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

Scope

Keywords

Glossary / abbreviations

(… no changes …)

Related ITU-R Recommendations and Reports

(… no changes …)

1 Introduction

(… no changes …)

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

(… no changes …)

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

(… no changes …)

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 changes …)

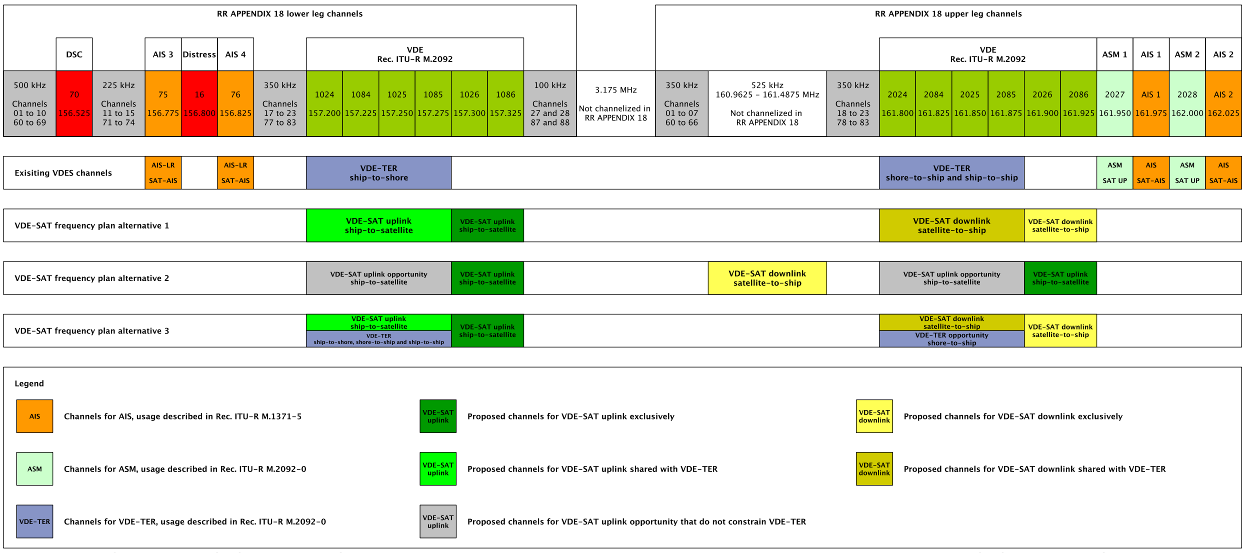
3.3 Frequency plan alternatives

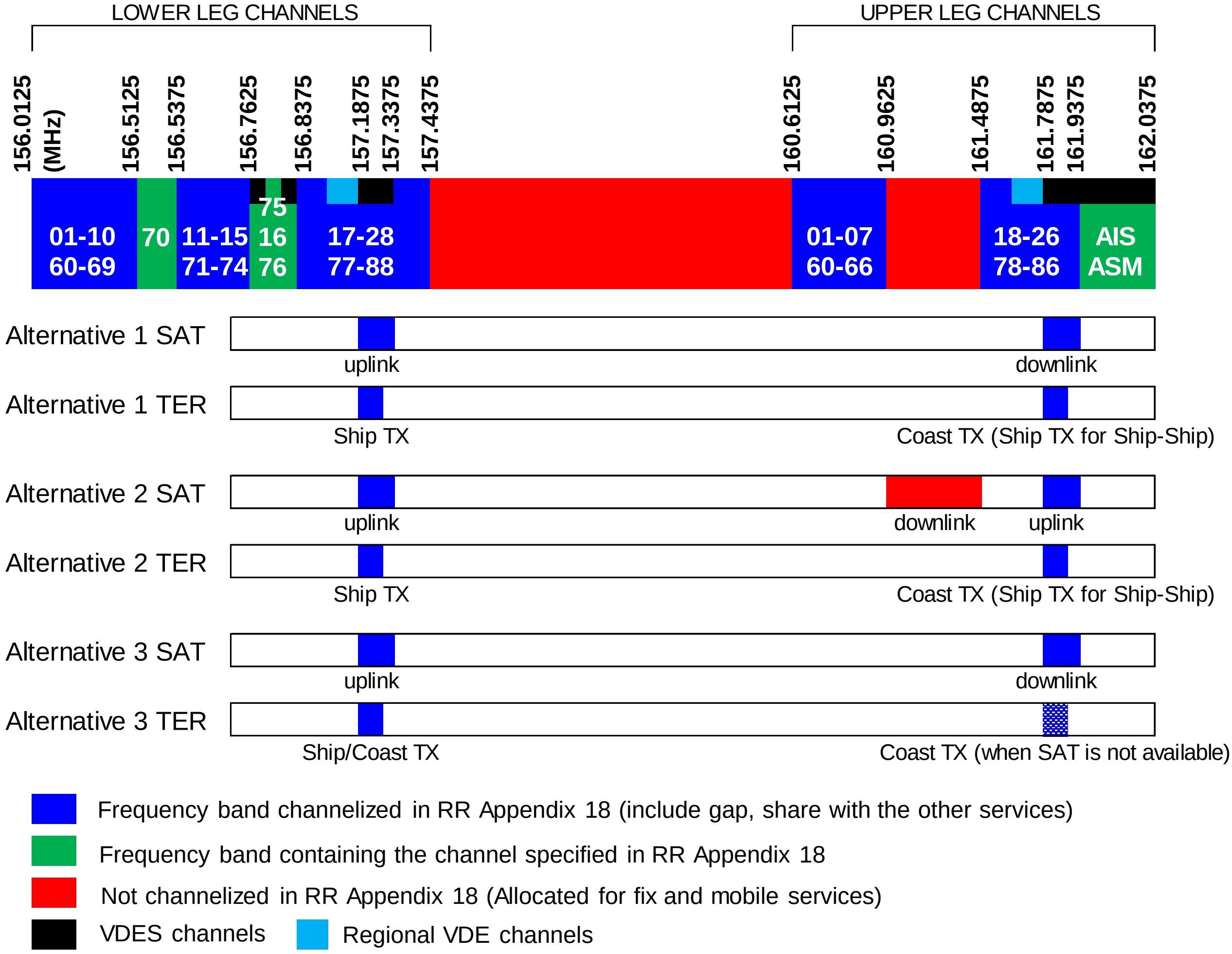
The channels 24, 84, 25, 85, 26 and 86 are allocated for VDE after WRC-15, with the lower leg frequencies used for ship-to-shore and the upper leg frequencies used for shore-to-ship and ship-to-ship. The channels 2027 (ASM 1) and 2028 (ASM 2) are allocated for ASM. Currently, 3 alternative frequency utilization plans for VDES are under consideration. They describe how resources are allocated and shared between VDE-TER, VDE-SAT and ASM. These 3 alternative frequency utilization plans are illustrated in Figure 6 in two different manners, and described further below.

FIGURE 6

RR Appendix 18 and VHF data exchange system frequency utilization plans

~~*Editorial note: This figure needs to be redrawn in 3 parts in order to better present the alternative plans*~~





3.3.1 Frequency plan alternative 1

Alternative 1 has been evaluated according to the criteria defined within the Report ITU-R M.2371-0.

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.

– Four channels 1024, 1084, 1025 and 1085 are shared between ship-to-shore and ship-to-satellite (VDE-SAT uplink) services
– Two channels 1026 and 1086 are exclusively reserved for ship-to-satellite (VDE-SAT uplink) services
