement

Resource request/Transmission announcement				
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.
3	0 to 2^{32}-1	4	Original Source ID	Source MMSI of station where the message originated from.
4	0 to 2^{32}-1	4	Node Source ID	Source MMSI of the current node transmitting the message.
5	0 to 2^{32}-1	4	Node Destination ID	Destination MMSI of the current node receiving the message.
6	0 to 2^{32}-1	4	Original Destination ID	Destination MMSI of the original destination.
7	0-255	1	Priority	Set to 0. Reserved for future use.
8	0 to 2^{32}-1	4	Terminal capabilities	This field is a 32-bit bitmask with each bit set to indicate capabilities/restrictions of a unit: Bit 0: All Bandwidths and modulation schemes as per VDE v1.0 supported. Bit 1: Unit has only 1 VDE receiver. Bit 2 to 31: Reserved for future use. Should be set to zero.

Note:
The Resource request message will be transmitted on the RAC by ships and ASC by shore stations.
The four MMSI numbers allow for multiple hops of data messages between many stations. The original source and original destination IDs are the end points of the communication while the node source and node destination IDs are the immediate stations communicating with each other during the current hop.

C 4.11.6. SHORT DATA MESSAGE (WITH ACK)

Table 38 – Short Data Message (with ACK)

Short data message (with ACK)				
Field no	Value (Dec)	Size (bytes)	Function	Comment
1	92	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable.
3	0 to 2^{32}-1	4	Source ID	Source MMSI.
4	0 to 255	1	Session ID	Session ID. The session is uniquely identified by the combination of the session ID, transmitting station MMSI, receiving station MMSI.
5	0 to 2^{32}-1	4	Destination ID	Destination MMSI.
6	0 to 255	1	Retransmission no	Starts with value 0 and increments with every retransmission. Handles lost ACKs Value of 255 indicates no ACK is requested.
7		Variable	Payload	

Note:
Must always be transmitted on the RAC by ship and ASC by shore station. The short data message ACK message must be transmitted on the RAC by ship and ASC by shore.

C 4.11.7. BULLETIN BOARD START FRAGMENT MESSAGE

Table 39 – Bulletin Board Start Fragment Message

Bulletin board start fragment message				
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	0 to 2^{32}-1	4	Source ID	Source MMSI.
4	0 to 255	1	Control station ID	
5	0 to 2^{16}-1	2	Bulletin Board version	Version number of this Bulletin Board All valid versions are stored in the ship terminal (includes Configuration Message)
6	0 to 255	1	Number of fragments	Must be a value from 1 to 6 (TBC)
7		Variable	Bulletin Board Payload	See Bulletin Board Payload Definition Table 40

Table 40 – Bulletin Board Payload

Bulletin board payload				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	0 to 2^{32}-1	4	Start time for this version	UTC start time for this version of the Bulletin Board in number of seconds since 1. January 2000 00:00:00 UTC
2	0 to 2^{16}-1	2	Validity of this version	Lifetime of this version in number of 1 minute frames Up to 45 days
3	0 to 255	1	TDMA frame size	The size of TDMA frames in hexslots. May have the following values: 2, 3, 5, 6, 9, 10, 15 (default) Only 15 have to be supported. Not used for satellite.

4		Variable	Physical Channel definitions	See Physical Channel Definition Table 43.
5	0 to 255	1	Modulation, coding and protocol versions supported	Reserved for future use. Set to zero. 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. Reserved for future use. Must be set to 0.
6		7	Control station service area point 1	Parameter (longitude and latitude) defining the control station service area North East corner. GNSS rectangle longitude and latitude as defined in Recommendation ITU-R M.1371 Annex 5 3.1 and used for AIS Message 1, 2, 3 position report.
7		7	Control station service area point 2	Parameter (longitude and latitude) defining the control station service area South West corner. GNSS rectangle longitude and latitude as defined in Recommendation ITU-R M.1371 Annex 5 3.1 and used for AIS Message 1, 2, 3 position report.
8		32	Authentication and integrity sequence	Reserved for future use. Set to zero.
9		9	Padding	Reserved for future use. Set to zero.

C 4.11.8. BULLETIN BOARD CONTINUATION FRAGMENT MESSAGE

Table 41 – Bulletin Board Continuation Fragment Message

Bulletin board continuation fragment message				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	021	1	Type	
2	0 to 2^{32}-1	4	Source ID	Source MMSI.
3	0 to 255	1	Control station ID	
4	0 to 2^{16}-1	2	Bulletin Board version	Version number of this Bulletin Board All valid versions are stored in the ship terminal (includes Configuration Message)
5	0 to 255	1	Fragment number	Must be a value from 2 to 5 (TBC)
6		Variable	Bulletin Board Payload	See Bulletin Board Payload Definition Table 40

C 4.11.9. BULLETIN BOARD END FRAGMENT MESSAGE

Table 42 – Bulletin Board End Fragment Message

Bulletin board end fragment message				
Field no	Value (Dec)	Size (Bytes)	Function	Content
1	022	1	Type	
2	0 to 2^{16}-1	2	Length	Total size in bytes, variable
3	0 to 2^{32}-1	4	Source ID	Source MMSI.
4	0 to 255	1	Control station ID	
5	0 to 2^{16}-1	2	Bulletin Board version	Version number of this Bulletin Board All valid versions are stored in the ship terminal (includes Configuration Message)
6	0 to 255	1	Fragment number	Must be a value from 2 to 6 (TBC)
7		Variable	Bulletin Board Payload	See Bulletin Board Payload Definition Table 40.

Table 43 - Physical Channel Definition

Name	Value	Field size (bits)	Comment
Number of Physical Channels N	0 to 255	8	Number of physical channels defined in control station service area.
Physical Channel 0 (PC0) number	0 to 255	8	Defines the first physical channel number.
PC0 Channel Frequency Index (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
PC0 Tx flag	0 or 1	1	0 – mobile may not transmit on this PC 1 – mobile may transmit on this PC
PC0 RA Selection Interval	0 to 511	9	The Random Access scheme selection interval in hexslots. 0 for default.
PC0 Short Data Message Limit	0 to 127	7	Maximum allowed number of Short Data Message transmissions on the RACH during a frame.
PC0 Logical Channel Definition	See Logical Channel Definition Table 44.	Variable	Defines the logical channel definition of physical channel 0
…	…	…	…
Physical Channel N (PCN) number	0 to 255	8	Defines the last physical channel number.
PCN Channel Frequency Index (CFI)	156-162.0375 MHz, 12.5 kHz step Channels 0-482	9	VDES upper leg: 465: 161.8125 MHz (TER default) 469: 161.8625 MHz 473: 161.9125 MHz (SAT default)
PCN Tx flag	0 or 1	1	0 – mobile may not transmit on this PC 1 – mobile may transmit on this PC
PCN RA Selection Interval	0 to 511	9	The Random Access scheme selection interval in hexslots. 0 for default.
PCN Short Data Message Limit	0 to 127	7	Maximum allowed number of Short Data Message transmissions on the RACH during a frame.
PCN Logical Channel Definition	See Logical Channel Definition Table 44.	Variable	Defines the logical channel definition of physical channel N.

Table 44 - Logical Channel definition

Name	Value	Field size (bits)	Comment
TDMA 0 LC Count	0 to 63	6	Number of logical channels defined inside TDMA channel 0.
TDMA 1 LC Count	0 to 63	6	Number of logical channels defined inside TDMA channel 1.
TDMA 2 LC Count	0 to 63	6	Number of logical channels defined inside TDMA channel 2.
TDMA 3 LC Count	0 to 63	6	Number of logical channels defined inside TDMA channel 3.
TDMA 4 LC Count	0 to 63	6	Number of logical channels defined inside TDMA channel 4.
TDMA 5 LC Count	0 to 63	6	Number of logical channels defined inside TDMA channel 5.
LC 0 Function	0 to 4	3	Slot Function for Terrestrial 0 – Bulletin Board 1 – Random Access 2 – Announcement Signalling 3 – Data 4 – Data Signalling Slot Function for Satellite

Name	Value	Field size (bits)	Comment
			0 – Bulletin Board 1 – Random Access 2 – AS/Data Down 3 – Data Down 4 – Data Up
LC 0 Repeat	0 to 511	9	Slot duration of function. When set to 0, the slot function is set to a duration of 1 slot and doesn't repeat.
…	…	…	…
LC N Function	0 to 4	3	Slot Function for Terrestrial 0 – Bulletin Board 1 – Random Access 2 – Announcement Signalling 3 – Data 4 – Data Signalling Slot Function for Satellite 0 – Bulletin Board 1 – Random Access 2 – AS/Data Down 3 – Data Down 4 – Data Up
LC N Repeat	0 to 511	9	Slot duration of function. When set to 0, the slot function is set to a duration of 1 slot and doesn't repeat.
Padding	0	4 if total number of LC definition pairs are even. 0 if total number of LC definition pairs are odd.	Padded with 0 valued bits to ensure byte alignment of Logical Channel Definition.

Note:
See C 4.15 for explanation.

C 4.11.10. VERY SHORT RA MESSAGE FROM SHIP – SATELLITE LINK ID 20 ONLY (WITH ACK)

Table 45 – Very Short RA Message from ship – SatelliteLink ID 20 Only

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	Source ID	Source MMSI
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

C 4.11.11. VERY SHORT RA MESSAGE FROM SHIP – SATELLITE LINK ID 20 ONLY (WITHOUT ACK)

Table 46 – Very Short RA Message from ship – Satellite Link ID 20 Only

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	Source ID	Source MMSI
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

C 4.11.12. START FRAGMENT

Table 47 – Start Fragment

Start 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^{32}-1	4	Source ID	Source MMSI of the current node transmitting this message.
4	0 to 2^{32}-1	4	Destination ID	Destination MMSI of the current node receiving this message. Set to 0 for broadcast.
5(1)	0-255	1	Session ID	Session ID. The session is uniquely identified by the combination of the session ID, Source ID, Destination ID and channel.
6	0 to 255	1	Number of Fragments	Number of fragments in this session. Must be a value from 1 to 14.
7	0 to 255	1	Fragment Number	Fragment number of the payload in this message.
8		Variable	Payload	

Note:
Must always be transmitted on the TDMA channel (derived from the Logical Channel) as assigned by a resource allocation.
Will always be transmitted to carry payload of first data fragment.
(1)Session ID is reserved for future use.

C 4.11.13. CONTINUATION FRAGMENT

Table 48 – Continuation Fragment

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	Source ID	Source MMSI.
4(1)	0-255	1	Session ID	Session ID. The session is uniquely identified by the combination of the session ID, Source ID, Destination ID and channel.
5	0 to 2^{32}-1	4	Destination ID	Destination MMSI of the current node receiving this message. Set to 0 for broadcast.

6	0-255	1	Fragment Number	Fragment number of the payload in this message.
7	0 to 255	1	Reserved	Reserved for future use. Set to zero.
8		Variable	Payload	

Note:
Must always be transmitted on the data channel (derived from the Logical Channel) as assigned by a resource allocation.
(1)Session ID is reserved for future use.

C 4.11.14. END FRAGMENT

Table 49 – End Fragment

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	Source ID	Source MMSI.
4(1)	0-255	1	Session ID	Session ID. The session is uniquely identified by the combination of the session ID, Source ID, Destination ID and channel.
5	0 to 2^{32}-1	4	Destination ID	Destination MMSI of the current node receiving this message. Set to 0 for broadcast.
6	0-255	1	Fragment Number	Fragment number of the payload in this message
7	0-255	1	Continue Data Session	0 – Ends data session. 1 – Continues data session with new session ID.
8		Variable	Payload	

Note: The resource allocation broadcast by the base station repeatedly broadcasts during the TDMA Frame length.
Must always be transmitted on the data channel (derived from the Logical Channel) as assigned by a resource allocation.
Will always be transmitted on last fragment signalling the end of Logical Channel use, unless only one fragment will be transmitted. When only one fragment will be transmitted, then only a Start Fragment will be transmitted.
(1)Session ID is reserved for future use

C 4.11.15. PADDING SINGLE BYTE

Table 50 – Padding Single Byte

Padding single byte				
Field no	**Value (Dec)**	**Size (Bytes)**	**Function**	**Content**
1	081	1	Type	1 byte padding

C 4.12. CYCLIC REDUNDANCY CHECK

Refer to A 1.2.5.

C 4.13. ACKNOWLEDGEMENT (ACK)

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

Acknowledgement behaviour for the terrestrial link is described in C 4.20.

C 4.14. LOGICAL CHANNELS (LC)

A logical channel defines a grouping of slots that can be uniquely identified and assigned for a specific use.

Logical Channels map slots to slot functions. Logical Channel numbers are used to assign resources to data sessions.

C 4.15. BULLETIN BOARD

The Bulletin Board message defines the slot map for each Physical Channel. The Bulletin Board content is defined in C 4.11.7. A Bulletin Board message defines a list of Physical Channels and each Physical Channel Definition contains six TDMA Channels, each TDMA channel can contain one or more Logical Channels.

