ATTACHMENT

~~WORKING DOCUMENT TOWARDS A~~ PRELIMINARY DRAFT NEW REPORT ITU-R M.[VDES-SAT]

Keywords

Glossary / abbreviations

ACM: Adaptive coding ande modulation

AIS: Automatic identification system

ARQ: Automatic repeat request

ASM: Application specific message

FEC: Forward error correction

IALA: International Association of Marine Aids to Navigation and Lighthouse Authorities

LNA: Low noise amplifier

MMSS: Maritime mobile-satellite service

MSI: Maritime safety information

~~Pfd~~pfd: Power flux density

SAT-AIS: Satellite – automatic identification system

VDES: VHF data exchange system

VDE-SAT: VHF data exchange – ~~– system –~~satellite

VDE-TER: VHF data exchange ~~system~~ – terrestrial

VDL: VHF datalink

~~*[Chairman's note: does VDE when referenced to VDE-SAT and VDE-TER refer to VHF data exchange or VHF data exchange system because it is used inconsistently in this document]*~~

1 Introduction

(… no change …)

2 VHF data exchange-satellite, the essential supplement to terrestrial VHF data exchange system

(… no change …)

3 Identification of spectrum requirements and rationale for the use of the frequency bands of RR Appendix 18

3.1 Spectrum requirement for the VHF data exchange-satellite

~~*[Editor's note: IALA to provide more explanation for the spectrum requirement]*~~

The VDE-SAT communications functions (ship-to-satellite and satellite-to-ship) are intended to be fully integrated with the VDE-TER communications functions (AIS, ASM, ship-to-ship, ship-to-shore and shore-to-ship) in the shipborne VDES equipment. The shipborne VDES equipment will preferably utilize one combined transmitting/receiving VDES antenna system. For this reason, it is desirable to utilize frequencies that are within the range of RR Appendix **18** (156.025 MHz to 162.025 MHz), as shown in Figure 3-1. The bandwidth allocated to each function should be as much as possible, considering the large number of ships globally that carry AIS and may decide to upgrade to VDES.

The spectrum requirements and the use of the frequencies specified in Rec. ITU-R M.2092-0 was determined based on:

- Assessment of the maritime electromagnetic environment in ports, waterways and open sea, plus the shipborne electromagnetic operating environment as documented in Report ITU-R M.2317-0 "VHF data exchange system channel sounding campaign" and
- Assessment of the data requirements to support the use cases as documented in Report ITU-R M.2371-0 "Selection of the channel plan for a VHF data exchange system."

For terrestrial operations ship-to-ship, ship-to-shore and shore-to-ship, the channel plan designated in Rec. ITU-R M.2092-0 was agreed and approved, but for the satellite operations, the further study that was prescribed in WRC-15 Resolution 360, which is the foundation for WRC-19 Agenda Item 1.9.2, is the subject of this Report.

For the satellite uplink, potential vulnerability of the satellite receiving station from other terrestrial services has been noted, and techniques to mitigate this interference are proposed in this Report, including frequency diversity by the addition of a second 50 kHz uplink at 4.6 MHz frequency separation, as proposed in frequency plan alternative 2.

For the satellite downlink, the power flux density (pfd) mask specified in Rec. ITU-R M.2092-0 that was agreed by the effected ITU-R Working Parties is set to a very low level to avoid interference with terrestrial services, and this poses a potential vulnerability to adverse conditions due to a low link margin satellite-to-ship. To mitigate this potential vulnerability, application of spread spectrum techniques, which requires a wider bandwidth, is proposed in frequency plan alternative 2.

3.2 Potential use of the frequency band 160.975-161.475 MHz versus channels 2024/2084/2025/2085/2026/2086 for the satellite downlink

(… no change …)

3.3 Frequency plan alternatives

(… no change …)

3.3.1 Frequency plan alternative 1

(… no change …)

3.3.2 Frequency plan alternative 2

(… no change …)

3.4 Evaluation of the two frequency plan alternatives

Section 3.1 explained the reasons for the introduction of frequency plan alternative 2. A comparison of the relative merits of the two alternatives is shown in Table 3-1 below.

TABLE 3-1

Comparison of frequency plan alternatives 1 and 2

Frequency plan	**Resource Sharing**	**Available bandwidth**	**Service interdependency**	**Service capacity and link robustness**
Alternative 1	Bulletin board based. Time-sharing + Band-sharing For the upper 150 kHz band	Both in upper and lower leg: 50 kHz for VDE-TER 50 kHz for VDE-SAT 50 kHz is time shared based on bulletin board	High for both services Coordination of resource usage between VDES services required for efficient spectrum utilization	Moderate for VDE-TER Limited for VDE-SAT
Alternative 2	No resource sharing between VDES services Dedicated separate bands	In upper leg: 100 kHz for VDE-TER 575 kHz for VDE-SAT In lower leg: 100 kHz for VDE-TER	Low for both service VDES services operate independently	High for both service

		50 kHz for VDE-SAT		

3.4.1 Conclusions for the selection of a frequency plan alternative

Based on the discussion in Section 3.1 and the comparison of the two alternatives in Table 3-1, it is concluded that frequency plan alternative 2 is clearly superior. Frequency plan alternative 2 offers significant advantages in terms of higher available bandwidth, reduced service interdependency, improved system capacity and link robustness for both the terrestrial and the satellite components of the VDES.

4 Technical description of the VHF data exchange-satellite

4.1 VHF data exchange system - satellite key parameters

(… no change …)

4.1.1 Satellite to surface distance range

(… no change …)

4.1.2 Satellite transmission carrier frequency error

(… no change …)

4.1.3 Ship station antenna gain and transmitter requirements

(… no change …)

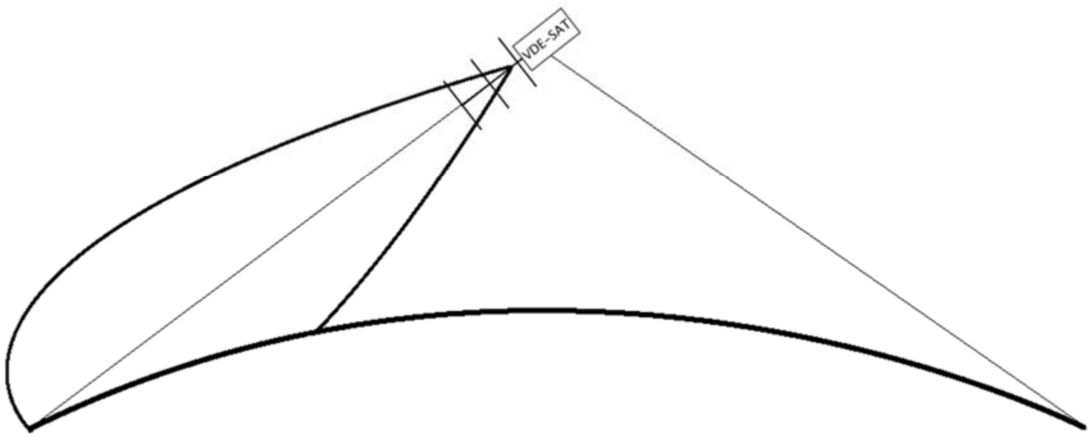
4.1.4 Satellite antenna gain

The following two satellite antennas have been analysed and provide acceptable performance for VDE-SAT:

1) Yagi Antenna: For this antenna the link budget is optimised for 0 degrees ship elevation angle using a three element circularly polarized Yagi antenna with the satellite pointed at the horizon. This is illustrated in Figure 4-3, showing how the Yagi antenna and its main lobe is pointed towards the horizon of the earth. The thin solid line indicates the field of view from the satellite, but the communications coverage area will be limited to the area within the main lobe of the Yagi antenna. Assuming a peak antenna gain of 8 dBi, satellite antenna gain versus ship elevation angle and nadir offset angle are shown in Table 4-2.