– Four channels 2024, 2084, 2025 and 2085 are shared among shore-to-ship, ship-to-ship and satellite-to-ship (VDE-SAT downlink) services
– 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

3.3.2 Frequency plan alternative 2

This alternative plan 2 is similar to alternative 1 except the downlink which has been relocated. In addition, parts of this alternative have not been evaluated according to the criteria defined within the Report ITU-R M.2371-0.

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**.

– 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.
– 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.
– 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.

3.3.3 Frequency plan alternative 3

This alternative plan 3 is similar to alternative 1 except the VDE TER which has been relocated. In addition, parts of this alternative have not been evaluated according to the criteria defined within the Report ITU-R M.2371-0.

Frequency plan alternative 3 allow for utilization of the channels 24, 84, 25 and 85 in a shared manner between VDE-TER and VDE-SAT, while channels 26 and 86 exclusively reserved for VDE-SAT.

– Four channels 1024, 1084, 1025 and 1085 are shared between ship-to-shore, ship-to-ship, shore-to-ship and ship-to-satellite (VDE-SAT uplink) services
– Two channels 1026 and 1086 are exclusively reserved for ship-to-satellite (VDE-SAT uplink) services

– Four channels 2024, 2084, 2025 and 2085 are primarily for satellite-to-ship (VDE-SAT downlink) service, while shore-to-ship services are possible without imposing constraints on ship-to-satellite services

– Two channels 2026 and 2086 are exclusively reserved for satellite-to-ship (VDE-SAT downlink) services.