A Logical Channel definition starts by announcing the number of Logical Channel definitions per TDMA Channel. Each TDMA Channel, in turn, gets its number of Logical Channels defined by function and duration item pairs. The complete TDMA Channel slotmap is built up by repeating each TDMA channel's Logical Channel definition from the first hexslot up to the end of a frame. The Logical Channels must be sized to ensure the repeating pattern aligns with a full frame.

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 C 4.16.

A VDES station shall always use the latest valid Bulletin Board that is received. The Bulletin Board shall be used in the frame immediately following the frame in which it is received.

The Bulletin Board may be transmitted in either the upper or the lower leg in channels 2084 or 1084 respectively. The mobile station must therefore always listen for the bulletin board announcement in both upper leg (channel 2084) and lower leg (channel 1084).

C 4.16. VDE-TER DEFAULT PHYSICAL CHANNEL AND SLOTMAP

A slotmap defines the LC of all the slots in a frame. Each Physical Channel in a VDES system will have a valid slotmap defined. By monitoring the Terrestrial Bulletin Board, ships will determine if they are within a control station service area and adopt the Physical Channel and slotmap from the Bulletin Board. In the absence of a Bulletin Board the default Physical Channel and slotmap will be applied.

The default Physical Channel centre frequency is located in the middle of each VDE1 upper (161,8375MHz) and lower VDE leg (157,2375MHz) and the default bandwidth is set to 100kHz.

Default LC for VDE lower and upper legs are defined as shown in Figure 27 and Figure 28.

Signalling only takes place in RA, ASC and DSCH slots. For VDE-TER, the default slot map keeps all signalling in TDMA 0 channel and at the DSCH slot at the end of every TDMA frame.

TDMA 1-5 channels are broken into TDMA frames of 15 slots where data transfer can take place on the first 14 (DC) slots while the 15^{th} slot (DSCH) is used for ACK/NACK and resource allocation signalling.

The default Link ID for all BBSC, RA and ASC slots is 17 (Pi/4 QPSK-100kHz) and the default Link ID for all DC and DSCH slots is 19 (16 QAM-100kHz). The Link ID is set by the control station. The control station can optimise the capacity used for random access and signalling based on traffic loading.

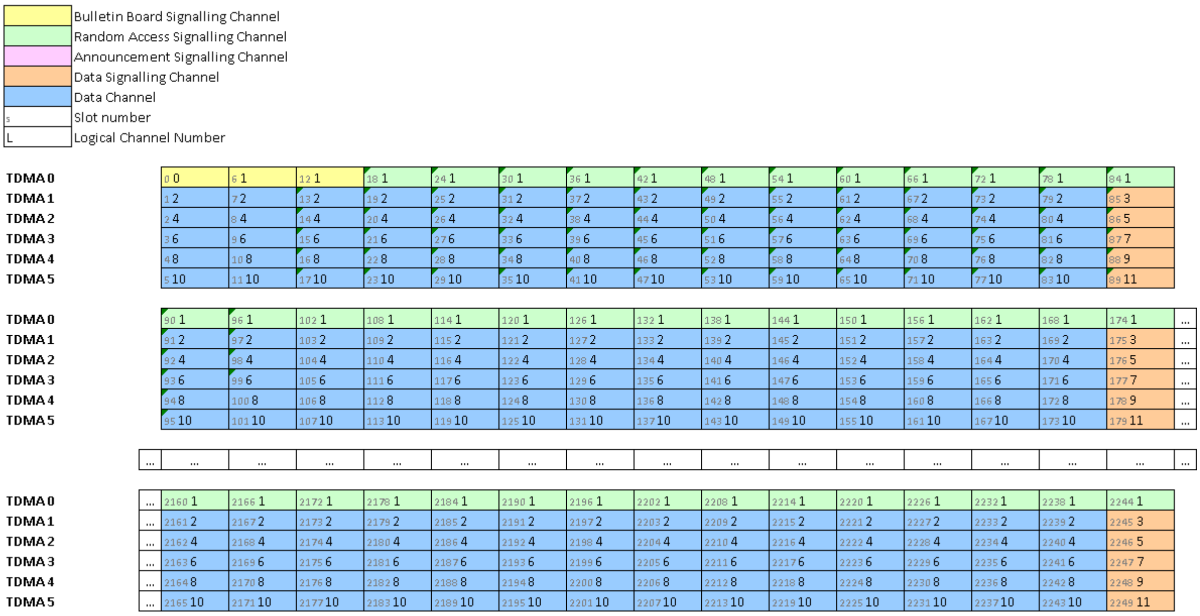

Figure 27 - VDE-TER Ship to Shore default slot to LC mapping (lower leg)

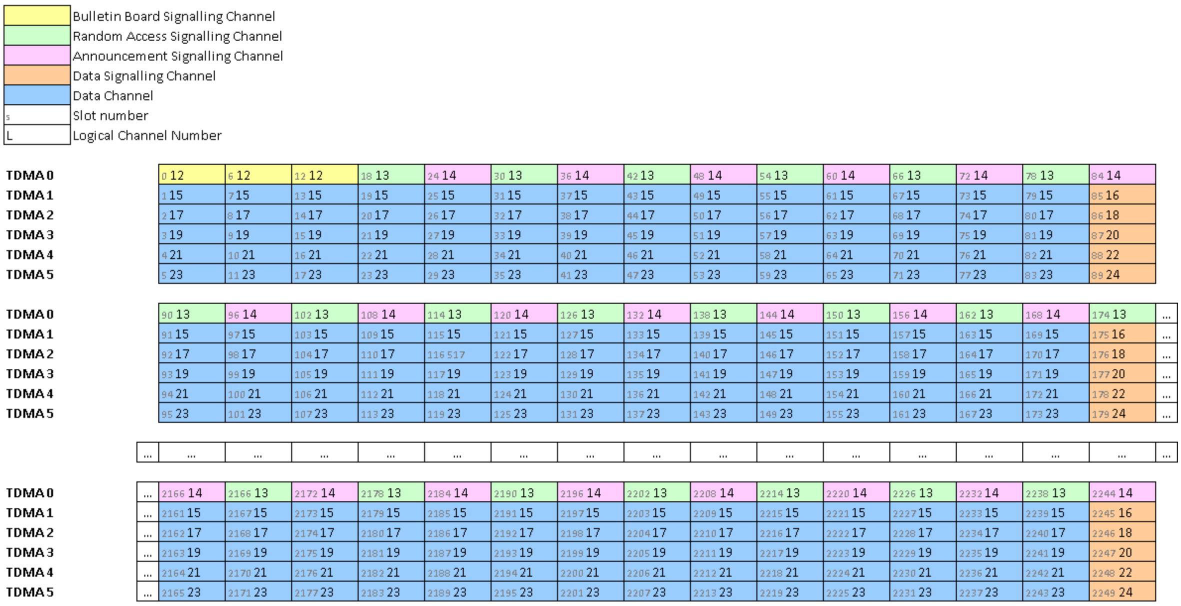

Figure 28 - VDE-TER Ship to Ship default slot to LC mapping (upper leg)

C 4.17. VDE-SAT DEFAULT BULLETIN BOARD

Hexslot 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 29 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 29 - 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 lose 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.

C 4.18. 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.

C 4.19. DATA TRANSFER PROTOCOLS

The following downlink protocols shall be supported:

- Shore originated broadcast
- Ship originated broadcast inside/outside control station service area
- Shore to ship addressed message
- Ship to shore addressed message
- Ship to ship addressed message inside/outside control station service area
- Shore to ship short data message
- Ship to shore short data message
- Ship to ship short data message

C 4.20. DATA SESSION TRANSMISSION AND CONTINUATION

For each data session between two stations, each station will be assigned one Logical Channel for data transmission and one Logical Channel for acknowledgement reception. The two Logical Channels must have identical TDMA Channel numbers but does not have to be on the same Physical Channel. This ensures adequate processing time between message transmissions. When both Logical Channels are on the same Physical Channel, the session is considered simplex (Figure 30). When the two Logical Channels are on different Physical Channels, the session is considered duplex (Figure 31).

Logical Channels assigned for data transmission sessions must have a DC slot function, while Logical Channels assigned for acknowledgement reception, must have DSCH slot function. See C 4.9.

0 and 0 shows examples of the required slot use during simplex and duplex data session transmissions when 14 fragments are transmitted during each data session. Two TDMA channels are shown from different Physical Channels.

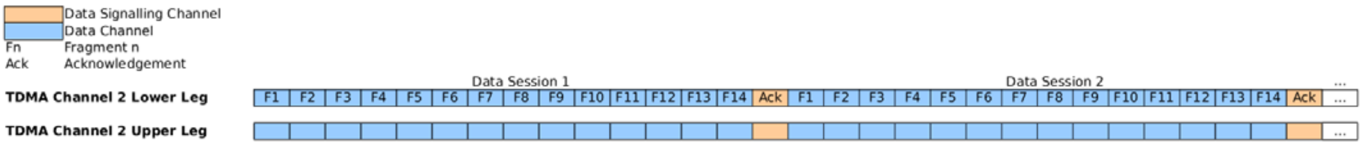

Figure 30 - Simplex data session

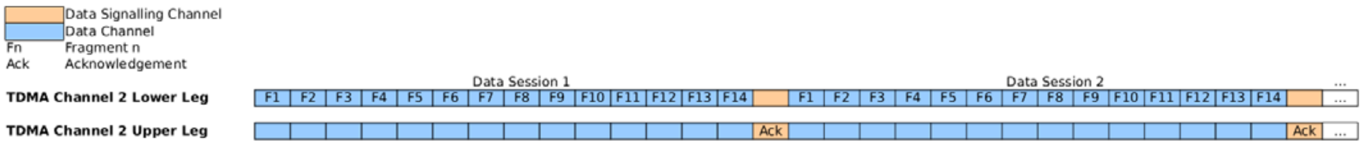

Figure 31 - Duplex data session

All data fragments will be transmitted on DC slots on the assigned Logical Channel only. ACK/NACK messages will be transmitted on the DSCH slots as assigned.

When data exceeds the data packet payload capacity, then data must be broken up and transmitted in fragments. During successful data session transmission, each session will fit into a TDMA frame. This will result in a maximum of 14 fragments per data session (one in each DC slot), before reaching a DSCH slot used for the ACK/NACK.

The first data fragment starts with a Start Fragment (#74) message, continues with Continuation Fragment (#76) messages onwards and ends with an End Fragment (#76) message.

When only one fragment is transmitted, the one fragment must be a Start Fragment (#74).

When two fragments are transmitted, then transmission order will be

1. Start Fragment (#74)
2. End Fragment (#76)

When three fragments are transmitted, then transmission order will be

3. Start Fragment (#74)
4. Continuation Fragment (#75)
5. End Fragment (#76)

Etc.

If the maximum number of fragments (14) are being used and there are data left for transmission, then the data transmission can be continued by requesting a new session ID for the next data session. The data transmission can be continued by setting the "Continue Data Session" parameter in the End Fragment (#76) message to 1. On successful transmission, the data transmission session will be acknowledged with an ACK/NACK (#7) message and a logical channel and session ID will be immediately assigned by means of a Resource Allocation (#4) message. Both messages ACK/NACK (#7) and Resource Allocation (#4) will be transmitted in the same data signalling slot. If no more LC resources are available, then an ACK/NACK #7 message may be transmitted with the ACM or EDN parameter set to 3.

C 4.21. DATA FRAME RETRY

During data frame transmission, it is expected that data fragments can be lost occasionally. When some data fragments are not received, the receiving station shall transmit a NACK message (#13) and flag the lost fragments in the ACK/NACK mask parameter.

The transmitting station shall retry transmission of each individual fragment for a maximum of 3 times before giving up.

The receiving station shall request retransmission of data fragments for a maximum of 3 attempts.

It is also possible that the NACK message (#13) is not received by the transmitting station. It is for this reason that the NACK message (#13) contains redundancy with three ACK/NACK masks, referencing the previous three sessions.

When the transmitting station does not receive an ACK/NACK, it shall continue as if all the fragments has been acknowledged. If there were any errors, then the transmitting station will see this when it receives the next ACK/NACK message. If no ACK is received within 3 sessions, then the transmitter shall stop transmitting immediately.

(orange)	Data Signalling Channel
(blue)	Data Channel
Fn	Fragment n
Fn	Dropped Fragment
ACK	Acknowledgement
NACK x,y	Negative Acknowledgement of fragments x & y

	Data Session																
TDMA Frame 1 Lower Leg	F1	F2	**F3**	F4	F5	F6	F7	**F8**	F9	F10	F11	F12	F13	F14	N.A.	N.A.	NACK 3,8
TDMA Frame 2 Lower Leg	**F3**	F8	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	N.A.	NACK 3,8	NACK 3
TDMA Frame 3 Lower Leg	**F3**	F27	F28	F29	F30	F31	F32	F33	F34	F35	F36	F37	F38	F39	NACK 3,8	NACK 3	NACK 3
TDMA Frame 4 Lower Leg	F40	F41	F42	F43	F44	F45	F46	F47	F48	F49	F50	F51	F52	F53	NACK 3	NACK 3	ACK
TDMA Frame 5 Lower Leg	F54	F55	F56	F57	F58	F59	F60	F61	F62	F63	F64	F65	F66	F67	NACK 3	ACK	ACK
TDMA Frame 6 Lower Leg	F68	F69	F70	F71	F72	F73	F74	F75	F76	F77	F78	F79	F80	F81	ACK	ACK	ACK

Figure 32 - Simplex Data Session Retry

C 4.22. COOPERATION WITH AIS

VDE transmissions must always give preference to AIS transmissions. It would be expected of AIS message transmissions to occasionally conflict with VDE message transmission times. This conflict would cause VDE messages not to be transmitted and cause the data session retry mechanism to retransmit the dropped VDE message.

