# 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

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  50 kHz for VDE-SAT | Low for both service  VDES services operate independently | High for both service |

**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 VDE-SAT key parameters

(… no change …)

## 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

*[Editor note: This pfd mask is currently under review.]*

The VDE-SAT downlink is in compliance with the pfd mask specified in Recommendation ITU-R M.2092-0. The pfd mask is presented in Table 4-4.

TABLE 4-4

Proposed power spectral and power flux density mask

To protect the land mobile service, additional measures will be applied by improving the pfd mask specified in Recommendation ITU-R M.2092-0 at very low elevation angles and high elevation angles according to the mask presented in Table 4-5. See Section 6.1.2.2.1 for the technical foundation for this mask.

TABLE 4-5

Power spectral and power flux density (pfd) mask to ensure protection of the land mobile service.

From the mask given in Table 4-5 a theoretical maximum satellite e.i.r.p can be calculated as a function of ship elevation angle. The result is provided in Table 4-6.

TABLE 4-6

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 | −150.9 | 2 831 | −2.9 |
| 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 | −135.1 | 683 | 0.5 |
| 70 | −135.0 | 635 | 0.0 |
| 80 | −134.9 | 608 | −0.3 |
| 90 | −134.8 | 600 | −0.3 |

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) 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. 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 4‑7.

TABLE 4-7

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 A4‑6 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 | −150.9 | 1.5 |
| 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 | −135.1 | 9.4 |
| 70 | 18.2 | 47.9 | 0.7 | −11.7 | 635 | −146.7 | −135.0 | 11.7 |
| 80 | 9.1 | 57 | −2.2 | −14.6 | 608 | −149.2 | −134.9 | 14.3 |
| 90 | 0 | 66.1 | −5.5 | −17.9 | 600 | −152.4 | −134.8 | 17.6 |

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 4-8.

TABLE 4-8

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 A4‑6 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 | −150.9 | 0.1 |
| 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 | −135.1 | 10.6 |
| 70 | 18.2 | 47.9 | −7 | −12.0 | 635 | −147.0 | −135.0 | 12.0 |
| 80 | 9.1 | 57 | −8 | −13.0 | 608 | −147.6 | −134.9 | 12.7 |
| 90 | 0 | 66.1 | −8.5 | −13.5 | 600 | −148.0 | −134.8 | 13.2 |

### 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 |
| Threshold Es/N0 for a Gaussian channel (dB) (PER=10-2) | -1.5 | 3.9 | 3.9 | 8.0 | 12.2 |
| Required C/N0 (dBHz) | 31.7 | 49.2 | 49.2 | 53.3 | 57.5 |
| Required C/(N+I) (dB) | -13.5 | 2.9 | 2.9 | 7.0 | 11.2 |

Recommendation ITU-R М.1184 provides information on non-GSO systems operating below 1 GHz, including associated required C/(N+I) thresholds. However, the systems described in Recommendation ITU-R М.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 *Es/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. 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 *Es/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 *Es/N*0 threshold of –1.5 dB for waveform *1* the result is a required *C/(N+I)* threshold of –13.5. dB:

FIGURE 4-3

Es/N0 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 pfd mask specified in Recommendation ITU-R M.2092-0 was intended to provide protection for fixed and mobile terrestrial services. To further ensure protection of the land mobile service, additional measures will be applied by improving the pfd mask specified in Recommendation ITU-R M.2092-0 at very low elevation angles and high elevation angles according to the mask presented in Table 4-5. This pfd mask also ensures that the VDE-SAT downlink will not cause harmful interference to fixed services.

### 6.1.2 Land and aeronautical mobile services in-band

### 6.1.2.1 Interference to mobile services from the uplink

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.

### 6.1.2.2 Interference to mobile services from the downlink

### 6.1.2.2.1 VIEW 1 about pfd mask­

Recommendation ITU-R M.1808 provides the characteristics of mobile systems and the useful information is reproduced in Table 6-1 and Table 6-2.