FIGURE 4-3

Illustration showing how the Yagi antenna and its main lobe is pointed towards the horizon of the earth. The thin solid line indicates the field of view from the satellite, but the communications coverage area will be limited to the area within the main lobe of the Yagi antenna.



2) Isoflux antenna: This antenna is designed to point at the nadir direction providing a symmetric radiation pattern around the pointing direction. This is illustrated in Figure 4-4, showing how the whole field of view, indicated by the thin solid line, is within the communications coverage of the isoflux antenna. Assuming a peak antenna gain of 2 dBi, satellite antenna gain versus ship elevation and nadir offset angle are shown in Table 4-3.

FIGURE 4-4

Illustration showing how the whole field of view, indicated by the thin solid line, is within the communications coverage of the isoflux antenna.

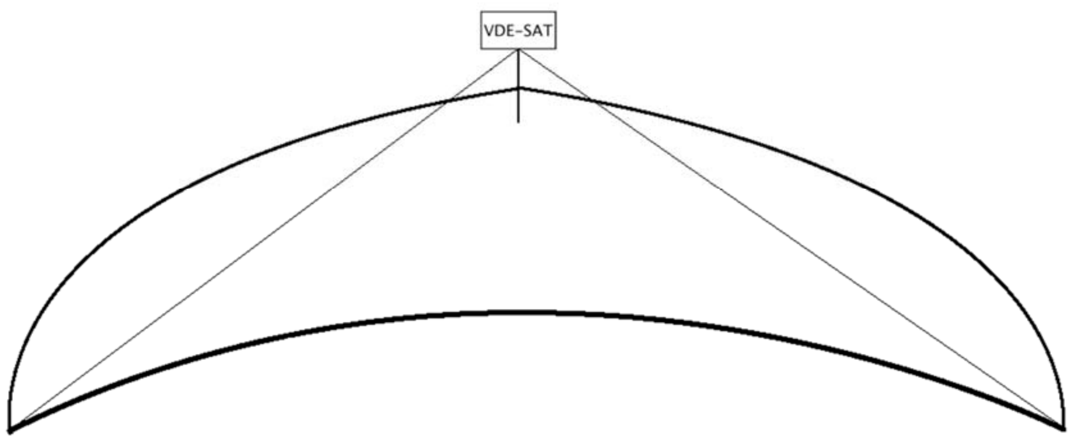


TABLE 4-2

Satellite Yagi-antenna gain vs. nadir offset angle

Ship elevation angle	Nadir offset angle	Satellite antenna gain
Degrees	degrees	dBi
0	66.1	8
10	64.2	8
20	59.2	8
30	52.3	7.8
40	44.4	6.9
50	36	5.5
60	27.2	3.6
70	18.2	0.7
80	9.1	–2.2
90	0	–5.5

TABLE 4-3

Satellite Isoflux-antenna gain vs. nadir offset angle

Ship elevation angle	Nadir offset angle	Satellite antenna gain
Degrees	degrees	dBi
0	66.1	2
10	64.2	1.5
20	59.2	1
30	52.3	–0.5
40	44.4	–2
50	36	–4
60	27.2	–5
70	18.2	–7
80	9.1	–8
90	0	–8.5

4.2 Technical characteristics of the VDE-SAT downlink in the VHF maritime mobile frequency band

(… no change …)

4.2.1 Satellite downlink e.i.r.p

The VDE-SAT downlink is in compliance with the ~~agreed~~ pfd mask specified in Recommendation ITU-R M.2092-0. ~~[This pfd mask ensures that the VDE-SAT downlink will not cause harmful interference to fixed and mobile services]. The pfd mask was coordinated and agreed between WP 5A, WP 5B and WP 5C ahead of WRC-15. In a liaison statement to~~

~~WP 5B (Doc. 5B/199), WP 5A confirmed that the Recommendation ITU-R M.1808 has not been revised since and as such the mask is still valid.~~ The pfd mask is presented in Table 4-4. ~~Editor note: This pfd mask is currently under review.~~

TABLE 4-4

Proposed power spectral and power flux density mask

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

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

From the mask given in Table 4-4 a theoretical maximum satellite e.i.r.p can be calculated as a function of ship elevation angle. The result is provided in Table 4-5.

TABLE 4-5

Satellite maximum e.i.r.p. versus elevation angle

Ship Elevation angle θ	Powerflux density on ground	Satellite range	Maximum downlink satellite e.i.r.p.
(degrees)	(dBW/m²/4 kHz)	(km)	(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
45	−142.0	815	−4.8
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

The maximum achievable satellite e.i.r.p depends on the antenna on-board the satellite, and how well the antenna pattern can be made to fit the theoretical maximum satellite e.i.r.p mask. 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 two satellite antenna types given in section 4.1.4 have been analysed to calculate the maximum possible satellite e.i.r.p that meets the pfd mask:

1) <u>Yagi Antenna</u>: For this antenna the link budget is optimised for 0 degrees ship elevation angle using a three element <u>circularly polarized</u> Yagi antenna with the satellite pointed at the horizon. 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 mask. Satellite e.i.r.p. versus ship elevation angle and resulting margin to the pfd mask are shown in Table 4-6.

TABLE 4-6

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

Ship elevation angle	Nadir offset angle	Boresight offset	Satellite antenna gain	Satellite e.i.r.p. in circular polarization	Satellite range	PFD	Table A4-5 PFD limit	PFD margin
degrees	degrees	degrees	dBi	dBW	km	dBW/m²/4 kHz	dBW/m²/ 4 kHz	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 mask. Satellite e.i.r.p. vs. ship elevation and resulting margin to the pfd mask are shown in Table 4-7.

TABLE 4-7

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

Ship elevation angle	Nadir offset angle	Boresight offset	Satellite antenna gain	Satellite e.i.r.p. in circular polarization	Satellite range	PFD	Table A4-5 PFD limit	PFD margin
degrees	degrees	degrees	dBi	dBW	km	dBW/m²/4 kHz	dBW/m²/4 kHz	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

4.2.2 Ship station noise and interference level

(… no change …)

4.2.3 VDE-SAT downlink receiver thresholds

(… no change …)

4.2.4 VDE-SAT downlink link budget

(… no change …)

4.3 Technical characteristics of the VDE-SAT uplink in the VHF maritime mobile frequency band

(… no change …)

4.3.1 VDE-SAT uplink receiver thresholds

The VDES maximizes frequency efficiency by using adaptive coding and modulation based on the actual link quality. Initial system access is done using a combination of spread spectrum, low bitrate and powerful FEC. The VDE-SAT uses the waveforms defined in Table 4-12 for uplink. The thresholds C/N_0 and $C/(N+I)$ on a Gaussian channel have been estimated.