A data session may greatly decrease the amount of VDE-AIS message transmission conflicts by monitoring the future slots in the current TDMA frame. During the transmission of the Start Fragment (#74), the number of fragments will be announced in the Start Fragment (#74) message. Before determining the number of fragments to be announced, the future slots can be monitored for internally allocated AIS transmissions during the current TDMA frame of the transmission LC. If the maximum number of fragments would be announced, then the announced number of fragments will be decremented by one for every VDE-AIS messate transmission conflict.

For example, if the transmitting station wanted to transmit Start Fragment (#74) with an announcement of 14 fragments but detects one AIS message transmission conflict with one of the VDE data fragments, then the transmitting station may transmit Start Fragment (#74) with an announcement of 13 fragments. This way the transmitting station will avoid the data session retry from happening and slowing down the data transfer.

C 4.23. SHORT DATA MESSAGE

Vessels may transmit short data messages in RAC slots as long as the vessel adheres to the selection interval and short data message transmission limits while inside the control station service area. When vessels are not inside a control station service area, then the default selection interval and short data message transmission limits apply.

To minimize transmissions to ships outside communications range, short data message transmission limit applies. Sending short data messages to other ships shall not use more than 2 slots over a duration of 1 minute.

C 4.24. RANDOM ACCESS CHANNEL SCHEME

When a message is scheduled for immediate RAC transmission, then all transmission candidate slots must be gathered over the selection interval. The default selection interval is 150 slots, but may be set via a control station. Only slots with slot function set as RAC may be considered as candidate slots. As an AIS transceiver forms part of the VDES system, the AIS transmission schedules must also be considered. AIS will always have priority over VDE transmissions.

One candidate slot will be randomly selected from all the available candidate slots. If no candidate slot is available or if for some reason, the VDE message could not be transmitted (AIS messages could be scheduled after the VDE schedule), then the VDE transmission will fail and the normal retry mechanism will follow. The retry mechanism will allow up to 3 retries of the RAC transmission.

C 4.25. ANNOUNCEMENT CHANNEL ACCESS SCHEME

Ad hoc messages (messages 4, 90 & 92) shall be transmitted on AC by the control station and transmitted on RAC by a mobile station to avoid any conflicts between control station and mobile stations.

When scheduling a message for AC transmission, then the first available announcement slot may be selected for transmission. A control station may choose to use RAC slots for the transmission of ad hoc messages during high congestion but must always use the Random Channel Access Scheme when accessing the RAC.

C 4.26. LOGICAL CHANNEL ACCESS

A resource assignment message assigns two LCs. One LC for TX and one LC for RX. In addition, the LC pair is assigned with a TDMA frame delay. The LC assignment goes into effect after the TDMA frame delay expires.

After the assignment of LCs to a vessel, the vessel may immediately start transmitting in the allowed LCs. Only DC slots may be used for transmission and only DSCH slot may be used for the reception of ACK/NACK and resource re-assignment or de-assignment messages.

C 4.27. LOGICAL CHANNEL USE MAP

Each station must continuously monitor the activity of VDE logical channels to be able to assign LC resources when required. A station must keep a map of all LCs and mark all of the LC as free. Whenever any data is received in a LC, reserve that LC as unavailable for the current TDMA frame and for the following three TDMA frames. Whenever a LC is used for own station transmission or reception, then a LC must be marked as internally assigned for the current TDMA frame and for the following three TDMA frames.

C 4.28. LOGICAL CHANNEL ASSIGNMENT

When a ship is outside of the control station service area, the receiving ship should be capable of assigning a LC to another ship after reception of a Resource Request message. The LC assignment must be made by randomly selecting a free LC from the Logical Channel Use Map.

C 4.29. RETRY MECHANISM

All individual message transmissions and receptions will in general be retried three times before the session will fail and be removed. Because of different selection intervals of different access schemes, the rules for the general retry mechanism will not hold for all the situations and all the special rules and cases will be shown in the state diagrams.

The retry timeouts will also be modified as the selection interval gets changed via the control station.

C 4.30. DATA TRANSFER PROTOCOL DETAIL

C 4.30.1. SHORE ORIGINATED BROADCAST

The sequence diagram for shore originated broadcast without ACK is shown in Figure 33. The transfer starts with a resource allocation. The diagram shows a large multi-fragmented data session.

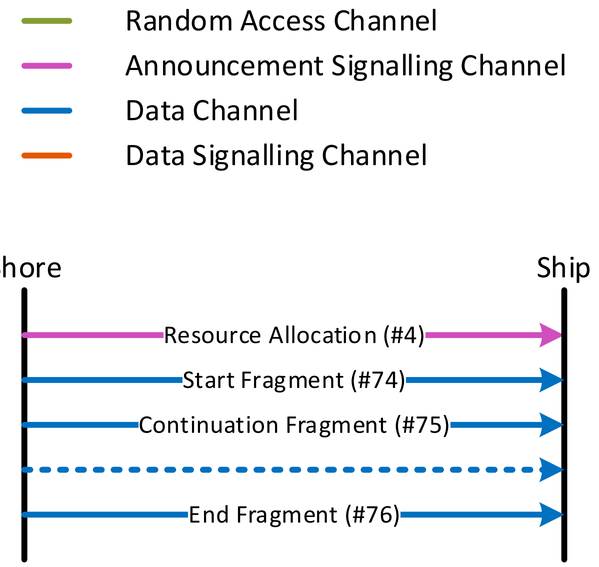

Figure 33 - Shore originated broadcast sequence diagram

C 4.30.2. SHIP ORIGINATED BROADCAST OUTSIDE CONTROL STATION SERVICE AREA

The sequence diagram for ship originated broadcast outside of control station service area is shown in Figure 34.

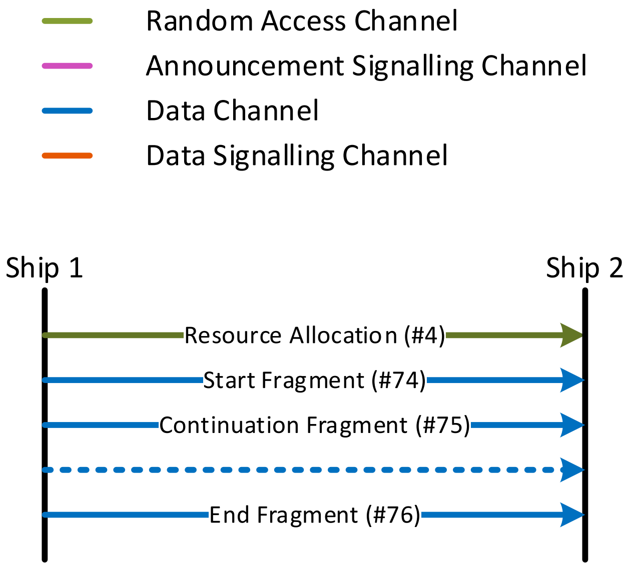

Figure 34 - Ship originated broadcast outside control station service area sequence diagram

C 4.30.3. SHIP ORIGINATED BROADCAST INSIDE CONTROL STATION SERVICE AREA

The sequence diagram for ship originated broadcast inside of control station service area is shown in Figure 35.

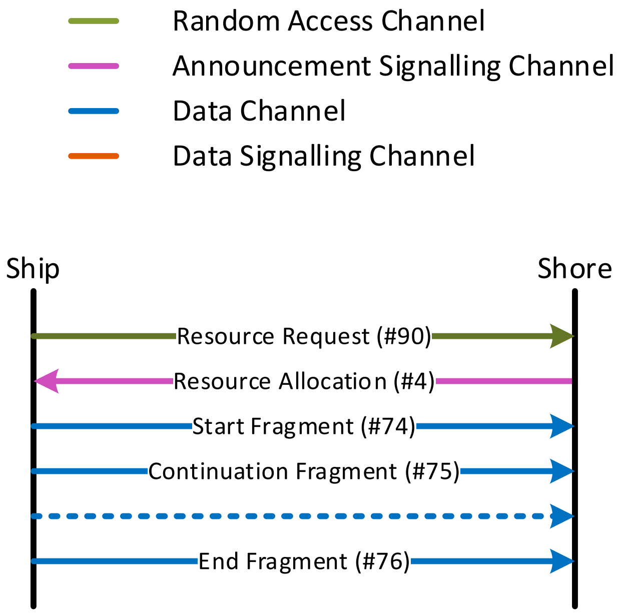

Figure 35 - Ship originated broadcast inside control station service area sequence diagram

C 4.30.4. SHORE TO SHIP ADDRESSED MESSAGE

The sequence diagram for shore to ship addressed message is shown in Figure 36. The transfer starts with a Resource Request/Transmission Announcement message to announce the source and destinations of the data session. In the same slot, a Resource Allocation message is transmitted to assign a logical channel to the data session. The diagram shows a large multi-fragmented data session. Up to 14 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 an 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.

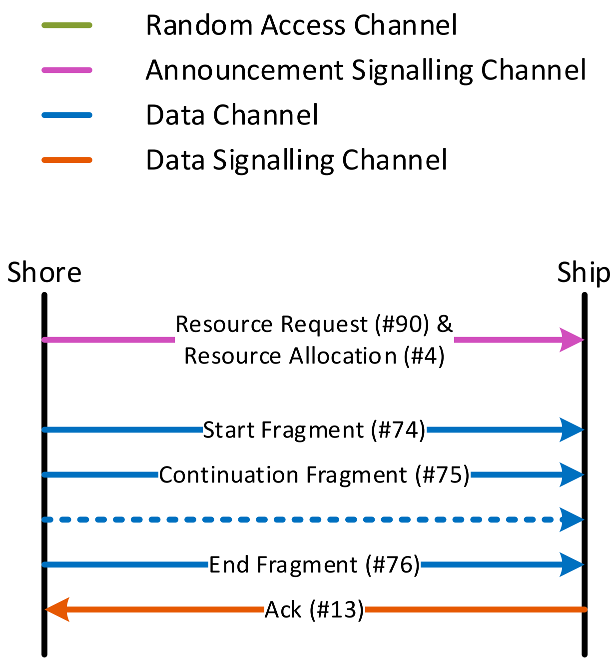

Figure 36 - Shore to ship addressed message sequence diagram

C 4.30.5. SHIP TO SHORE ADDRESSED MESSAGE

The sequence diagram for ship to shore addressed message is shown in Figure 37. The transfer starts with a Resource Request message to request a logical channel for the data session. The following Resource Allocation message is transmitted to assign a logical channel to the data session. The diagram shows a large multi-fragmented data session.

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

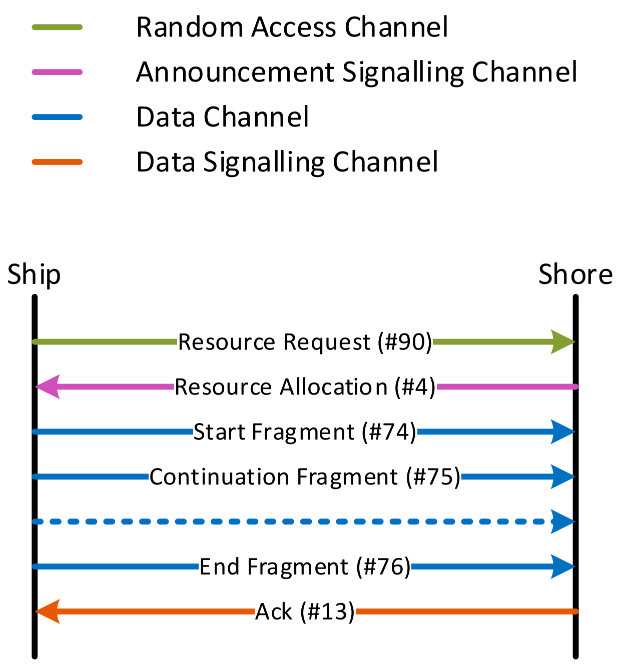

Figure 37 - Ship to shore addressed message sequence diagram

C 4.30.6. SHIP TO SHIP ADDRESSED MESSAGE OUTSIDE CONTROL STATION SERVICE AREA

The sequence diagram for ship to ship addressed message outside of control station service area is shown in Figure 38. The transfer starts with a Resource Request message to request a logical channel for the data session. The following Resource Allocation message is transmitted to assign a logical channel to the data session. The diagram shows a large multi-fragmented data session.