3.4 Evaluation of the three frequency plan alternatives

(… no changes …)

3.4.1 Conclusions for the selection of a frequency plan alternative

(… no changes …)

4 Technical description of the VHF data exchange-satellite

4.1 VHF data exchange system - satellite key parameters

(… no changes …)

4.2 Technical characteristics of the VHF data exchange -satellite downlink in the VHF maritime mobile frequency band

(… no changes …)

4.3 Technical characteristics of the VHF data exchange-satellite uplink in the VHF maritime mobile frequency band

(… no changes …)

4.3.1 VHF data exchange-satellite 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 13 for uplink. The thresholds C/N_0 and $C/(N+I)$ on a Gaussian channel have been estimated.

TABLE 13

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 E_s/N_0 for a Gaussian channel (dB) (PER=10^{-2})	-1.5	3.9	3.9	8.0	12.2
Required C/N_0 (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 M.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 M.1184 do not ~~take into account~~ implement the advanced coding, forward error correcting and spread spectrum techniques utilized by the VDES.

There are two views on the material in this section. One view state that the C/(N+I) performance thresholds provided in this section is correct and appropriate to use. Another view states that the C/(N+I) values provided in Annex 2 of Recommendation ITU-R M.1184-3 should be used as protection criteria. The following discussion describes the advantages of the advanced modulation and coding techniques proposed for VDE-SAT, that are not implemented by the systems described in Recommendation ITU-R M.1184.

~~The material in this section is currently under consideration by WP 4C. However, the technical information still needs to be agreed and studied by WP 4C and WP 5B.~~ Waveform *1* uses a combination of spread spectrum, low bitrate and powerful 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 has a symbol energy to noise density ratio (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 11, 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 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.

Recommendation ITU-R SM.1055 defines the processing gain, PG, as

$$PG = 2B_{S_{in}}T_S$$

where $2B_{S_{in}}$ is the bandwidth of the RF input signal power density spectrum at first nulls and T_S is the time duration of the input signal information. For a root raised cosine filtered direct sequence spread spectrum signal, $2B_{S_{in}}$ corresponds to the chip rate, which for waveform 1 in Table 13 is 33.6 kHz. For any digital signal, T_S corresponds to the inverse of the information symbol rate, R_S, which for waveform 1 in Table 13 is 2.1 ksps. Thus, the processing gain, PG, for waveform 1 in Table 13 is:

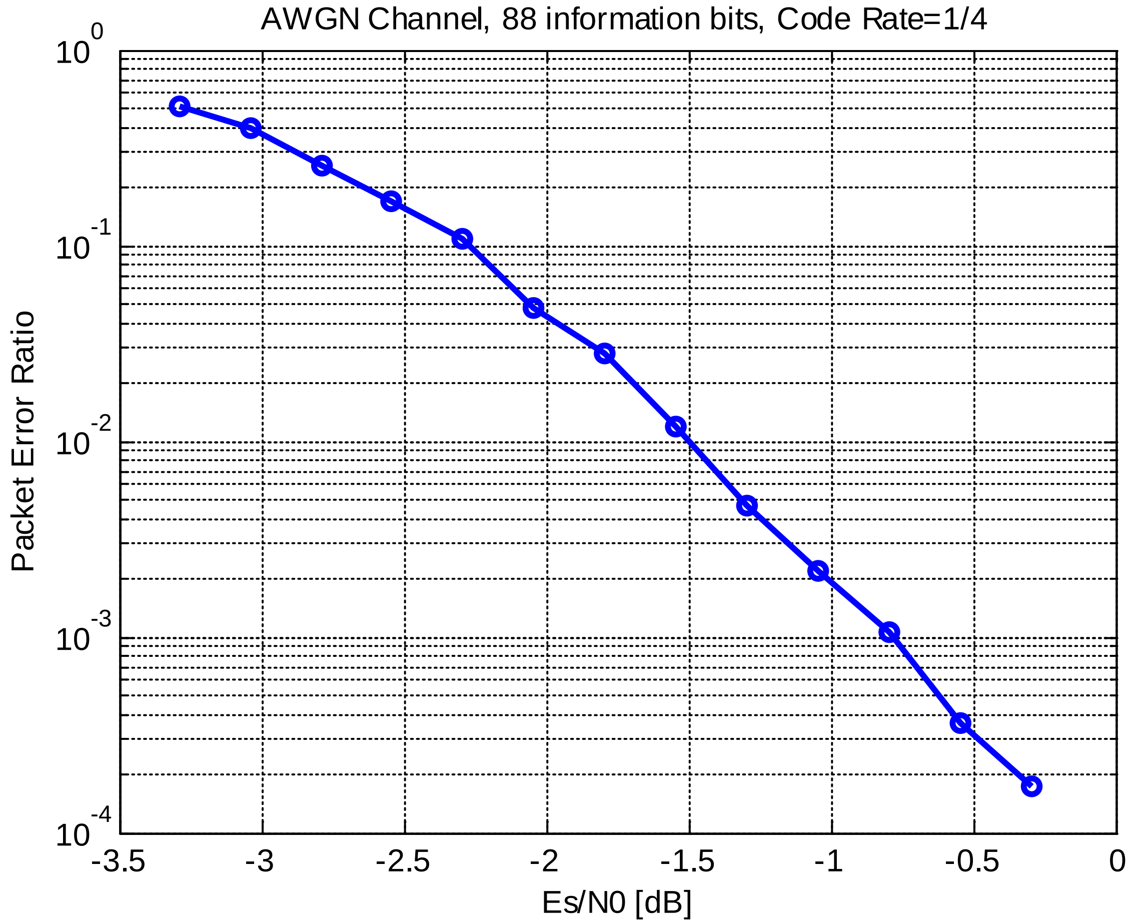
$$PG = 2B_{S_{in}}T_S = \frac{2B_{S_{in}}}{R_S} = \frac{33.6}{2.1} = 16$$