Table 6-1

Base station characteristics for frequency sharing below 869 MHz

| Frequency band (MHz) | 138 to 174 | |
| --- | --- | --- |
| Type of emission | Analogue | Digital |
| Receiver |  |  |
| Noise figure (dB) | 6 to 12 (7) | 6 to 12 (7) |
| IF filter bandwidth (kHz) | 8/11/12.5/16 | 5.5/5.5/5.5/5.5 |
| Antenna gain (dBd) | 0 to 9 (6) | 0 to 9 (8) |
| Radiation pattern | Omnidirectional | Omnidirectional |
| Antenna polarization | Vertical | Vertical |
| Total loss (dB) | 0 to 6 (3) | 0 to 6 (3) |

Table 6-2

Mobile station characteristics for frequency sharing below 869 MHz

| Frequency band (MHz) | 138 to 174 | |
| --- | --- | --- |
| Type of emission | Analogue | Digital |
| Receiver |  |  |
| Noise figure (dB) | 6 to 12 (7) | 6 to 12 (7) |
| IF filter bandwidth (kHz) | 8/11/12.5/16 | 5.5/5.5/5.5/5.5 |
| Antenna gain (dBd) | −10 to 4 (H: −10, V: 0) | −10 to 4 (H: −10, V: 0) |
| Radiation pattern | Omnidirectional | Omnidirectional |
| Antenna polarization | Vertical | Vertical |
| Total loss (dB) | 0 to 1 (H: 0, V: 1) | 0 to 1 (H: 0, V: 1) |

For the mobile and base stations an average side-lobe pattern is considered in our study according to the Recommendation ITU-R F.1336 for omnidirectional radiation patterns as presented in Equation (1) below.

(1)

with:

(2)

where:

: gain relative to an isotropic antenna (dBi);

: the maximum gain in the azimuth plane (dBi) knowing that in dBi equals  in dBd + 2.15;

: elevation angle relative to the angle of the maximum gain (degrees)   
;

: the 3 dB beamwidth in the elevation plane (degrees) ;

: parameter which accounts for increased side-lobe levels above what would be expected for an antenna with improved side-lobe performance (for antennas operating in the 1-3 GHz range, the parameter should be 0.7).

Figure 6-1 represent resulting the mobile/base station antenna patterns with antenna gain from 0 dBd to 9 dBd.

Figure 6-1

Mobile/base station antenna patterns

ECC Recommendation T/R 25-08 (Lecce 1989, revised in Vienna 1999, revised in Utrecht 2005, revised in Brussels 2008) “Planning criteria and coordination of frequencies in the land mobile service in the range 29.7-921 MHz” provide co-ordination thresholds typically used to determine if co-ordination between land mobile systems are required. It is appropriate to assume that interference levels below these co-ordination thresholds do not constitute harmful interference in a land mobile interference. This assumption is in accordance with Report ITU-R M.2172-1.

The indicative coordination thresholds for narrowband (up to 25 kHz) applications (co-channel, 50% locations, 10% time, 10 m receiving antenna height, at the border-line) are:

* 0 dB(μV/m) for frequencies between 29.7 and 47 MHz;
* 6 dB (μV/m) for frequencies between 47 and 108 MHz;
* 12 dB (μV/m) for frequencies between 108 and 380 MHz;
* 18 dB (μV/m) for frequencies between 380 and 400 MHz;
* 20 dB (μV/m) for frequencies between 400 and 606 MHz;
* 26 dB (μV/m) for frequencies between 606 and 921 MHz.

Thus, according to ECC Recommendation T/R 25-08, for the frequency range proposed for the VDE-SAT downlink, between 160.6 and 162.0 MHz, the appropriate coordination threshold would be 12 dB(μV/m). The maximum power spectral density at the antenna output that would be produced by a vertically polarised signal with a power spectral and flux density of 12 dB(μV/m) in 25 KHz, corresponds to dB(W/(m2 \* 4 kHz))[[1]](#footnote-1). Such maximum value will occur for signals coming at 0 degrees of elevation () as this is the point where the mobile station has maximum gain ().

Using the Friis formula in its simplest form:

(3)

where is the received power spectral density (PSD), is the transmitted power spectral density, is the gain of the transmitting antenna in the direction of the receiver, is the wavelength, is the distance between transmitter and receiver and is the gain of the receiving antenna in the direction of the transmitter.

The power spectral and flux density is given by:

(4)

therefore (3) can be rewritten accordingly:

(5)

The maximum power spectral and flux density that would produce the maximum allowed power spectral density is then:

(6)

where is dB(W/(m2 \* 4 kHz)).

From (5) it is possible to express the power spectral and flux density as a function of the received power spectral density:

(7)

Given that is constant and that as defined in (1) is a function of the elevation angle , then by substituting (6) in (7) the maximum power spectral and flux density is also a function of the elevation angle:

(8)

where:

(9)

It should be noted that with this approach, the electric field strength thresholds are achieved for 100% of the time and 100% locations, that is a conservative interpretation of the threshold values depicted in the equations above.