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

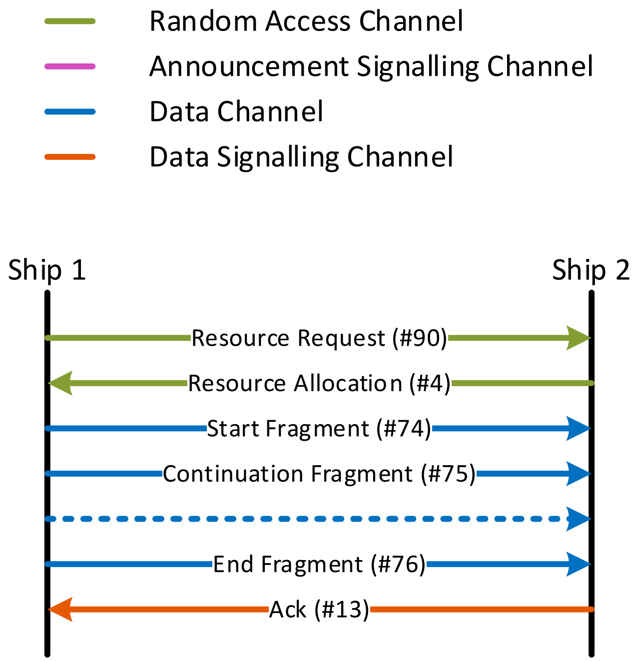

Figure 38 - Ship to ship addressed message outside control station service area sequence diagram

C 4.30.7. SHIP TO SHIP ADDRESSED MESSAGE INSIDE CONTROL STATION SERVICE AREA

The sequence diagram for ship to ship addressed message inside of control station service area is shown in Figure 39. The transfer starts with a Resource Request message to request a logical channel for the data session. The following Resource Allocation message is transmitted to assign a logical channel to the data session. The diagram shows a large multi-fragmented data session.

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

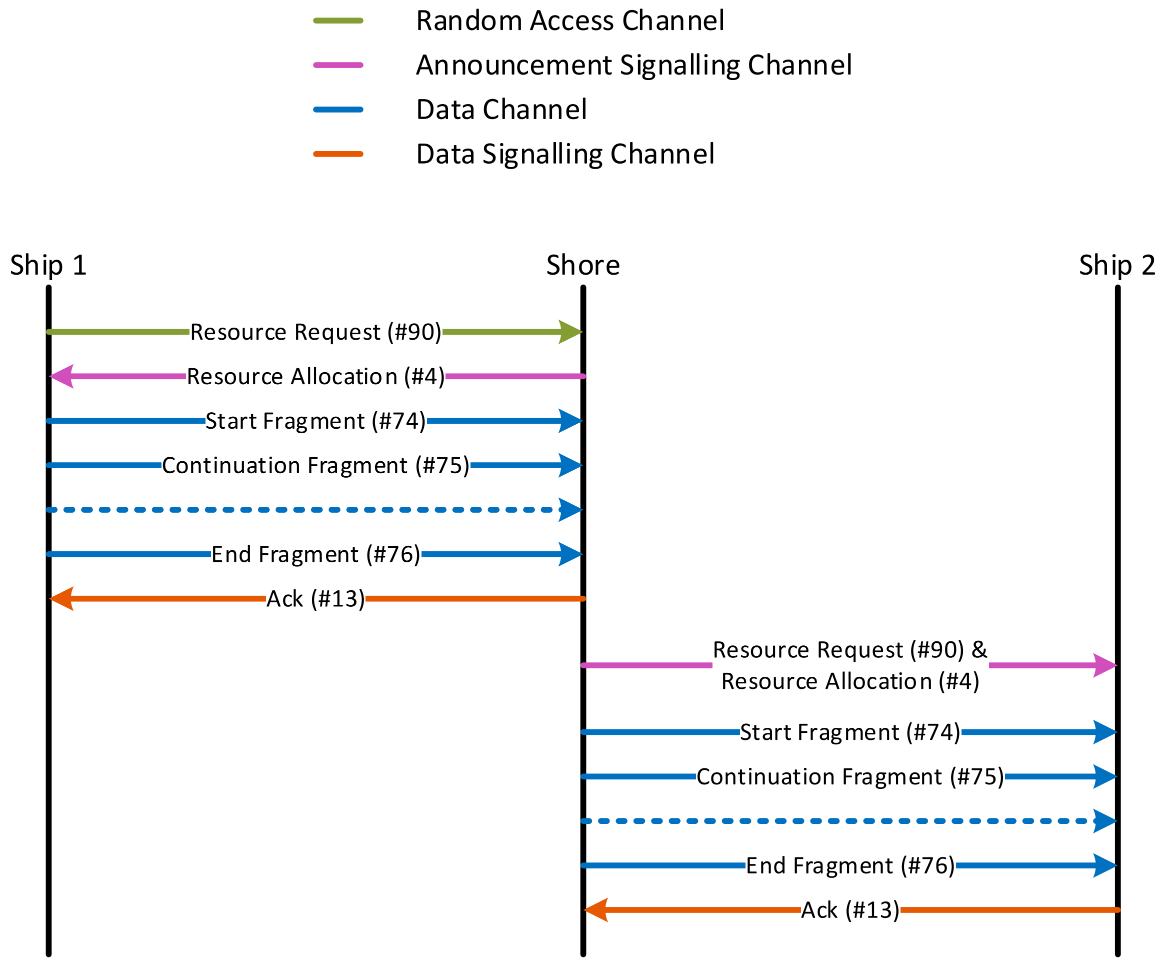

Figure 39 - Ship to ship addressed message inside control station service area sequence diagram

C 4.30.8. SHORE TO SHIP SHORT DATA MESSAGE

The sequence diagram for shore to ship short data message is shown in Figure 40. This protocol is used for short data messages that fit within a single transmission burst.

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

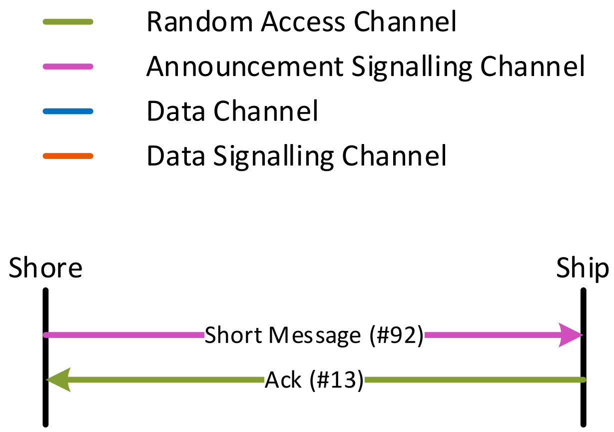

Figure 40 - Shore to ship short data message sequence diagram

C 4.30.9. SHIP TO SHORE SHORT DATA MESSAGE

The sequence diagram for ship to shore short data message is shown in Figure 41. This protocol is used for short data 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.

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

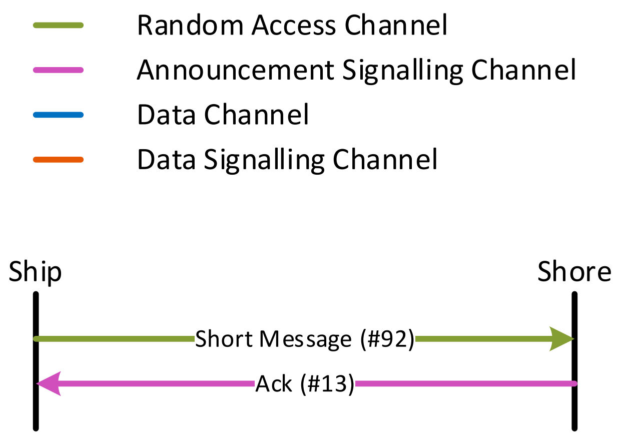

Figure 41 - Ship to shore short data message sequence diagram

C 4.30.10. SHIP TO SHIP SHORT DATA MESSAGE

The sequence diagram for ship to ship short data message is shown in Figure 42. This protocol is used for short data 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.

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

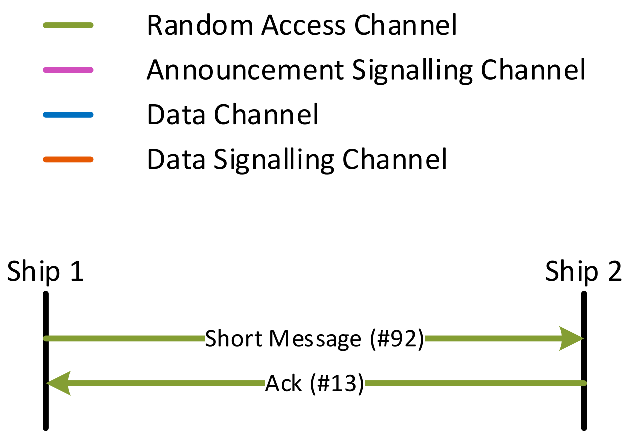

Figure 42 - Ship to ship short data message sequence diagram

C 4.31. DATA TRANSFER PROTOCOL STATE DIAGRAMS

C 4.31.1. SHIP TO SHIP ADDRESSED MESSAGE OUTSIDE CONTROL STATION SERVICE AREA

The state diagrams Figure 43 and Figure 44 shows an example of an implementation for the default PC and LC.