TABLE 4-12

Estimated thresholds for the VHF data exchange-satellite uplink waveforms

Physical Layer Frame Format #	1	2	3	4	5
Channel bandwidth (kHz)	50	50	50	50	50
Occupied bandwidth (kHz)	42	42	42	42	42
CDMA chip rate (kcps)	33.6	NA	NA	NA	NA
Symbol rate (ksps)	2.1	33.6	33.6	33.6	33.6
Burst length (slots)	5	1	3	3	3
Modulation	QPSK/CDMA	π/4 QPSK	π/4 QPSK	8PSK	16QAM
FEC rate	1/4	2/3	2/3	2/3	5/6
Information rate (kbps)	1.1	44.8	44.8	67.2	112.0
~~Estimated t~~Threshold Es/N0 for a Gaussian channel (dB) (PER=10^{-2})	-1.5	3.9	3.9	8.0	12.2
~~Estimated r~~Required C/N0 (dBHz)	31.7	49.2	49.2	53.3	57.5
~~Estimated r~~Required C/(N+I) (dB)	-13.5	2.9	2.9	7.0	11.2

Recommendation ITU-R M.1184 provides information on[Editorial note: The typical protection criteria C/(N+I) could be similar for protection criteria for non-GSO systems operating below 1 GHz are given in Recommendation ITU-R M.1184.]

non-GSO systems operating below 1 GHz, including associated required C/(N+I) thresholds. However, the systems described in Recommendation ITU-R M.1184 do not take into account the advanced coding, forward error correcting and spread spectrum techniques utilized by the VDES.

[Waveform *1* uses a combination of spread spectrum, low bitrate and powerful forward error correction (FEC) to create a waveform with high robustness against interference. VDES, as defined in Recommendation ITU-R M.2092-0, implements FEC as specified by [*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*] and used in the DVB-SH standard, as well as adaptive coding and modulation (ACM) and automatic repeat request (ARQ).

The use of spread spectrum techniques is considered in Recommendation ITU-R SM.1055. Specifically, it defines the Processing Gain (PG) as the ratio between the output wanted signal-to-interference ratio and the input wanted signal-to-interference ratio. For a Direct Sequence (DS) spread spectrum signal, as used in waveform *1*, this corresponds to the ratio between the spread spectrum chip rate and the symbol rate. Recommendation ITU-R SM.1055 also clearly states that from the point of the output power ratios, a DS spread spectrum signal overcomes interference to the same degree that it overcomes noise.

Report ITU-R S.2173 provides an overview of channel coding techniques, link rate adaption methods, such as ARQ and ACM, and review standards and transmission methods for satellite communications, including DVB-SH, and associated performance parameters.

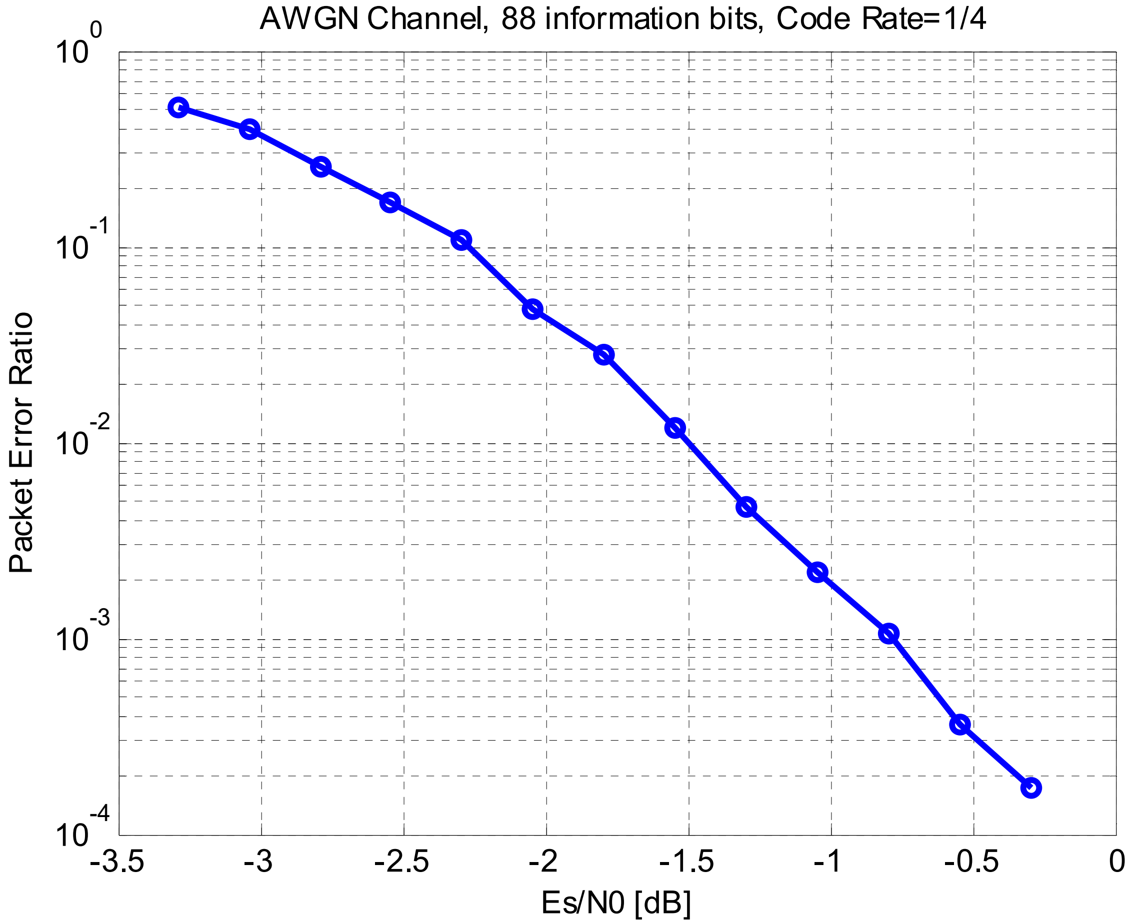
A QPSK modulated carrier with Turbo FEC code rate of ¼ [RD1] has an E_s/N_0 threshold of –1.5 dB for a packet error ratio (PER) of 10^{-2}. The threshold can be extracted from Figure 4-3, and is based on simulations performed according to an additive white Gaussian Channel model for a packet containing 88 information bits encoded at a coding rate ¼. This result is supported and cross-checked against Report ITU-R S.2173, which provides the performance of QPSK with FEC code rate ¼ for DVB-S2 as –2.35 dB at a PER of 10^{-7}. This is further supported by *Informational Report CCSDS 130.1-G-2: TM Synchronization and channel coding – Summary of concept and rationale*, see Figure 7-6 of that report.. The same level of performance cannot be expected from the FEC implementation in VDE-SAT due to significantly shorter information block length and smaller packets. Thus, the simulation results showing an E_s/N_0 threshold of -1.5 dB for a PER of 10^{-2} should be viewed as a conservative design point. As VDES will implement both FEC and automatic repeat request (ARQ) in a hybrid manner, see Report ITU-R S.2173, a target PER of 10^{-2} is considered a conservative design point to maintain the target quality of service in VDES.