When applying equation (1) to the *PSFDMAX*, the result is elevation dependent. Assuming the typical antenna gain given in Table 1 for the base station of 6 dBd (8.15 dBi) the *PSFDMAX,BS* in will be:

(10)

with the elevation angle, , and .

Assuming the typical antenna gain given in Table 2 for the mobile station of 0 dBd (2.15 dBi) the *PSFDMAX,MS* in will be:

(11)

with the elevation angle, , and .

Table 6-3 presents the *PSFDMAX,BS* and *PSFDMAX,MS* for elevation angles from 0 to 90 in 10 increments, together with the pfd mask specified in Recommendation ITU-R M.2092-0.

TABLE 6-3

*PSFDMAX,BS* and *PSFDMAX,MS* for elevation angles from 0 to 90 in 10 increments, together with the pfd mask specified in Recommendation ITU-R M.2092-0.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Receiver station elevation angle θ | *PSFDMAX,BS* | *PSFDMAX,MS* | pfd mask specified by Recommendation ITU-R M.2092-0 | Margin between pfd mask and *PSFDMAX,BS* | Margin between pfd mask and *PSFDMAX,MS* |
| (degrees) | (dBW/m2/4 kHz) | (dBW/m2/4 kHz) | (dBW/m2/4 kHz) | (dB) | (dB) |
| 0 | −150.9 | -144.9 | -149.0 | −1.9 | 4.1 |
| 10 | −146.4 | -144.6 | -147.4 | 1.0 | 2.8 |
| 20 | −137.5 | -143.8 | -145.8 | 8.3 | 2.0 |
| 30 | −136.3 | -142.4 | -144.2 | 7.9 | 1.8 |
| 40 | −135.7 | -140.4 | -142.6 | 6.9 | 2.2 |
| 50 | −135.4 | -137.9 | -139.4 | 4.0 | 1.5 |
| 60 | −135.1 | -134.8 | -134.0 | −1.1 | -0.8 |
| 70 | −135.0 | -131.9 | -133.0 | −2.0 | 1.1 |
| 80 | −134.9 | -131.5 | -132.0 | −2.9 | 0.5 |
| 90 | −134.8 | -131.1 | -131.0 | −3.8 | -0.1 |

The information provided in Table 6-3 shows that the margin between the pfd mask specified in Recommendation ITU-R M.2092-0 with respect to *PSFDMAX,BS* and *PSFDMAX,MS* is negative for some of the receiver station elevation angles. Thus, the pfd mask specified in Recommendation ITU-R M.2092-0 exceeds the coordination threshold of 12 dB (μV/m) at very low elevation angles and very high elevation angles. Minor changes to the pfd mask specified in Recommendation ITU-R M.2092-0 are appropriate to ensure the protection of the land mobile service. An updated mask that would provide protection of the land mobile service is presented in Table 6-4.