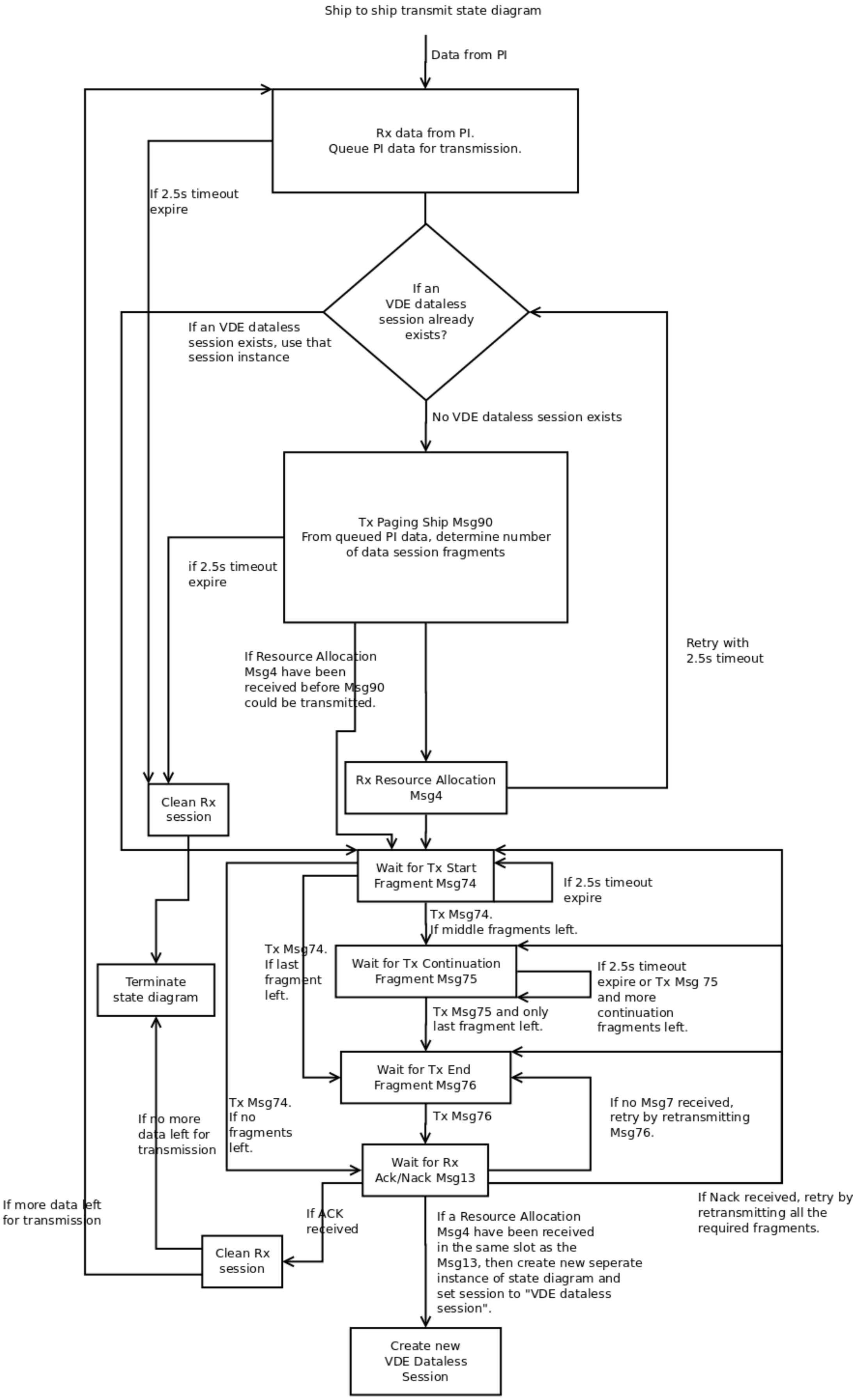

Figure 43 - Example Addressed ship to ship transmit state diagram

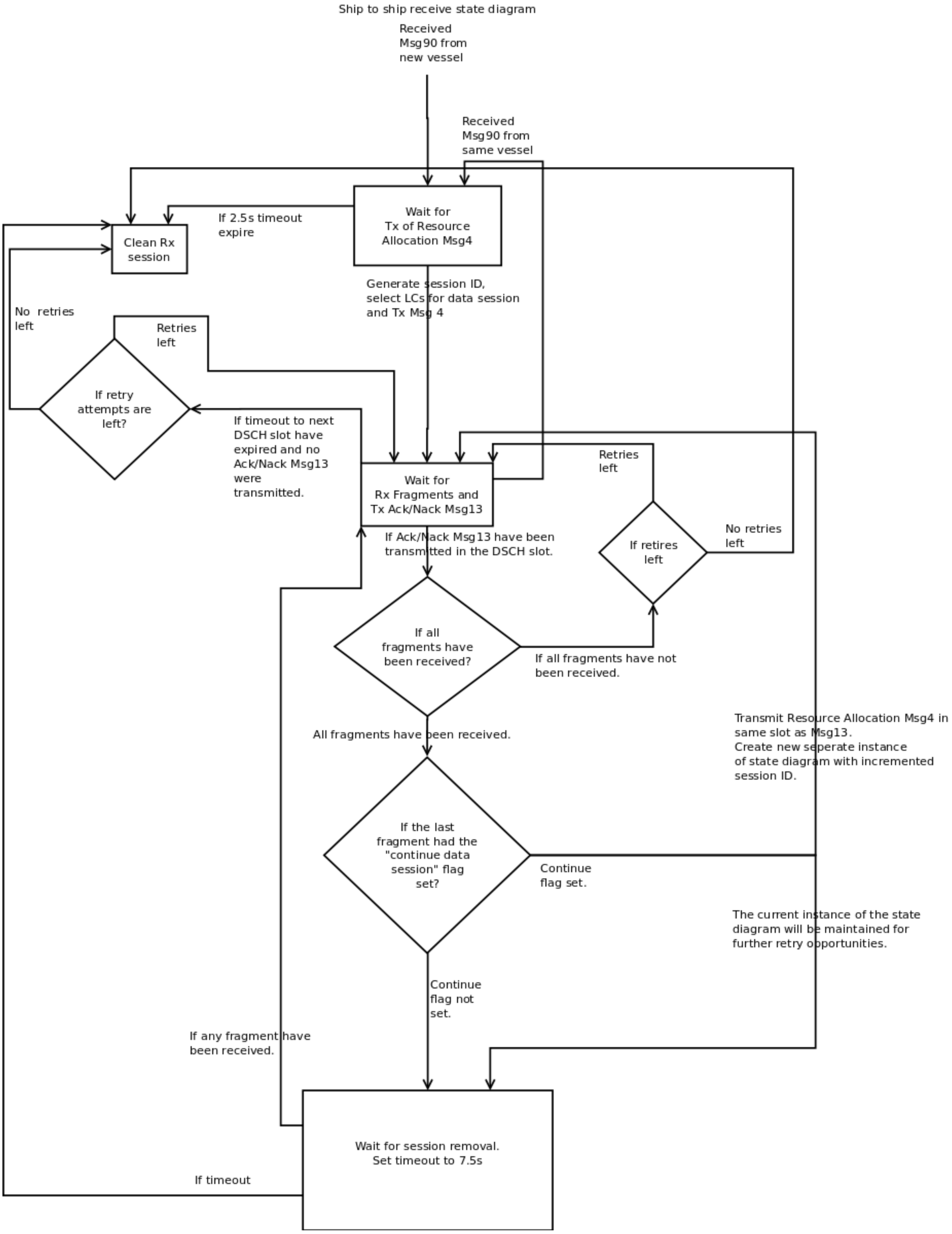

Figure 44 - Example Addressed ship to ship receive state diagram

C 4.32. SEGMENTATION OF VDE PAYLOAD

For the transmission of VDE data, the VDE payload data shall be entered via the PI by means of an EDM sentence. See C 8.1. Each EDM sentence enters an EDM data chunk and a sequential ID to be transmitted as VDE payload.

VDE payload segments get packed inside the fragment as shown in Figure 45.

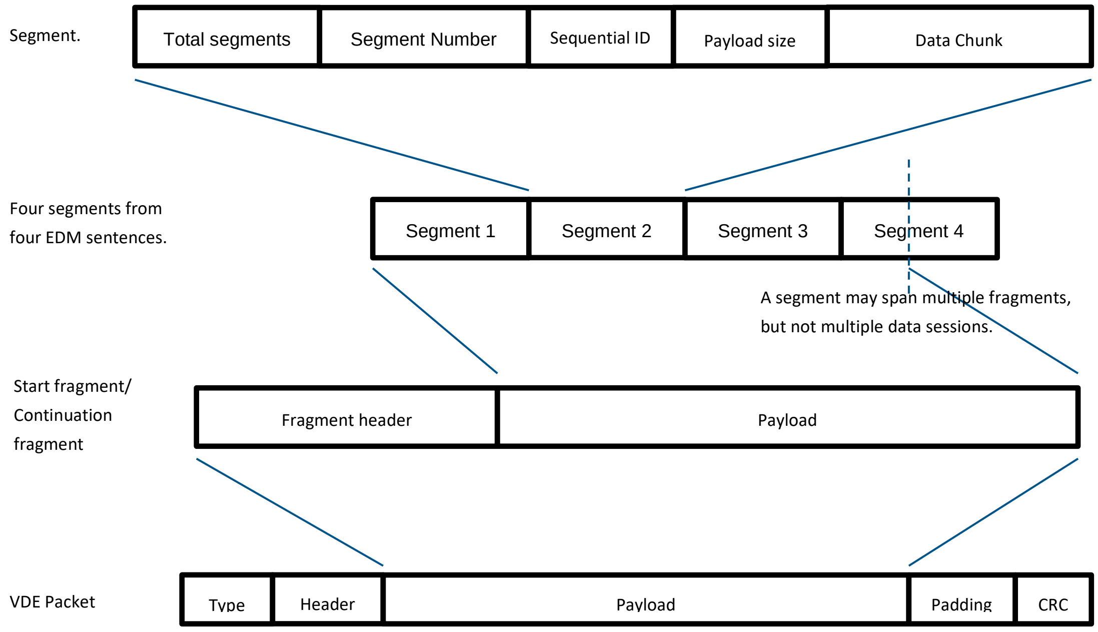

Figure 45 - Segmentation of VDE payload

Segments may span multiple fragments, but not multiple data sessions. EDM sentence data should normally be added as one segment. Only when a segment is found to span multiple data sessions, may the segment be split into multiple segments to align segments on data session boundaries. See Figure 46.

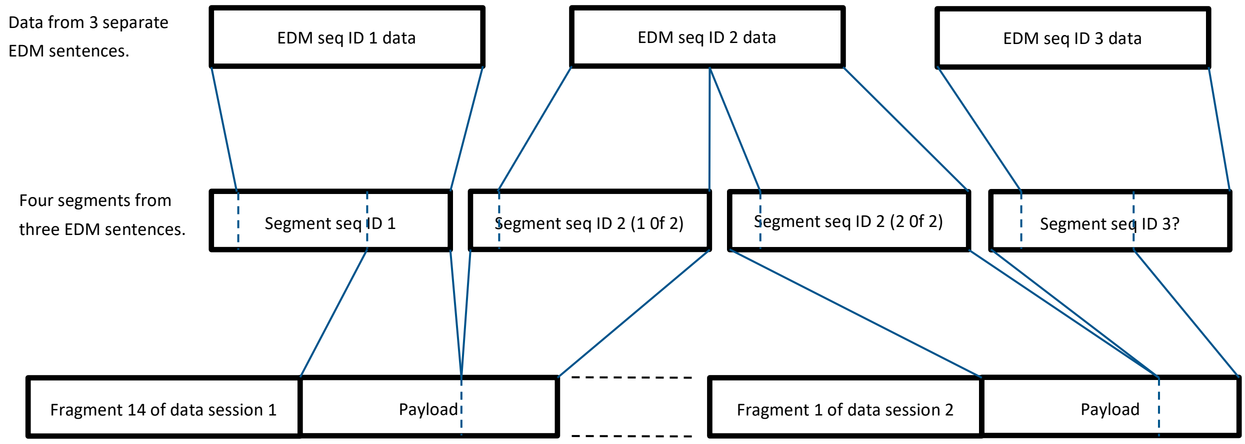

Figure 46 - Segmentation across data session boundaries

C 4.32.1. SEGMENT DESCRIPTION

Table 51 – Segment Description

Segment				
Field no	**Value (Dec)**	**Size (Bits)**	**Function**	**Content**
1	1-15	4	Total segments	Total number of segments to transfer the EDM sentence's data.
2	1-15	4	Segment number	The current segment number
2	0 to 2^{16}-1	16	Sequential ID	Sequential ID of matching EDM sentence.
3	0 to 2^{16}-1	16	Payload size	Size of the segment payload data only. (Bytes)
4		Variable	Payload Data	Payload data.

C 5 NETWORK LAYER

The priority assignment, distribution of transmission packets and data link congestion resolution requires close integration with the link layer. The responsibility of the network layer was therefore moved to the link layer.

C 6 TRANSPORT LAYER

The reliable transmission of data segments, segmentation, acknowledgement and multiplexing requires close integration with the link layer. The responsibility of the transport layer was therefore moved to the link layer.

C 7 SESSION LAYER

The session handling of PI sentence data requires close integration with the link layer. The responsibility of the session layer was therefore moved to the link layer.

C 8 PRESENTATION INTERFACE LAYER

The information contained in this section is provisional and is intended for guidance and is the subject of liaison with appropriate international bodies.

All VDE sentences transmitted and received will use "VE" as talker ID.

In Autonomous Data Transfer mode, all the VDE communication takes place on the data level. Only the data gets transferred over the presentation interface using the EDM and EDO sentences while all of the link layer communication takes place automatically.

C 8.1. VDE DATA MESSAGE SENTENCE

EDM sentences are used for initiating VDE data transmission when the sentence is sent to the presentation interface. When data has been successfully received over the VDE radio frequency link, then EDM sentences are output over the presentation interface to contain the VDE data.

The EDM sentence resembles the use of the VDM AIS sentence.

```
Sentence:
$--EDM,<seq_nr>,<source_mmsi>,<dest_mmsi>,<data>,<fill_bits>*<HH><CR><LF>
  <seq_nr>                : Sequence number of the PI data session. (0-999)
  <source_mmsi>           : MMSI of source. Only applicable when receiving VDE data over the
                            RF link. When the EDM sentence is sent to the presentation
```

interface, value is ignored and must be null.

<dest_mmsi> : MMSI of destination. Null field implies broadcast.

<data> : Encapsulated binary data to transmit. May contain a maximum of 498 bytes of data (or 664 chars).
The data limitation is constrained by the payload limit of a VDE data session when using the lowest data rate, because EDM payload can not currently span multiple VDE data sessions.

<fill_bits> : Number of fill bits.

<HH> : The checksum field.

<CR><LF> : Carriage return and line feed characters.

Example:$VEEDM,3,987654321,123456789,13u?etPv2;0n:dDPwUM1U1Cb069D,0*72

C 8.2. VDE DATA MESSAGE SENTENCE OWN-VESSEL REPORT

EDO sentences are sent with every successfully transmitted data packet over VDE RF link. For each transmitted EDO sentence, an exact EDM will appear on the receiving side. (Except for sequence number value.)

The EDO sentence resembles the use of the VDO AIS sentence.

Sentence:

$--EDO,<seq_nr>,<source_mmsi>,<dest_mmsi>,<data>,<fill_bits>*<HH><CR><LF>

<seq_nr> : Sequence number of PI data session. (0-999)

<source_mmsi> : MMSI of source.

<dest_mmsi> : MMSI of destination. Null field implies broadcast.

<data> : Encapsulated binary data received. May contain a maximum of 498 bytes of data (or 664 chars).

<fill_bits> : Number of fill bits.

<HH> : The checksum field.

<CR><LF> : Carriage return and line feed characters.

Example:$VEEDO,3,987654321,123456789,13u?etPv2;0n:dDPwUM1U1Cb069D,0*70

C 8.3. VDE DATA MESSAGE SENTENCE ACK/NACK

EAK sentence is used for ACK/NACK of each EDM sentence and is associated with the EDM sentence with the same seq_nr and dest_mmsi.

Sentence:

$--EAK,<seq_nr>,<dest_mmsi>,<edm_status>*<HH><CR><LF>

<seq_nr> : Sequence number of PI data session. (0-999)

<dest_mmsi> : MMSI of destination. Null field implies broadcast.

<edm_status> : EDM sentence status. 0-3

0 - Accepted in queue.

1 - Transmission success and successfully received by destination.

2 - Transmission failure.

```
                              3 - Transmission queue full. Retry later.
<HH>                    : The checksum field.
<CR><LF>                : Carriage return and line feed characters.
```

Example:$VEEAK,3,987654321,2*40

C 8.4. EPV COMMAND OR REPORT EQUIPMENT PROPERTY VALUE

EPV sentence as defined in IEC 61993-2 Annex E, but with the property identifiers shown in Table 52.