The spread spectrum chip rate to symbol rate ratio given in Table *4-12* for waveform *1* is 16. Such a chip to symbol ratio will give a PG of 12.0 dB. When the PG of 12.0 dB is combined with the E_s/N_0 threshold of –1.5 dB for waveform *1* the result is a required *C/(N+I)* threshold of –13.5. dB:

$$\frac{C}{N+I} = \frac{E_S}{N_0} - PG = -1.5\text{ dB} - 12.0\text{ dB} = -13.5\text{ dB}$$]

FIGURE 4-3

E_s/N_0 threshold ((Symbol energy to noise density ratio after de-spreading) versus PER for a QPSK modulated carrier using Turbo FEC Coding according to *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.*



4.3.2 VDE-SAT uplink receiver characteristics

(… no change …)

4.3.3 VDE-SAT uplink link budget

(… no change …)

5 Interoperability and resource sharing with VDE-TER and between VDE-SAT systems

(… no change …)

6 Interference to incumbent services and those in adjacent frequency bands

6.1 In-band interference

6.1.1 Fixed services in-band

The VDE-SAT uplink has common characteristics with VDE terrestrial ship-to-shore. Therefore, it will not create any additional interference to land and aeronautical mobile services.

The VDE-SAT downlink is in compliance with the ~~agreed~~ pfd mask specified in Recommendation ITU-R M.2092-0 and provided in section 4.2.1. ~~This pfd mask ensures that the VDE-SAT downlink will not cause harmful interference to fixed services. The pfd mask was coordinated and agreed between WP 5A, WP 5B and WP 5C ahead of WRC-15. In a liaison statement to WP 5B (Doc. 5B/199), WP 5A confirmed that the Recommendation ITU-R M.1808 has not been revised since and as such the mask is still valid.~~ The pfd mask is presented in Table 4-4.

6.1.2 Land and aeronautical mobile services in-band

[Editor note: In the following views, the pfd mask contained in view 1 is based on coordination threshold. This pfd mask is specified in Recommendation ITU-R M.2092; the pfd mask contained in views 2 and 3 is based on protection criteria defined in Recommendation ITU-R M.1808-0]

The VDE-SAT uplink has common characteristics with VDE terrestrial ship-to-shore. Therefore, it will not create any additional interference to land and aeronautical mobile services.

VIEW 1 about pfd mask

The VDE-SAT downlink is in compliance with the ~~agreed~~ pfd mask specified in Recommendation ITU-R M.2092-0 and provided in Section 4.2.1. ~~This pfd mask ensures that the VDE-SAT downlink will not cause harmful interference to land and aeronautical mobile services. The pfd mask was coordinated and agreed between WP 5A, WP 5B and WP 5C ahead of WRC-15. In a liaison statement to WP 5B (Doc. 5B/199), WP5A confirmed that the Recommendation ITU-R M.1808 has not been revised since and as such the mask is still valid.~~ The pfd mask is presented in Table 4-4.

VIEW 2 about pfd mask

(… no change …)

VIEW 3 about pfd mask

(… no change …)

6.2 Out-of-band interference

(… no change …)

6.2.1 Maritime distress and voice services

(… no change …)

6.2.2 Satellite automatic identification system

(… no change …)

6.2.3 Radiolocation service in the frequency band 154-156 MHz

(… no change …)

6.2.4 Broadcasting service in the frequency band 162-164 MHz

(… no change …)

6.2.5 Space operation service (space-to-Earth) in the frequency band 162-164 MHz

(… no change …)

6.2.6 Land and aeronautical mobile services in adjacent frequency bands

~~*[Editorial note: Relevant frequency band as specified in ITU-R Resolution **360** is 154-164 MHz]*~~

The VDE-SAT uplink has common characteristics with VDE terrestrial ship-to-shore. Therefore, it will not create any additional interference to land and aeronautical mobile services.

The VDE-SAT downlink is in compliance with the ~~agreed~~ pfd mask specified Recommendation ITU-R M.2092-0 and provided in Section 4.2.1. ~~This pfd mask ensures that the VDE-SAT downlink will not cause harmful interference to land and aeronautical mobile services. The pfd mask was coordinated and agreed between WP 5A, WP 5B and WP 5C ahead of WRC-15. In a liaison statement to WP 5B (Doc. 5B/199), WP 5A confirmed that the Recommendation ITU-R M.1808 has not been revised since and as such the mask is still valid.~~ The pfd mask is presented in Table 4-4. In addition, as discussed in section 6.2.3.4, the out of band emissions from the VDE-SAT downlink will be at least 65 dB below the in-band emissions when more than 500 kHz out from the VDE-SAT downlink. Thus, land mobile stations in adjacent frequency bands will not experience harmful interference from the VDE-SAT downlink.

6.2.7 Radio astronomy out of band power flux density mask

(… no change …)

7 Satellite receiver resilience to harmful interference from incumbent services and those in adjacent frequency band

(… no change …)

7.1 Compatibility of VDE-SAT with the mobile service operating in the frequency band 156-162 MHz

7.1.1 Introduction

(… no change …)

7.1.2 Characteristics of land mobile systems operating in the 156 to 162 MHz band

(… no change …)

7.1.3 Characteristics of the VDE-SAT uplink

(… no change …)

7.1.4 Estimation of interference level from base and mobile stations operating in the land mobile service in the 156 to 162 MHz band

(… no change …)

7.1.5 Effect on VDE-SAT uplink link budget from interference from base and mobile stations operating in the land mobile service in the 156 to 162 MHz band

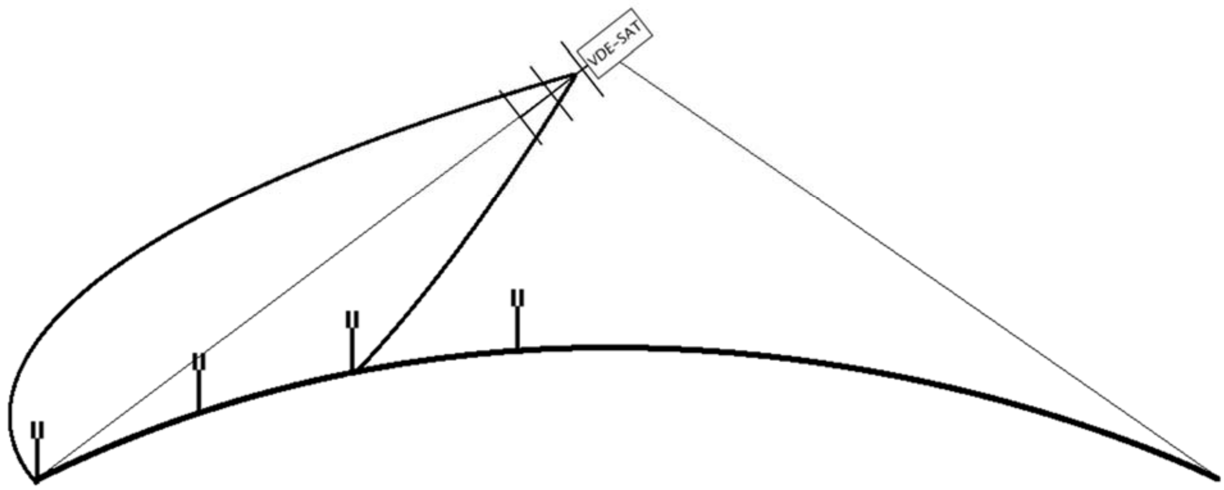
(… no change …)

7.1.6 Effect of interference from multiple land mobile stations

As a satellite at all times will cover a large area, there is a chance that the VDE-SAT receiver on-board a satellite will experience simultaneous interference from multiple land mobile stations. To evaluate the effect of simultaneous interference from multiple land mobile stations an interference scenario as illustrated in Figure 7-2 has been defined.