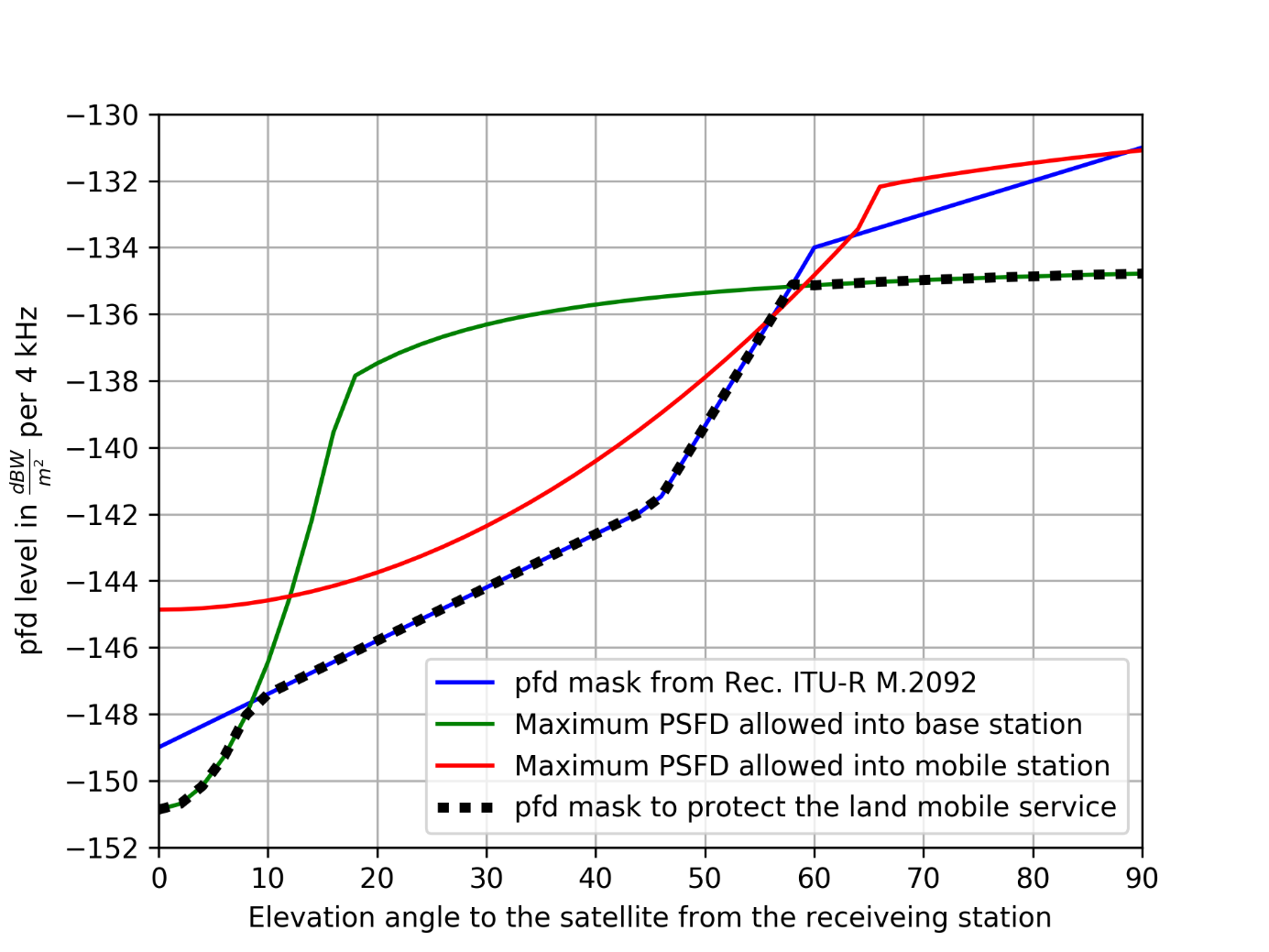
TABLE 6-4

Power spectral and power flux density (pfd) mask to ensure protection of the land mobile service.

Figure 6-2 shows the *PSFDMAX,BS* and *PSFDMAX,MS* for elevation angles from 0 to 90, together with the pfd mask specified in Recommendation ITU-R M.2092-0. Also shown in Figure 6-2 is the updated pfd mask from Table 6-4 that ensures protection of the land mobile service.

Figure 6-2

*PSFDMAX,BS* and *PSFDMAX,MS* as a function of receiver station elevation angles, together with the specified in Recommendation ITU-R M.2092-0 and the updated pfd mask ensuring protection of the land mobile service.



### 6.1.2.2.2 VIEW 2 about pfd mask

### (… no change …)

### 6.1.2.2.3 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

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 agreed pfd mask specified Recommendation ITU-R M.2092-0 was intended to provide protection for fixed and mobile terrestrial services. To further protect the land mobile service, additional measures will be applied by improving the pfd mask specified in Recommendation ITU-R M.2092-0 at very low elevation angles and high elevation angles according to the mask presented in Table 4-5. This pfd mask ensures that the VDE-SAT downlink will not cause harmful interference to land and aeronautical mobile services. See Section 6.1.2.2.1 for the technical foundation for this mask. 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 …)

# 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

### (… 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.[[2]](#footnote-2)

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 |
| 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) | 6 | 0 |
| Maximum e.i.r.p. | 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 |



### 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 4.1 and 4.3, and summarized in Table 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 7-21-7-24 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 123.1 dBW in case of interference caused by base station to satellite receiver with Isoflux antenna;

• minus 116.6 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 Isoflux antenna;

• minus 117.7 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 7-25-7-28. With this waveform 1 of VDES uplink as the most noise immune signal shape was considered.