A PG of 16 corresponds to 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 11

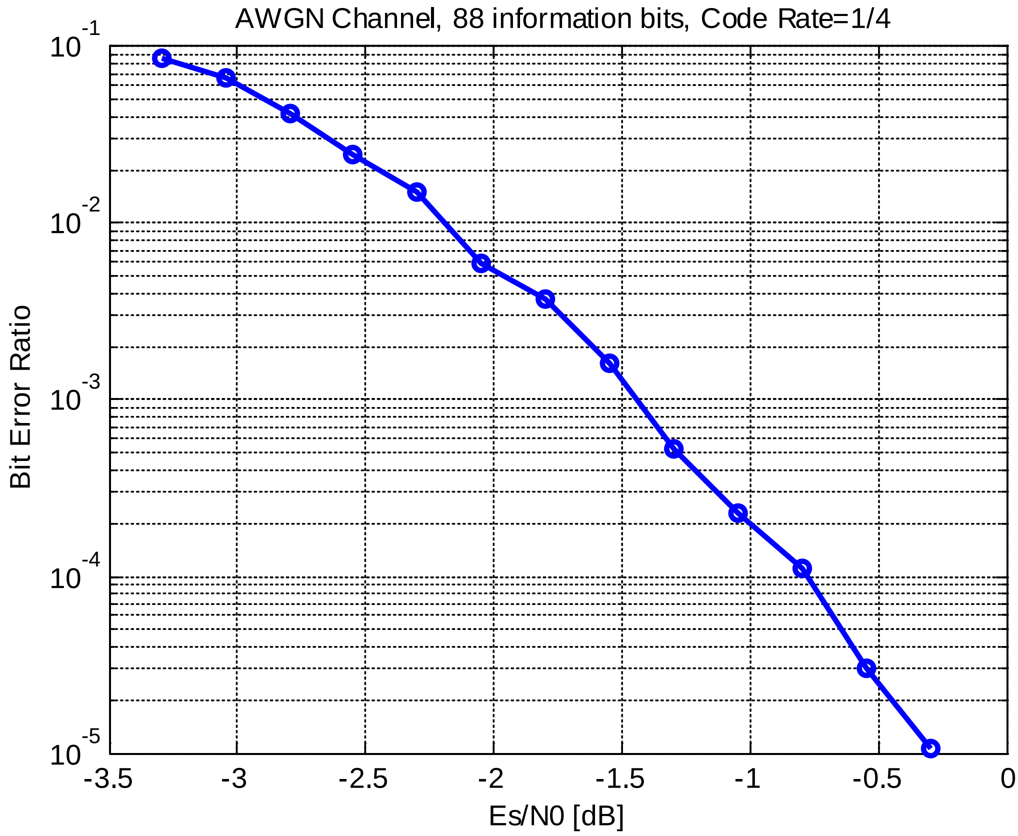
Estimated symbol energy to noise density ratio threshold after de-spreading) versus packet error ratio for a quadrature phase shift keying modulated carrier using turbo forward error correction coding according to *ETSI EN 302 583 (V1.2.1) – Digital Video Broadcasting (DVB); Framing Structure, channel coding and modulation for Satellite Services to Handheld devices (SH) below 3 GHz.*



Furthermore, according to Figure 12, a QPSK modulated carrier with FEC code rate of ¼ has an estimated E_s/N_0 threshold of -0.3 dB for a bit error ratio (BER) of 10^{-5}. This estimated threshold is based on simulations carried out based on an Additive White Gaussian Channel model. In addition, this result has been performed using packets of 88 information bits.