FIGURE 7-2

Illustration of interference scenario to evaluate the effect of simultaneous interference from multiple land mobile stations.



The land mobile stations are illustrated by the antennas, and are placed along the boresight axis of the Yagi antenna. The number of interfering land mobile stations are given by the separation distance between the stations. Given the coverage radius for land mobile base station provided Table 7-1 of typically 50 km. To limit interference between land mobile systems, the separation distance will normally be larger than 250 km.

Figure 7-3 to 7-5 presents estimated link margin for a range of land mobile base station separation distances. The results are based on interference power calculations performed using the same approach as that used in Table 7-8 and 7-10, and summarizing multiple interference sources. For interference from land mobile base stations with a separation distance of 250 km the link margin is positive for a large range of ship elevation angles between about 20 and 44 degrees. The range of elevation angles with positive link margin grows to between 17 and 50 degrees with a land mobile base station separation distance of 300 km and to between about 10 and 57 with a land mobile base station separation distance of 500 km.

FIGURE 7-3

Estimated link margin for the VDE-SAT uplink waveform 1 with 8 interfering land mobile stations separated by 250 km.

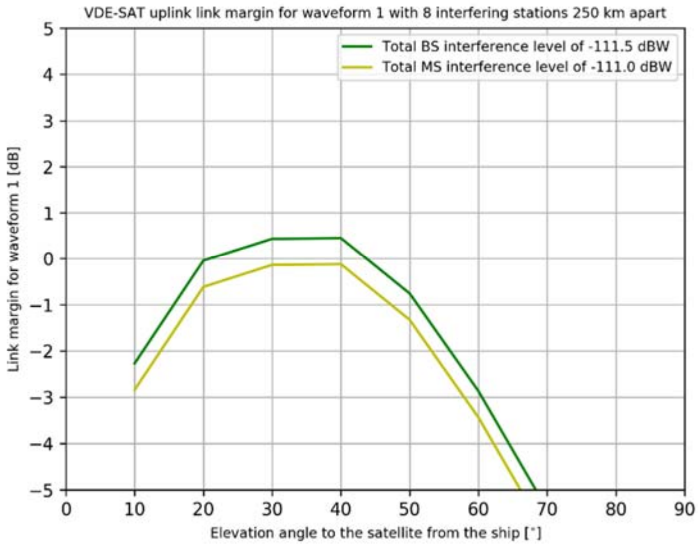


FIGURE 7-4

Estimated link margin for the VDE-SAT uplink waveform 1 with 6 interfering land mobile stations separated by 300 km.

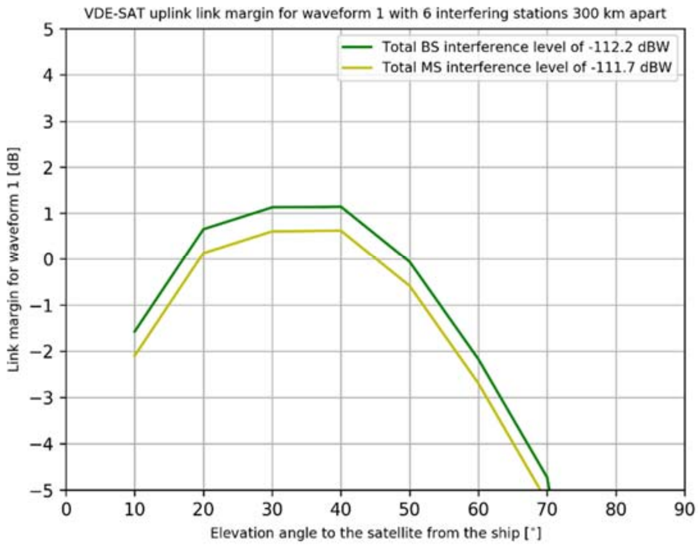
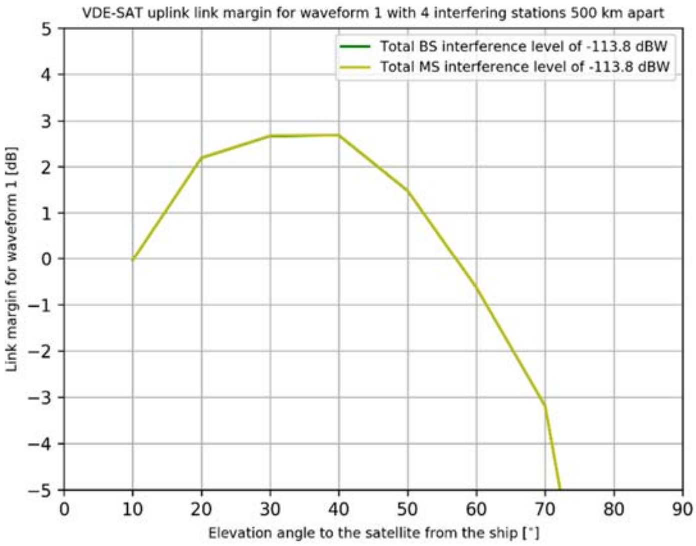


FIGURE 7-5

Estimated link margin for the VDE-SAT uplink waveform 1 with 4 interfering land mobile stations separated by 500 km.



A separation distance of 250 km can be assumed to represent a worst case scenario, since the VDE-SAT system is designed for maritime usage and the antenna therefore will be pointed towards sea and ocean areas where there are no land mobile stations. In addition, the discrimination factors and mitigation techniques summarized in Table 7-15 can be applied.

7.1.~~6~~7 Conclusions

(… no change …)

7.2 Compatibility of VDE-SAT with the radiolocation service operating in the frequency band 154-156 MHz

(… no change …)

[7.3 Impact assessment of systems operating in the frequency band 156-162 MHz in the mobile service to new satellite component of the VHF data exchange system (VDES).

[Editorial note: This section can be removed as this material is covered by Section 7.1]

7.3.1 Introduction

Section 3.3 of this Report considers two alternative frequency utilization plans for VDES satellite component. In accordance with the frequency plan alternative 1 the frequency band 157.1875 – 157.3375 MHz is proposed to be used for uplink. In accordance with the frequency plan alternative 2 the frequency band 161.7875 – 161.9375 MHz is also proposed to be used for uplink in addition to the frequency band 157.1875 – 157.3375 MHz.[1]

The considered frequency bands are allocated to the mobile service (except aeronautical mobile in Region 1) subject to Radio Regulations.