Table 52 – Property identifier

Property identifier	Property meaning	Value range
120	Link ID setting	0 – Autonomous Link ID 1-32 – Tx Link ID set as defined by Tables 7-10.

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 2.2. 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 47 and Figure 48.

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.

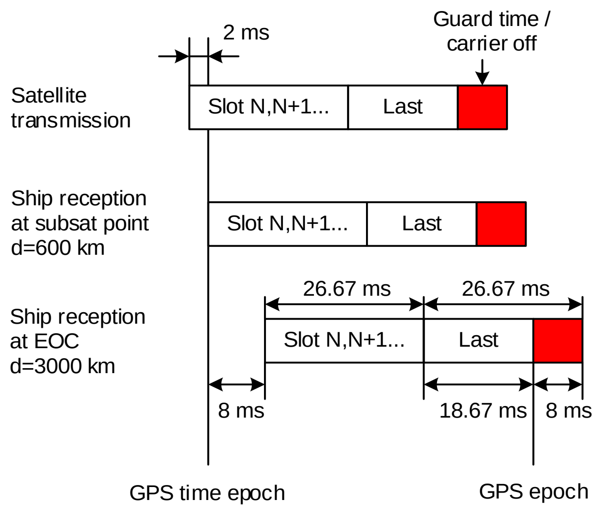

Figure 47 - VDE-SAT downlink timing

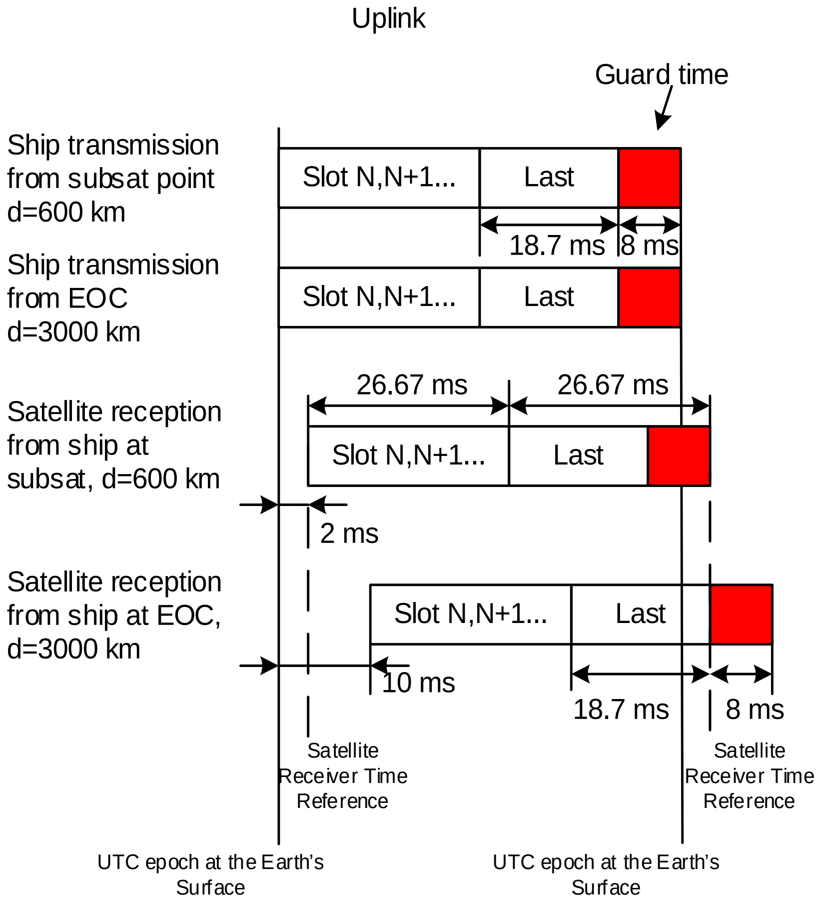

Figure 48 - VDE-SAT Uplink timing

D 2.2.1. 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 2.2.2. SHIP STATION TRANSMITTER REQUIREMENTS

For ship station transmitter requirements, see Annex A.

D 2.2.3. SHIP STATION ANTENNA GAIN

For ship station antenna gain, see Annex A.

D 2.2.4. SHIP STATION NOISE PLUS INTERFERENCE LEVEL

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

D 2.3. 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 2.3.1. VDE-SAT DOWNLINK LINK BUDGET

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

D 2.3.1.1. Satellite downlink e.i.r.p.

The e.i.r.p. can be derived from PFD mask given in Table 53.

Table 53 - Proposed power spectral and PFD mask

$$\boldsymbol{\theta^\circ = earth - satellite\ elevation\ angle}$$

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

Table 54 shows the theoretical maximum satellite e.i.r.p. as a function of elevation angles for this mask.

Table 54 - 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 2.3.1.2. 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 55.

Table 55 - 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 56.

Table 56 - 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 2.3.1.3. 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 57. Isoflux antenna is shown in Table 58.

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

Table 57 - 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 58 - 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 2.3.2. VDE-SAT UPLINK LINK BUDGET

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

D 2.3.2.1. Ship station e.i.r.p. vs. elevation angle

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

D 2.3.2.2. Satellite antenna gain

Table 59 presents the gain of a 3-element Yagi satellite antenna with a peak gain of 8 dBi as a function of elevation angle.

Table 59 - 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 2.3.2.3. Satellite system noise temperature

The satellite noise level at the receiver input is shown in Table 60. Without external interference, the system noise temperature is 25.7 dBK.

Table 60 - 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 2.3.2.4. Uplink C/N_0

The baseline uplink link budget is given in Table 61. 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 61 - 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 2.3.3. PROPAGATION EFFECTS

The received signal level on-board a ship will vary due to a number of factors as shown in Table 62. A Rice distribution with a carrier to multipath (C/M) ratio of 10 dB and fading bandwidth of 3 Hz is assumed (see Figure 49), however the system shall be adaptable to handle significantly worse and better propagation conditions.

Measured NorSat-2 satellite downlink signal levels vs. time and CDF are shown in Figure 50 and Figure 51 for a typical 10-minute pass for an antenna mounted 14 m above the sea level. (Satellite AIS reception caused the 12 s periodic interruptions). The median signal level at the antenna port was -118 dBm. The signal level pdf matched a lognormal model (normal for levels in dBm) with a standard deviation of 4.2 dB. The fading behaviour is consistent with a single specular reflection model. It can be seen that the fade interval is typically 60 s. The fade durations depend on the fade depth; fade durations often lasts more than 10 seconds.

Table 64 and Table 65 provide measured signal levels and the resulting required demodulator threshold for a given PER.

Mid-latitude fade depths due to ionospheric scintillation are shown in Table 63.

Table 62 - 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/m^2, 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 63 - 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

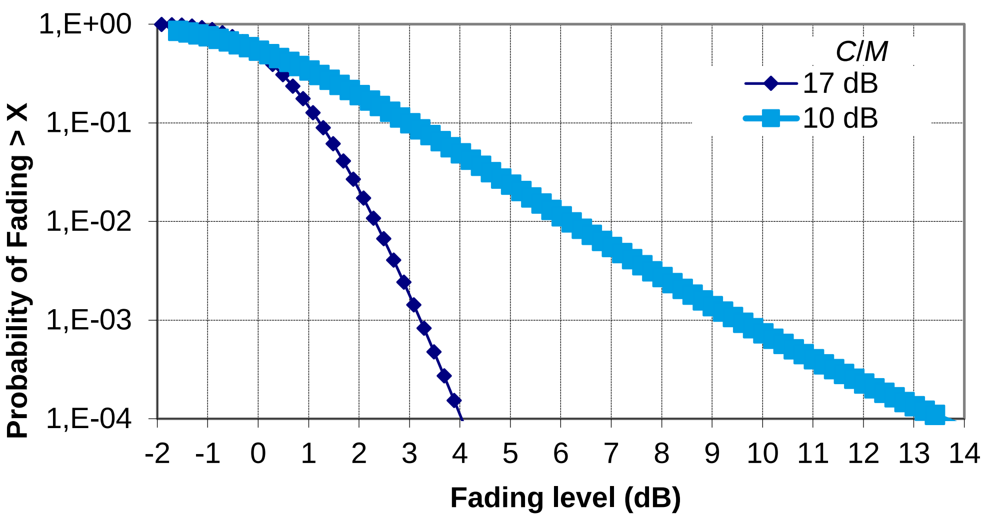

Figure 49 - Ricean fade depth probability

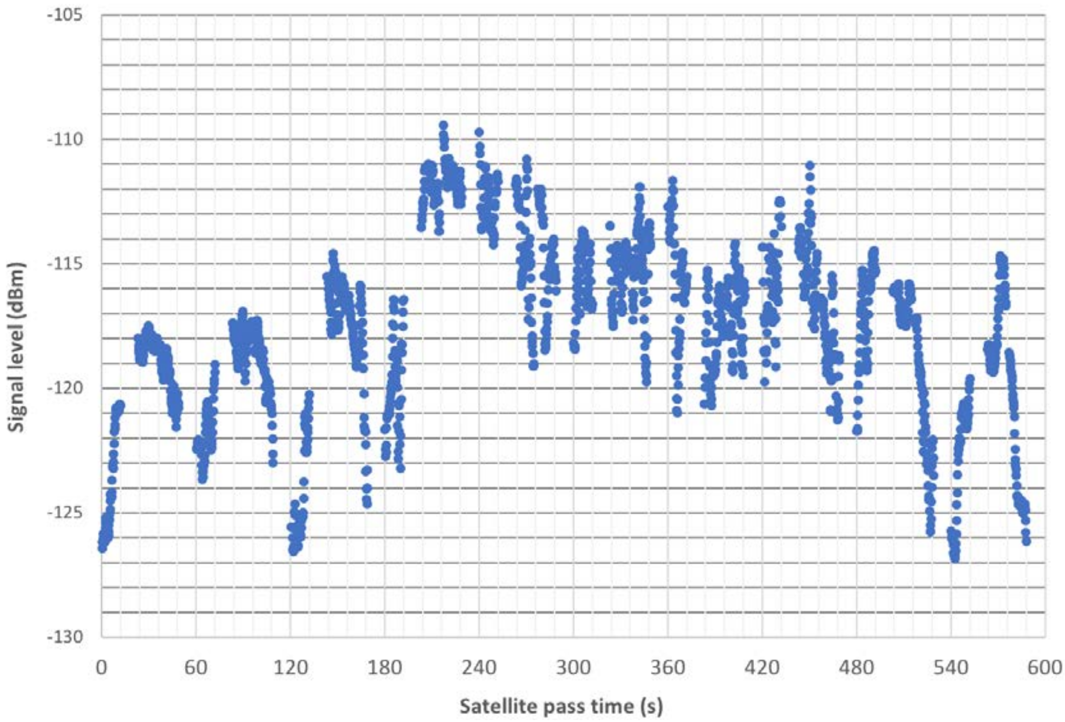

Figure 50 – Representative satellite RX level vs. pass time

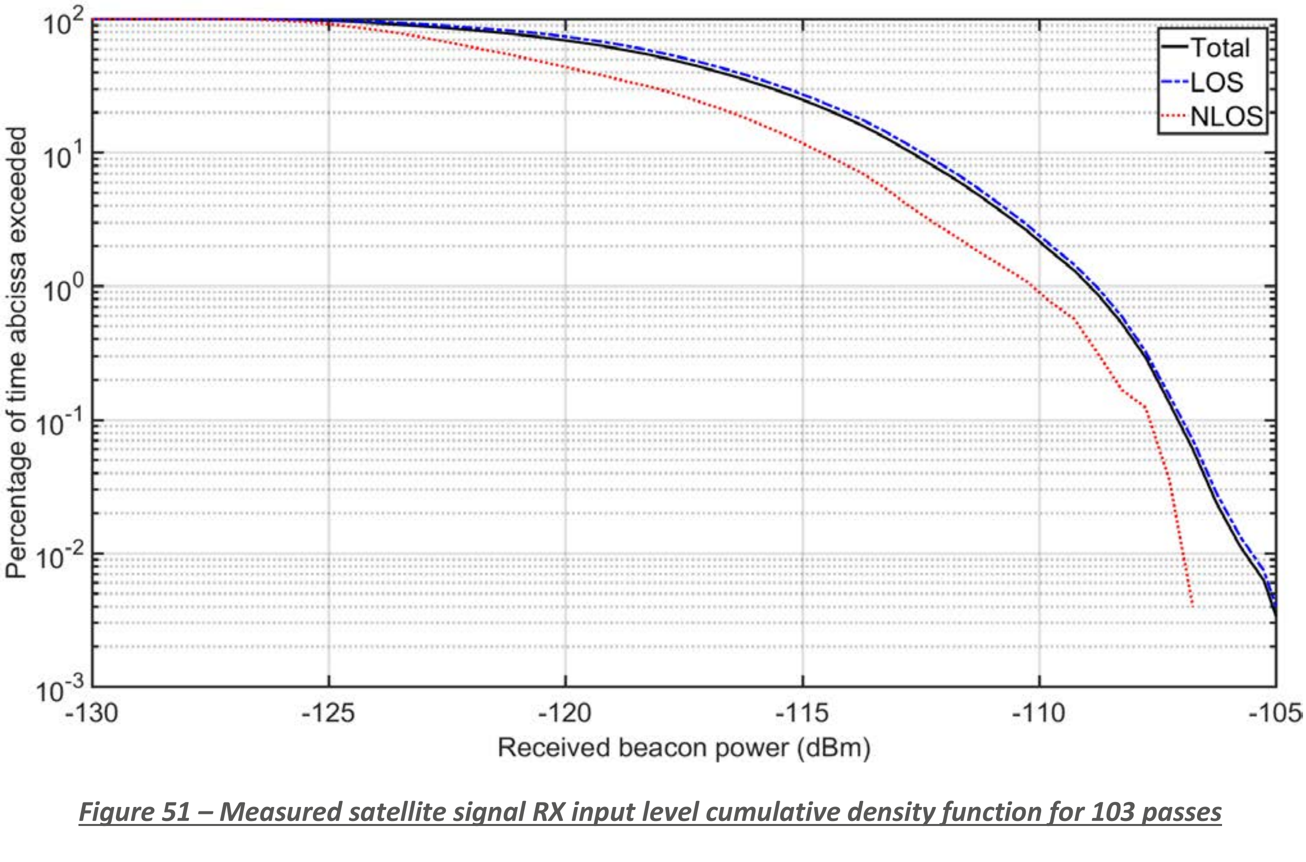

Figure 51 – Measured satellite signal RX input level cumulative density function for 103 passes