TABLE 7-21

Assessment of interference caused by base station at the VDES satellite receiver input   
with Isoflax 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 | 3 | 2 830 | 145.4 | 2 | 1 | -121.4 |
| 10 | 21.5 | 3 | 1 932 | 142.1 | 1.5 | 1 | -123.1 |
| 20 | 12.5 | 3 | 1 392 | 139.3 | 1 | 1 | -129.8 |
| 30 | 11.5 | 3 | 1 075 | 137 | -0.5 | 1 | -130.0 |
| 40 | 11.0 | 3 | 882 | 135.3 | -2 | 1 | -130.3 |
| 50 | 10.5 | 3 | 761 | 134 | -4 | 1 | -131.5 |
| 60 | 10.0 | 3 | 683 | 133.1 | -5 | 1 | -132.1 |
| 70 | 10.0 | 3 | 635 | 132.4 | -7 | 1 | -133.4 |
| 80 | 10.0 | 3 | 608 | 132.1 | -8 | 1 | -134.1 |
| 90 | 10.0 | 3 | 600 | 131.9 | -8.5 | 1 | -134.4 |

TABLE 7-22

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 | 3 | 2 830 | 145.4 | 8 | 1 | -115.4 |
| 10 | 21.5 | 3 | 1 932 | 142.1 | 8 | 1 | -116.6 |
| 20 | 12.5 | 3 | 1 392 | 139.3 | 8 | 1 | -122.8 |
| 30 | 11.5 | 3 | 1 075 | 137 | 7.8 | 1 | -121.7 |
| 40 | 11.0 | 3 | 882 | 135.3 | 6.9 | 1 | -121.4 |
| 50 | 10.5 | 3 | 761 | 134 | 5.5 | 1 | -122.0 |
| 60 | 10.0 | 3 | 683 | 133.1 | 3.6 | 1 | -123.5 |
| 70 | 10.0 | 3 | 635 | 132.4 | 0.7 | 1 | -125.7 |
| 80 | 10.0 | 3 | 608 | 132.1 | -2.2 | 1 | -128.3 |
| 90 | 10.0 | 3 | 600 | 131.9 | -5.5 | 1 | -131.4 |

TABLE 7-23

Assessment of interference caused by mobile station at the VDES satellite receiver input with Isoflax 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 | 3 | 2 830 | 145.4 | 2 | 1 | -129.4 |
| 10 | 18.0 | 3 | 1 932 | 142.1 | 1.5 | 1 | -126.6 |
| 20 | 17.0 | 3 | 1 392 | 139.3 | 1 | 1 | -125.3 |
| 30 | 15.5 | 3 | 1 075 | 137 | -0.5 | 1 | -126.0 |
| 40 | 13.5 | 3 | 882 | 135.3 | -2 | 1 | -127.8 |
| 50 | 11.0 | 3 | 761 | 134 | -4 | 1 | -131.0 |
| 60 | 8.0 | 3 | 683 | 133.1 | -5 | 1 | -134.1 |
| 70 | 5.0 | 3 | 635 | 132.4 | -7 | 1 | -138.4 |
| 80 | 4.5 | 3 | 608 | 132.1 | -8 | 1 | -139.6 |
| 90 | 4.0 | 3 | 600 | 131.9 | -8.5 | 1 | -140.5 |

TABLE 7-24

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 | 3 | 2 830 | 145.4 | 8 | 1 | -123.4 |
| 10 | 18.0 | 3 | 1 932 | 142.1 | 8 | 1 | -120.1 |
| 20 | 17.0 | 3 | 1 392 | 139.3 | 8 | 1 | -118.3 |
| 30 | 15.5 | 3 | 1 075 | 137 | 7.8 | 1 | -117.7 |
| 40 | 13.5 | 3 | 882 | 135.3 | 6.9 | 1 | -118.9 |
| 50 | 11.0 | 3 | 761 | 134 | 5.5 | 1 | -121.5 |
| 60 | 8.0 | 3 | 683 | 133.1 | 3.6 | 1 | -125.5 |
| 70 | 5.0 | 3 | 635 | 132.4 | 0.7 | 1 | -130.7 |
| 80 | 4.5 | 3 | 608 | 132.1 | -2.2 | 1 | -133.8 |
| 90 | 4.0 | 3 | 600 | 131.9 | -5.5 | 1 | -137.5 |

TABLE 7-25

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

*[TBD]*

TABLE 7-26

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

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

*[TBD]*

TABLE 7-28

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 …)

1. The conversion from dB (μV/m) (25 kHz reference bandwidth) to dB(W/(m2 \* 4 kHz)) can be computed with the following formula: [↑](#footnote-ref-1)
2. 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. [↑](#footnote-ref-2)