The impact assessment of mobile systems to VDES satellite receivers is given below.

7.3.2 Characteristics of systems operating in the 156-162 MHz in the mobile service

The characteristics of systems in the mobile service operating in the frequency band 156-162 MHz are given in Recommendation ITU-R M.1808. Table 7-16 presents the characteristics of base stations transmitters and Table 7-17 contains characteristics of mobile stations transmitters taken from the mentioned Recommendation.

TABLE 7-16

Base station transmitter characteristics in the frequency band 138-174 MHz

Frequency band (MHz)	**138–174**	
Type of emission	**Analogue**	**Digital**
System-wide		
Channel bandwidth (kHz)	12,5/15/25/30	6,25/7,5/12,5/15
Modulation type	FM	C4FM
Type of operation	Simplex/duplex	Duplex
Typical SINAD (dB) or BER (%)	12 dB	5%
Transmitter		
Output power (W)	5–125 (30) (100)	20–125 (60) (100)
e.r.p. (dBW)	7–26 (19) (24)	13–26 (18) (24)
Necessary bandwidth (kHz)	11/11/16/16	5,5/5,5/8,1/8,1
Coverage radius (km)	1–75 (50)	1–75 (50)
Antenna gain (dBd)	0–9 (6)	0–9 (6)
Antenna height (m) (relative to ground level)	10–150 (60)	10–150 (65)
Radiation pattern	Omnidirectional	Omnidirectional
Antenna polarization	Vertical	Vertical

[1] Subject to the second option the frequency bands 157.2875-157.3375 MHz and 161.8875-161.9375 MHz are used for data transmission for satellite receiver while in the frequency bands 157.1875-157.2875 MHz and 161.7875-161.8875 MHz the satellite will listen to ship data transmission the same as satellite AIS.

Frequency band (MHz)	138–174	
Type of emission	**Analogue**	**Digital**
Total loss (dB)	0–7 (2)	3–9 (6) (2)

NOTE 1 – Simplex systems use the same frequency for both the base station and mobile station to transmit.

NOTE 2 – Frequency division duplex systems have different frequencies for the base station and mobile station which allows simultaneous communications.

NOTE 3 – Typical values are shown in parenthesis. In some instances, more than one typical value is provided.

NOTE 4 – e.r.p. is equal to the output power (dBW) plus antenna gain (dBd) minus total losses (dB).

TABLE 7-17

Mobile station transmitter characteristics in the frequency band 138-174 MHz

Frequency band (MHz)	138–174	
Type of emission	**Analogue**	**Digital**
System-wide		
Channel bandwidth (kHz)	12,5/15/25/30	6,25/7,5/12,5/15
Modulation type	FM	C4FM
Type of operation	Simplex/duplex	Duplex
Typical SINAD (dB) or BER (%)	12 dB	5%
Transmitter		
Output power (W)	1–100 (H: 5 V: 30, 50)	1–100 (H: 5 V: 30, 50)
e.r.p. (dBW)	−3–18 (H: −3 V: 14, 16)	−3–18 (H: −3 V: 14, 16)
Necessary bandwidth (kHz)	11/11/16/16	5,5/5,5/8,1/8,1
Antenna gain (dBd)	−10–4 (H: −10, V: 0)	−10–4 (H: −10, V: 0)
Antenna height (m) (relative to ground level)	(2)	(2)
Radiation pattern	Omnidirectional	Omnidirectional
Antenna polarization	Vertical	Vertical
Total loss (dB)	0–1 (H: 0, V: 1)	0–1 (H: 0, V: 1)

NOTE 1 – Simplex systems use the same frequency for both the base station and mobile station to transmit.

NOTE 2 – Frequency division duplex (FDD) systems have different frequencies for the base station and mobile station which allows simultaneous communications.

NOTE 3 – Typical values are shown in parenthesis, "H:" represents the value for handheld mobile stations and "V:" represents the value for vehicular mobile stations. In some instances, more than one typical value is provided.

NOTE 4 – e.r.p. is equal to the output power (dBW) plus antenna gain (dBd) minus total losses (dB).

The parameters given in Table 7-18 were chosen to estimate the interference impact to VDES satellite receivers based on the characteristics given in Tables 7-16 and 7-17. With this the mobile stations power was assumed of 50 W. In case the mobile stations power is 100 W directional antennae are assumed to be used and the interference impact caused by such mobile stations is the same as the impact caused by base station.

TABLE 7-18

Mobile station characteristics used for estimations

Station type	BS	MS
Frequency band (kHz)	16	16
Output power dBW (W)	20 (100)	17 (50)
Feed losses (dB)	2	1
Antenna gain (dBd)	~~9~~6	0
Maximum e.i.r.p.	~~27~~26	16

Figure 7-4 shows antenna patterns for typical antennas used in the land mobile service as described in Recommendation ITU-R F.1336-4. Assuming a 6 dBd antenna is used at the base station and a 0 dBd antenna is used at the mobile station, the antenna gain versus elevation angle can be tabulated as in Table 7-19 and Table 7-20 for the base station and mobile station respectively. Table 7-19 and Table 7-20 also present the resulting e.i.r.p versus elevation angle for the two station types.

FIGURE 7-4

Antenna patterns for typical antennas used in the land mobile service as described in Recommendation ITU-R F.1336-4