Table 64 – Measured satellite signal levels vs. elevation

Elevation bin (deg)	Rx input level (dBm)
2,5	-118,3
7,5	-117,2
12,5	-115,5
17,5	-115
22,5	-114,3
27,5	-113,9
32,5	-114,8
37,5	-114,6
42,5	-112,9
47,5	-112,9
52,5	-114,6
57,5	-116,3
62,5	-118,1
67,5	-119,3
72,5	-119,5
77,5	-120,6
82,5	-120,8

Table 65 – Required demodulator threshold for given PER

PER (%)	Signal level (dBm)	Demodulator threshold $C/(N_0+I_0)$ (dBHz)
50,0	-118	44
40,6	-119	43
31,7	-120	42
23,8	-121	41
17,0	-122	40
11,7	-123	39
7,7	-124	38
4,8	-125	37
2,8	-126	36
1,6	-127	35
0,9	-128	34
0,4	-129	33
0,2	-130	32
0,10	-131	31
0,04	-132	30
0,02	-133	29
0,01	-134	28

D 2.4. 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 66.

Table 66 - 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 2.5. BIT MAPPING

For bit mappings, see Annex A.

D 2.6. SPREADING

Direct sequence spreading with constant envelope is applied for the physical layer burst format SAT-MCS-1.50-2, identified by Link Config ID 20. Spreading for the downlink burst waveforms carrying bulletin boards, Link Config ID 25 and Link Config ID 32 are achieved by utilising Gold sequences of length 2047. A short direct spreading sequence of length four is applied for the downlink burst waveforms defined by Link Config ID 28-31.

D 2.6.1. 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 52.

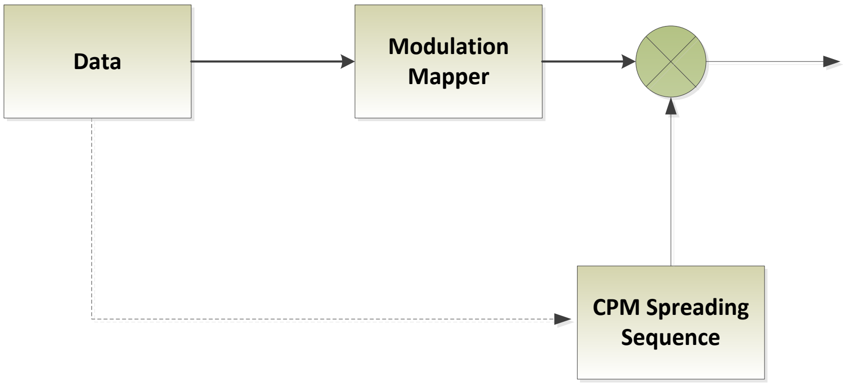

Figure 52 - CPM Spreading Principle

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 (see G1139-1) is then applied starting from the preamble and continuing in the data part (as shown in Figure 41). The generated constant envelope spreading output sequence $y(k)$ is given by

$$y(k) = \begin{cases} x(n) \cdot cp_a\big(l_a, p_a(n)\big), & \text{for } m < SL/2 \\ x(n) \cdot cp_e\big(l_e, p_e(n)\big), & \text{otherwise} \end{cases}$$

where $x(n)$ represents the QPSK modulated input signal of length BL symbols. Thus, $n \in [0, BL-1]$. It should be noted that the generated spreading sequence $y(k)$ 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 spreading sequence to be generated is oversampled by a factor NS relative to the chip rate. The total number of constant envelope output samples then becomes $BS = BL \cdot SF \cdot NS$, where one single input QPSK symbol is spread to $SL = SF \cdot NS$ output samples. The output sample index k is ranging from 0 to $BS - 1$, and the input symbol index n as function of the output sample index k is related by $n = \lfloor k/SL \rfloor$. Here the floor operator $\lfloor u \rfloor$ rounds u down to the nearest integer towards minus infinity. Furthermore, two predefined two-dimensional complex valued tables, cp_a and cp_e, containing optimised constant envelope spreading signature sequences are utilised in the constant envelope spreading process. The table cp_a is applied for generating the spreading sequence for the first half of an input symbol, while cp_e is used for the second half, where a half symbol period consists of $SL/2$ output samples. The present table to use, either cp_a or cp_e, is decided by the modulus index value given by $m = k \,\%\, SL = k - SL \cdot \lfloor k/SL \rfloor = k - SL \cdot n$, where % defines a modulus operator. The first dimensional, representing sample time, table indexes l_a and l_e are given by $l_a = (m + n \cdot SL/2) \,\%\, TL = (k - n \cdot SL/2) \,\%\, TL$ and $l_e = (m + (n-1) \cdot SL/2) \,\%\, TL = (k - (n+1) \cdot SL/2) \,\%\, TL$, where TL is the first dimensional size of the cp_a and cp_e tables. In our case, the spreading sequence is designed as maximum length, i.e. $TL = BS/2$, $l_a \in [0,\ BS/2 - 1]$ and $l_e \in [0,\ BS/2 - 1]$. The modulus TL in the timing index expressions is not needed. The second dimensional table indexes, $p_a(n)$and $p_e(n)$, depend on $x(n)$ and are based on differential QPSK symbol quadrant computation. Given the applied Gray-coded QPSK bits-to-symbol mapping definition, the belonging quadrant is given by

$$q = \begin{cases} 0, \text{ for QPSK input bits equal to 11} \\ 1, \text{ for QPSK input bits equal to 01} \\ 2, \text{ for QPSK input bits equal to 00} \\ 3, \text{ for QPSK input bits equal to 10} \end{cases}$$

and the second dimensional table indexes

$$p_a(n) = \begin{cases} 0, & \text{for } n = 0 \\ \big(q(n) - q(n-1)\big) \,\%\, 4, & \text{for } n > 0 \end{cases}$$

and

$$p_e(n) = \begin{cases} \big(q(n+1) - q(n)\big) \,\%\, 4, & \text{for } n < BL - 1 \\ 0, & \text{for } n = BL - 1 \end{cases}$$

As the differential phase table indexes $p_a(n)$ and $p_e(n) \in [0, 3]$, the overall size of the cp_a and the cp_e tables becomes $BS/2 \times 4$, thus containing $2 \cdot BS$ complex valued constant envelope values.

The specified constant envelope spreading scheme is at present only applicable for the SAT-MCS-1.50-2 physical layer burst format, with Link Config ID equal to 20, for which $BL = 261$ and $SF = 16$. The signature spreading sequences are optimised for an oversampling factor NS=16, and the cp_a signature table is stored in the ASCII file "cpa_SF16_NS16_BL261.txt", and the cp_e table is stored in file "cpe_SF16_NS16_BL261.txt". The table entities within the files are oriented in $BS/2$ rows and 8 columns. The row number thus directly related to the first dimensional table indexes, l_a and l_e. The first, third, fifth and seventh columns contain the real part of the complex valued entities, while the second, fourth, sixth and eighth columns hold the imaginary part. The full relationship between a loaded ASCII file table, $T[\quad]$, and a signature table $cp(\quad)$ becomes

$$cp(l, p) = T[l + 1, 2p + 1] + j \cdot T[l + 1, 2p + 2]$$

where $j = \sqrt{-1}$ and the row and column of $T[\quad]$ are assumed counted from one.

Even if the signature sequences are optimised for NS=16, appropriate constant envelope spreading sequences for NS=8 and NS=4 can be generated by decimating the signature spreading tables in time, i.e. along the first dimensional table index, by a decimation factor equal to 2 or 4 correspondingly.

Figure 54 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.

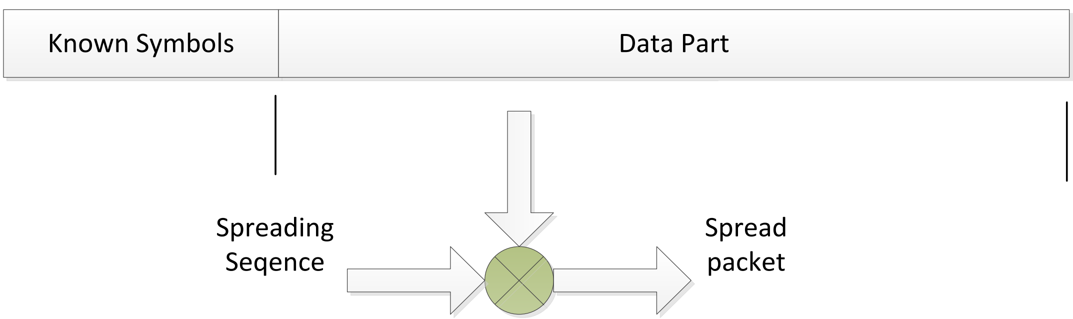

Figure 53 - Proposed Spreading in the CPM

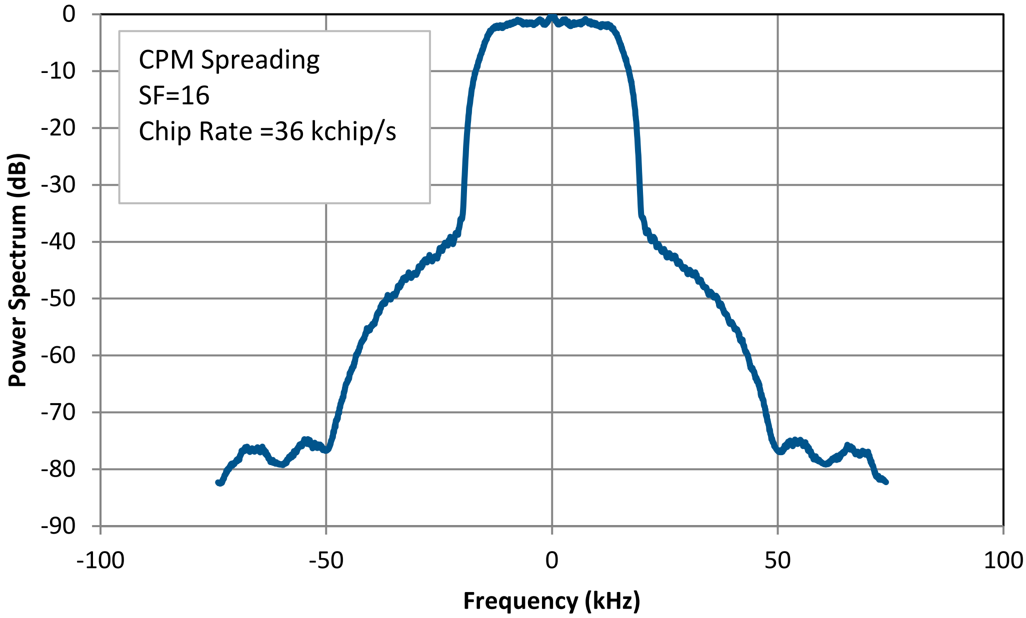

Figure 54 - Power spectral properties of spread spectrum with constant envelope

D 2.6.2. DIRECT SEQUENCE SPREADING FOR DOWNLINK WAVEFORMS

The waveform used for the bulletin board should allow for detection of overlapping signals received from two satellites. Two Gold spreading code sequences named SS0 and SS1 are selected to reduce the cross-correlation between delayed and frequency shifted versions of the overlapping waveforms. SS0 and SS1 is shown as byte oriented hexadecimal text strings in

Table 67. The first byte, bit sequence “00000100” for spreading sequence SS0, is used to spread the very first bit of the burst into 8 chips. The MSB of the bit sequence is to be transmitted first. The next byte, bit sequence “01100001” for SS0, is then used to spread the second bit of the burst. The spreading process making the chip sequence to transmit is further achieved by XORing between each burst bit and the 8 by 8 spreading sequence bits. As the length of the Gold spreading sequences is limited to 2047, only the 7 MSBs of the last Gold spreading sequence byte is utilised, i.e. “0101101” for byte 0x5A and “0001111” for byte 0x1E. Furthermore, spreading is based on periodic repetition of the spreading sequence, such that when reaching the end of the actual Gold sequence, the 8 bits sequence to utilise for spreading will consist of the 7MSBs of the last Gold sequence byte appending the MSB of the first byte. Due to this bit shift, the 8 by 8 bits spreading sequences obtained after repetition will not be equal to the original 8 by 8 spreading sequences.