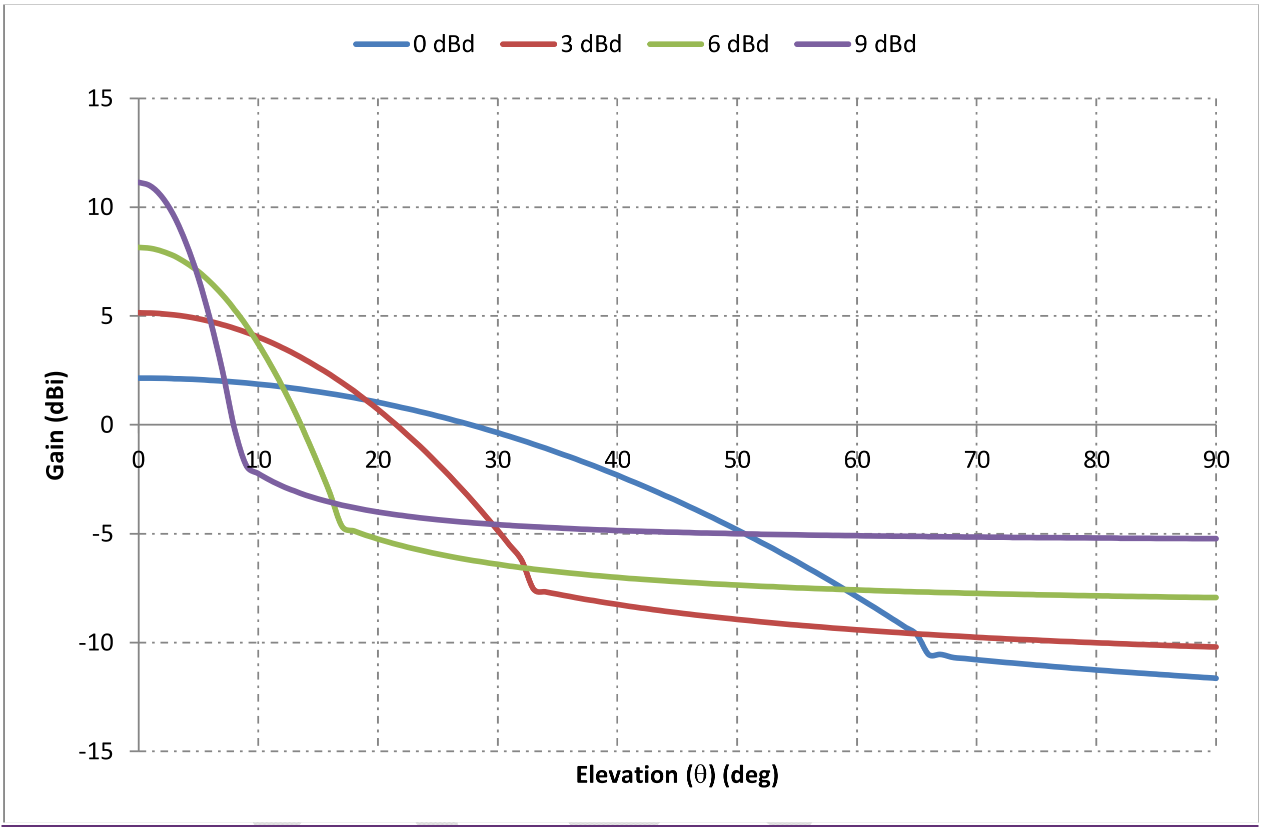


TABLE 7-19

Base station antenna gain and e.i.r.p versus elevation angle

Elevation angle	**Antenna gain**	**e.i.r.p.**
degrees	dBi	dBW
0	8.0	26.0
10	3.5	21.5
20	−5.5	12.5
30	−6.5	11.5
40	−7.0	11.0
50	−7.5	10.5
60	−8.0	10.0
70	−8.0	10.0
80	−8.0	10.0
90	−8.0	10.0

TABLE 7-20

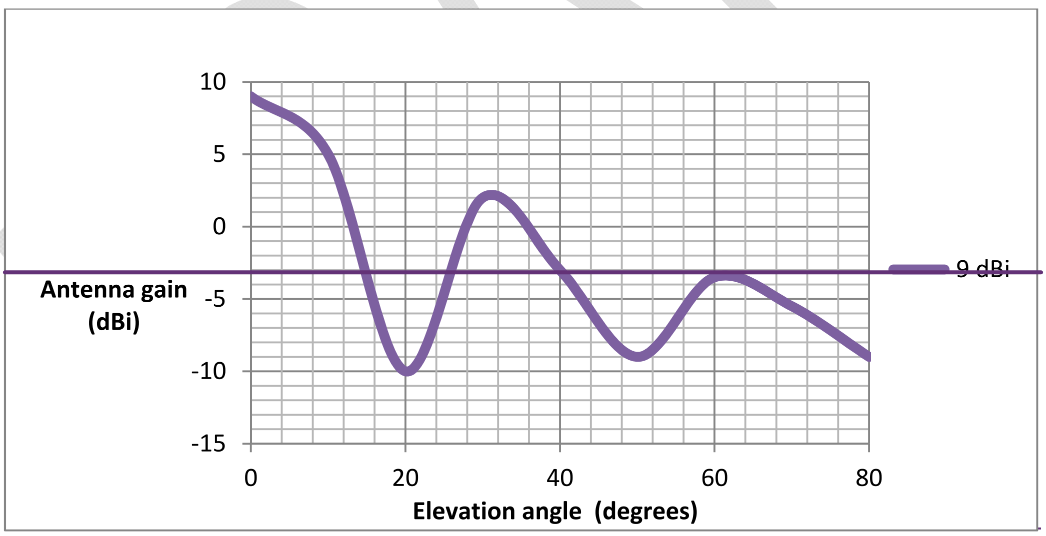
Mobile station antenna gain and e.i.r.p versus elevation angle

Elevation angle	**Antenna gain**	**e.i.r.p.**
degrees	dBi	dBW
0	2.0	18.0
10	2.0	18.0
20	1.0	17.0
30	−0.5	15.5
40	−2.5	13.5
50	−5.0	11.0
60	−8.0	8.0
70	−11.0	5.0
80	−11.5	4.5
90	−12.0	4.0

~~Taken into account the antenna selectivity of base station in vertical plane the antenna pattern with maximum antenna gain of 9 dBi (taken from Annex 1 to Recommendation ITU-R M.2092) was used (see Figure 7-3).~~

~~Figure 7-3~~

~~VHF typical antenna pattern in vertical plane~~



~~Table 7-19 presents base station e.i.r.p relation from elevation angle.~~

~~TABLE 7-19~~

~~**Base station e.i.r.p relation from elevation angle**~~

~~Elevation angle~~	~~Antenna power~~	~~Feed loss~~	~~Antenna gain~~	~~e.i.r.p.~~
~~deg~~	~~dBW~~	~~дБ~~	~~дБи~~	~~dBW~~

~~0~~	~~20~~	~~2~~	~~9~~	~~27.0~~
~~10~~	~~20~~	~~2~~	~~5~~	~~23.0~~
~~20~~	~~20~~	~~2~~	~~-10~~	~~8.0~~
~~30~~	~~20~~	~~2~~	~~2~~	~~20.0~~
~~40~~	~~20~~	~~2~~	~~-3~~	~~15.0~~
~~50~~	~~20~~	~~2~~	~~-9~~	~~9.0~~
~~60~~	~~20~~	~~2~~	~~-3.5~~	~~14.5~~
~~70~~	~~20~~	~~2~~	~~-5.5~~	~~12.5~~
~~80~~	~~20~~	~~2~~	~~-9~~	~~9.0~~
~~90~~	~~20~~	~~2~~	~~-20~~	~~-2.0~~

7.3.3 Characteristics of VDES satellite link Earth-to-space (ship-to-satellite)

The characteristics of VDES satellite link (Earth-to-space) between transmitting ship station and satellite receiver are presented in Sections ~~7.2.3~~4.1 and 4.3, and summarized in Table~~s~~ ~~7.2-~~7.~~-~~6.

7.3.4 Impact assessment of emissions caused by base and mobile stations of the mobile service to VDES satellite receiver (static analysis, single interference)

Tables 7-~~20~~21-7-~~23~~ 24 contain the assessment results of interference caused by base and mobile stations at VDES satellite receiver input at orbit with altitude of 600 km for Yagi antenna and Isoflux isotropic antenna. The analysis shows that the maximum interference level at elevation angles of mobile station of more than 10 degrees will be equal to:

- minus ~~121~~123.~~5~~ 1 dBW in case of interference caused by base station to satellite receiver with Isoflu~~a~~x antenna;
- minus ~~113~~116.~~2~~ 6 dBW in case of interference caused by base station to satellite receiver with Yagi antenna;
- minus 125.3 dBW in case of interference caused by mobile station to satellite receiver with Isoflu~~a~~x antenna;
- minus ~~116~~117.~~4~~ 7 dBW in case of interference caused by mobile station to satellite receiver with Yagi antenna.

These levels were used for estimation of C/(N+I) ratio at the satellite receiver input which are given in Tables 7-~~24~~25-7-~~27~~28. With this ~~Signal 2~~waveform 1 of VDES uplink as the most noise immune signal shape was considered.

~~Editor note: the different interference scenario should be detailed, in particular the relative positions of the MS/BS and the VDES transmitter on the ship to the satellite.~~

TABLE 7-~~20~~21

Assessment of interference caused by base station at the VDES satellite receiver input with ~~Isoflax~~ Isoflux antenna

Elevation angle	e.i.r.p. in 42 kHz bandwidth	Polarization loss	Path length	Path loss	Antenna gain	Feed loss	Interference level at satellite receiver input
deg	dBW	dB	km	dB	dBi	dB	dBW

0	26.0~~27.0~~	3	2 830	145.4	2	1	-121.4~~-120.4~~
10	21.5~~23.0~~	3	1 932	142.1	1.5	1	-123.1~~-121.6~~
20	12.5~~8.0~~	3	1 392	139.3	1	1	-129.8~~-134.3~~
30	11.5~~20.0~~	3	1 075	137	-0.5	1	-130.0~~-121.5~~
40	11.0~~15.0~~	3	882	135.3	-2	1	-130.3~~-126.3~~
50	10.5~~9.0~~	3	761	134	-4	1	-131.5~~-133.0~~
60	10.0~~14.5~~	3	683	133.1	-5	1	-132.1~~-127.6~~
70	10.0~~12.5~~	3	635	132.4	-7	1	-133.4~~-130.9~~
80	10.0~~9.0~~	3	608	132.1	-8	1	-134.1~~-135.1~~
90	10.0~~-2.0~~	3	600	131.9	-8.5	1	-134.4~~-146.4~~

TABLE 7-22~~1~~

Assessment of interference caused by base station at the VDES satellite receiver input with Yagi antenna

Elevation angle	**e.i.r.p. in 42 kHz bandwidth**	**Polarization loss**	**Path length**	**Path loss**	**Antenna gain**	**Feed loss**	**Interference level at satellite receiver input**
deg	dBW	dB	km	dB	dBi	dB	dBW
0	26.0~~27.0~~	3	2 830	145.4	8	1	-115.4~~-114.4~~
10	21.5~~23.0~~	3	1 932	142.1	8	1	-116.6~~-115.1~~
20	12.5~~8.0~~	3	1 392	139.3	8	1	-122.8~~-127.3~~
30	11.5~~20.0~~	3	1 075	137	7.8	1	-121.7~~-113.2~~
40	11.0~~15.0~~	3	882	135.3	6.9	1	-121.4~~-117.4~~
50	10.5~~9.0~~	3	761	134	5.5	1	-122.0~~-123.5~~
60	10.0~~14.5~~	3	683	133.1	3.6	1	-123.5~~-119.0~~
70	10.0~~12.5~~	3	635	132.4	0.7	1	-125.7~~-123.2~~
80	10.0~~9.0~~	3	608	132.1	-2.2	1	-128.3~~-129.3~~
90	10.0~~-2.0~~	3	600	131.9	-5.5	1	-131.4~~-143.4~~

TABLE 7-23~~2~~

Assessment of interference caused by mobile station at the VDES satellite receiver input with ~~Isoflax~~ Isoflux antenna

Elevation angle	**e.i.r.p. in 42 kHz bandwidth**	**Polarization loss**	**Path length**	**Path loss**	**Antenna gain**	**Feed loss**	**Interference level at satellite receiver input**
deg	dBW	dB	km	dB	dBi	dB	dBW
0	18.0~~16.0~~	3	2 830	145.4	2	1	-129.4~~-131.4~~
10	18.0~~16.0~~	3	1 932	142.1	1.5	1	-126.6~~-128.6~~
20	17.0~~16.0~~	3	1 392	139.3	1	1	-125.3~~-126.3~~

30	15.5~~16.0~~	3	1 075	137	-0.5	1	-126.0~~-125.5~~
40	13.5~~16.0~~	3	882	135.3	-2	1	-127.8~~-125.3~~
50	11.0~~16.0~~	3	761	134	-4	1	-131.0~~-126.0~~
60	8.0~~16.0~~	3	683	133.1	-5	1	-134.1~~-126.1~~
70	5.0~~16.0~~	3	635	132.4	-7	1	-138.4~~-127.4~~
80	4.5~~16.0~~	3	608	132.1	-8	1	-139.6~~-128.1~~
90	4.0~~16.0~~	3	600	131.9	-8.5	1	-140.5~~-128.4~~

TABLE 7-24~~3~~

Assessment of interference caused by base station at the VDES satellite receiver input with Yagi antenna

Elevation angle	**e.i.r.p. in 42 kHz bandwidth**	**Polarization loss**	**Path length**	**Path loss**	**Antenna gain**	**Feed loss**	**Interference level at satellite receiver input**
deg	dBW	dB	km	dB	dBi	dB	dBW
0	18.0~~16.0~~	3	2 830	145.4	8	1	-123.4~~-125.4~~
10	18.0~~16.0~~	3	1 932	142.1	8	1	-120.1~~-122.1~~
20	17.0~~16.0~~	3	1 392	139.3	8	1	-118.3~~-119.3~~
30	15.5~~16.0~~	3	1 075	137	7.8	1	-117.7~~-117.2~~
40	13.5~~16.0~~	3	882	135.3	6.9	1	-118.9~~-116.4~~
50	11.0~~16.0~~	3	761	134	5.5	1	-121.5~~-116.5~~
60	8.0~~16.0~~	3	683	133.1	3.6	1	-125.5~~-117.5~~
70	5.0~~16.0~~	3	635	132.4	0.7	1	-130.7~~-119.7~~
80	4.5~~16.0~~	3	608	132.1	-2.2	1	-133.8~~-122.3~~
90	4.0~~16.0~~	3	600	131.9	-5.5	1	-137.5~~-125.4~~

TABLE 7-25~~4~~

Estimation of C/(N+I) ratio at the VDES satellite receiver input with ~~Isoflax~~ Isoflux antenna in case of interference caused by base station

[TBD]

TABLE 7-26~~5~~

Estimation of C/(N+I) ratio at the VDES satellite receiver input with Yagi antenna in case of interference caused by base station

[TBD]

TABLE 7-27~~6~~

Estimation of C/(N+I) ratio at the VDES satellite receiver input with ~~Isoflax~~ Isoflux antenna in case of interference caused by mobile station

[TBD]

TABLE 7-28~~7~~

Estimation of C/(N+I) ratio at the VDES satellite receiver input with Yagi antenna in case of interference caused by mobile station

[TBD]   ]

8 Testing, demonstrations and measurements

(… no change …)

9 Future demonstrations and measurements

(… no change …)