The chip bit sequence is mapped into values by ordinary BPSK bit to symbol mapping.

Table 67 – Gold spreading sequences

Name	Spreading Sequence
SS0	04-61-4F-29-8E-A3-63-13-B4-81-44-3D-35-C9-BC-DF-06-05-D3-3E-A3-13-DE-DA-C9-37-F6-C0-2D-5A-81-B7-ED-4B-43-77-31-0D-DF-99-1C-49-E1-71-31-C1-12-30-58-9E-80-9E-AC-E7-83-AB-D8-9A-AD-24-56-89-BB-C2-37-EA-DB-49-F8-4D-80-B9-2C-E3-F1-98-1C-86-06-45-4C-31-25-68-6A-3F-1F-9B-62-CC-2D-42-4B-E1-9F-2C-0F-F0-84-4F-31-3C-B4-40-05-B6-FD-D2-D4-E8-63-A9-56-62-B6-08-80-DA-DD-07-AA-37-76-C7-8A-81-81-BD-95-31-79-E4-0D-EB-92-8C-A4-D1-A6-FF-45-47-C7-F9-09-D1-D2-2C-46-02-B1-B5-B2-83-6B-57-D0-BF-C3-4C-D6-2A-26-0A-EB-C1-D8-58-49-0A-FB-CF-DA-62-FD-41-60-FD-F7-0F-A2-8E-A4-90-B0-AD-37-FD-2E-E4-2B-75-E6-46-63-AB-FA-55-24-3D-93-CF-4E-72-CE-02-38-B7-77-95-97-30-86-7E-24-2E-80-81-C2-97-26-32-2A-71-90-CB-36-79-17-A5-D4-49-36-04-21-5F-1E-54-A2-88-D6-62-AD-E0-47-61-A7-89-ED-81-34-88-1A-D0-BE-5A
SS1	41-0B-57-66-A0-D1-94-36-C2-94-8C-60-10-FF-81-06-51-84-E3-80-EB-FE-B5-C2-26-5D-AE-A7-12-22-D2-94-18-CF-31-C0-3C-6A-C0-F5-47-EF-46-F6-02-BE-C2-22-53-DA-4A-62-8D-73-7B-48-B5-41-FB-E5-EE-62-D3-1B-40-7F-E3-72-E2-A3-AA-69-1E-FC-BD-D7-B2-A4-D3-75-72-29-EA-16-3A-DD-72-E0-70-27-05-B3-2D-7E-03-11-96-8F-14-75-2B-72-DA-BA-A7-B3-BF-DB-91-62-17-DD-E2-AE-49-E8-8C-DD-5E-36-54-F7-CE-8C-A6-72-66-32-A3-4C-88-A2-86-7F-2A-47-D8-00-54-38-7E-3D-15-CA-56-15-C8-A2-50-CB-0C-5C-FB-0E-9C-12-9A-B3-84-E7-F6-DE-42-B4-23-7C-91-55-EE-6D-A4-8B-90-CE-FE-C0-D0-13-9D-F7-81-9B-4C-D9-9D-1E-58-27-38-AD-C6-BE-BA-83-99-E9-93-2C-B7-C6-11-7E-40-D4-49-91-03-4D-F5-84-DD-BC-91-F7-11-92-E9-38-29-5F-BB-6F-2F-53-A5-97-33-FB-66-D3-41-D1-49-34-5F-6F-C0-20-56-6C-38-88-05-E1-47-C1-E3-A3-7D-9B-3A-CE-F1-78-1F-1E

The direct spreading sequence “0010” is applied for the downlink burst waveforms identified by Link Config ID 28-31, This sequence has excellent auto-correlation property. The first bit of the burst is spread by “00”, the second by “10”, and then the third again by “00” as the spreading sequence are periodically repeated. XORing is performed between burst bits and 2 by 2 spreading sequence bits, and the resulting chip sequence is mapped into values by ordinary BPSK bit to symbol mapping.

D 2.7. BASEBAND SHAPING AND QUADRATURE MODULATION

For baseband shaping of symbols, see Annex A.

D 2.8. TRANSMISSION TIMING ACCURACY

For transmission accuracy figures, see Annex A.

D 2.9. HALF DUPLEX AND FULL DUPLEX SATELLITES

The system can be configured for both half and full duplex satellites as shown in Figure 55.

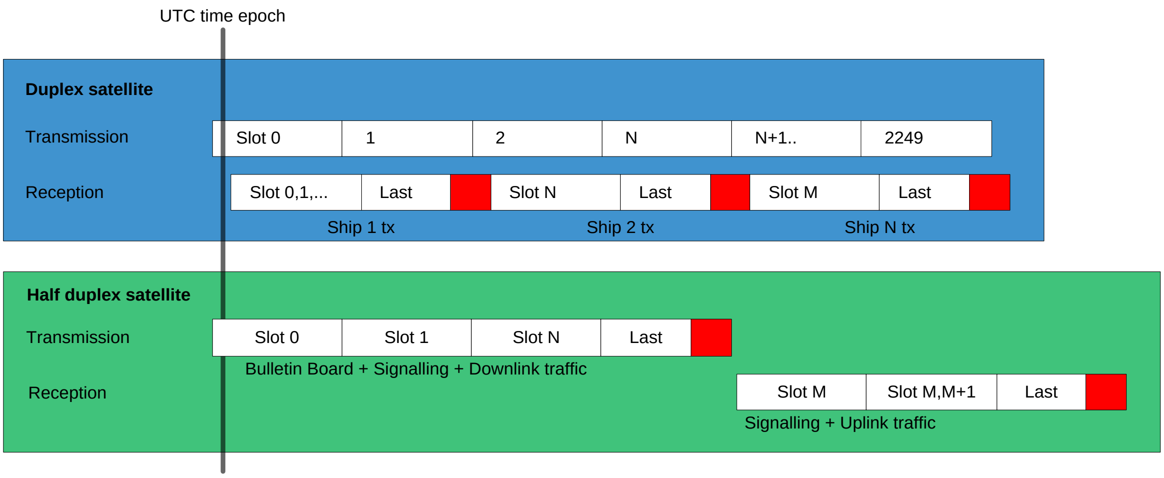

Figure 55 - Half-duplex and full duplex satellite operation

D 2.10. FRAME STRUCTURE

For frame and transmission burst structure, see Annex A.

D 2.11. PILOTS AND SYNCWORD SYMBOL LOCATION AND MODULATION

Pilot symbols are utilised for some of the VDE-SAT uplink and downlink PL burst waveforms. A pilot symbol is a single symbol with unity power mapped to the constellation point . Single pilot symbols are regularly distributed over the burst, and the position of each pilot symbol is defined by the pilot distance. Denoting the pilot distance, the very first pilot symbol in the burst is located symbols after the last symbol of the preceding training sequence. For the VDE-SAT uplink PL format SAT-MCS-5.50, the syncword size is 27 symbols and the pilot distance is 33 symbols. Counting from zero, the last training sequence symbol is thus located at symbol position 26, the first pilot symbol is located at position 43, and the next pilot symbol at position 76.

For VDE-SAT downlink, uniformly repeated syncword are utilised for synchronisation purpose. The bit pattern sequence of a repeated syncword is equal to the preamble training sequence, as defined for VDE-SAT in Table A1-2. The location of the uniformly repeated syncwords is given by the syncword distance, defined as the distance between the first symbol of two subsequently syncwords. For the VDE-SAT downlink PL format SAT-MCS-0.50-1, the syncword distance is 1004 symbols. The first symbol of the preamble syncword and the first repeated syncword in such a burst waveform is thus located at postion 0 and 1004 correspondingly.

Both uniformly repeated syncword and regularly distributed single pilot symbols are utilised for the π/4 QPSK and 8PSK modulated VDE-SAT downlink burst waveforms. The location of the repeated syncword and distributed pilot symbols is given by the pilot distance and the syncword distance as previously outlined. The first pilot symbol following a given syncword is thus always located symbols after the last symbol of that particular syncword. Furthermore, the distance from the last single pilot symbol preceding a given syncword to the first symbol of that particular syncword is also symbols. For the VDE-SAT downlink PL format SAT-MCS-1.50-1 and SAT-MCS-3.50-1, both the syncword size and the pilot distance is 27 symbols, and the syncword distance is 2268 symbols. The last preamble syncword symbol is thus located at position 26, the first pilot symbol at position 40, and the next pilot symbol at position 67. The location of the last pilot symbol preceding the first repeated syncword becomes 2254, and the first repeated syncword symbol is located at position 2268.

A generalised PL burst structure containing both uniformly repetitive syncword and regularly distributed single pilot symbols is visualised in the figure below. The distance is referred to as “half a pilot distance” in the figure.

For PL burst waveform applying π/4 QPSK, 8PSK and 16QAM modulation, the syncword is π/4 QPSK modulated. Odd symbol position indexes are then mapped to symbol constellation points that are phase offset by +45 degree from the nominal QPSK symbol constellation points used for even symbol position indexes. This even and odd position indexes toggling rule, as described in Section A 1.2.7 and visualised in Figure 12 shall also be applied for the uniformly repeated syncword. This rule results in two different syncword modulation signal patterns for these particular PL burst waveforms when the syncword distance is an even number of symbols.

For π/4 QPSK modulated PL burst waveforms, single pilot symbols located at odd symbol position indexes are phase offset by π/4 from the nominal QPSK symbol constellation points as all other odd symbol positioned symbols in the actual burst.

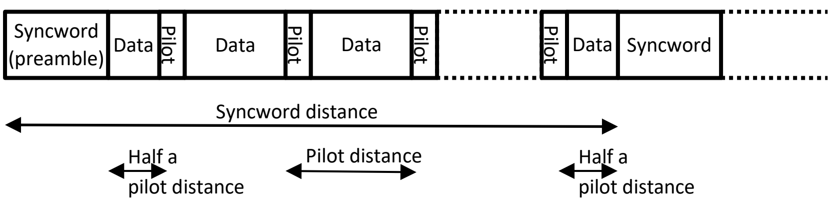

Figure 56 - General PL burst structure with repetitive sync word and distributed single pilot symbols

D 2.12. FORWARD ERROR CORRECTION AND INTERLEAVING

For forward error correction and interleaving, see Annex A.

D 2.13. VDE-SAT LINK CONFIGURATION FORMATS

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

D 2.14. 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

D 3.1. SESSION ASSIGNMENT

A session ID is assigned to every new data session by the data receiving station, except for broadcast messages[4] where the session ID is assigned by the transmitting station. The first data fragment will announce the total number of fragments to be transmitted. A session ID is valid until all the data session fragments have been transmitted and successfully acknowledged, or negatively acknowledged. Broadcast messages can be retransmitted using the same session ID in order to increase the probability for receiving stations to receive all fragments of the broadcasted message. To avoid the generation of duplicate session IDs and causing conflicting data sessions near each other, the following resource allocating algorithm is proposed:

The first session ID generated after a station's power up, should start at zero and be incremented by one for every session ID generation request, independent of station requesting the session ID.

For further 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.

4 Broadcast messages have Destination ID set to 0.

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 57, and described further in this section.

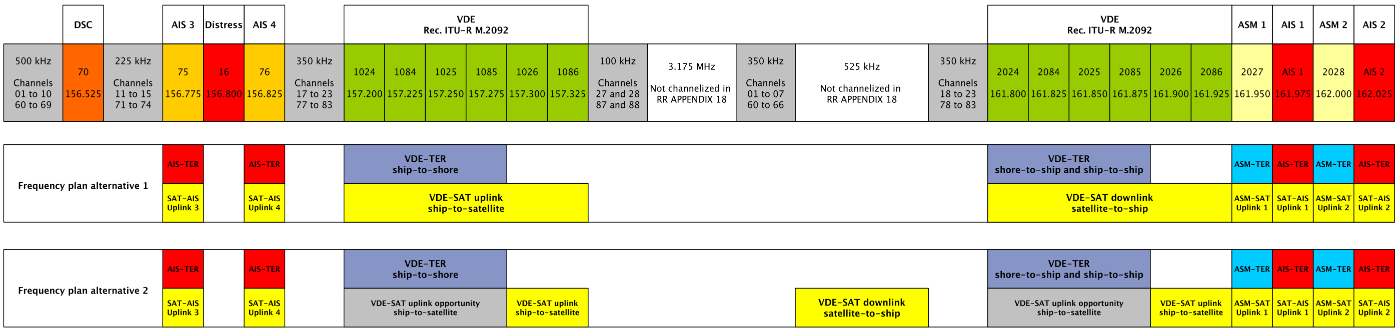

Figure 57 - RR APPENDIX 18 and VDES frequency utilization plans

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 4 overlapping satellite signals, depending on SAT-MCS.

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.