FIGURE 12

Estimated symbol energy to noise density ratio threshold after de-spreading versus bit error rate for a quadrature phase shift keying modulated carrier using turbo forward error correction coding [RD1].



RD2 report shows performance results for the same family of turbo codes and the same FEC rate, but with different information block size of 1 784 bits. Figure 7.6 in RD2, presents a E_b/N_0 value of 0.55 dB for a bit error ratio (BER) of 10^{-5}. Using the following formula:

$$E_s/N_0 \text{ (dB)} = E_b/N_0 \text{ (dB)} + \mathbf{10*} \log10 (k/N * m)$$

With k/N = code rate, m = number of bits per symbol. In our case, k/N = ¼ and m = 2 (for a quadrature phase shift keying (QPSK) modulation, M =2, m = 4).

Therefore, we have the following

$$E_s/N_0 = 0.55+10*\log10 (1/4*2) = 0.55 – 3 = –2.45 \text{ dB}.$$

This result was derived from simulations using a larger number of bits per code block (blocks of 1 784 bits).

In Figure 12 (VDES simulation), the comparative E_s/N_0 requires -0.3 dB in order to achieve a BER of 10^{-5}. The 2.15 dB difference can be explained as below.

It is known that shortening the information block length would increase the required decoder E_b/N_o threshold, as a penalty in the code performance. This penalty can be analytically computed (for example see Figure 2 in RD3). For code rate 1/4, reducing the block length from 1 784 bits to 88 bits would increase the required E_b/N_o threshold by around 1.9 dB as per Figure 2 of RD3. This theoretical analysis confirms the simulation results reported in 4C/232 vs. results reported in RD2.

Therefore, the results as presented in Figure 12 and in Table 13 for the physical layer frame format #1, have been verified and cross checked through existing technical literature, RD2 and RD3.

4.3.1.1 Documents referred to in this section

RD1 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.

RD2 TM synchronization and channel coding summary of concept and rationale, Informational Report CCSDS 130.1-G-2 Green Book, November 2012, https://public.ccsds.org/Pubs/130x1g2.pdf

RD3: S. Dolinar, D. Divsalar, and E Pollara. "Code Performance as a Function of Block Size". JPL TDA Progress Report 42-133. 15 May 1998, https://ipnpr.jpl.nasa.gov/progress_report/42-133/133K.pdf

4.3.2 VHF data exchange-satellite uplink receiver characteristics

(… no changes …)

4.3.3 VHF data exchange-satellite uplink link budget

(… no changes …)

5 Interoperability and resource sharing with VHF data exchange-terrestrial and between VHF data exchange-satellite systems

5.1 Resource sharing method for VHF data exchange-terrestrial and VHF data exchange-satellite services

The VDES resource assignment between the VDE-TER and the VDE-SAT services is outlined in the following sections. In particular the signalling and control mechanisms envisaged to coordinate the use of each time slot either for terrestrial or satellite communication.

Shore stations utilize the terrestrial bulletin board (TBB) and the announcement signalling channels (ASC) to coordinate the resource assignment within the control area. Shore stations may provide information regarding VDE-SAT communications and availability as part of their information service. VDE-SAT information may be acquired by shore stations, either directly from the satellite bulletin board (SBB) and the ASC or through 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.

Each satellite system will use SSB and ASC, as described in Recommendation ITU-R M.2092-0, to communicate the VDE-SAT resource assignments, for both downlink and uplink, to vessels in the coverage area. There are dedicated slots and frequency bands for the SBB and ASC 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.

How, and to what extent, resources are shared between VDE-TER and VDE-SAT are closely linked to the frequency utilization plan selected for VDES. Section 3 currently discuss ~~two~~ three alternative frequency plans and their implications on resource sharing between VDE-TER and VDE-SAT. Methods for resource sharing are discussed in the following sections.

5.2 VHF data exchange-terrestrial and VHF data exchange-satellite downlink resource sharing

5.2.1 Resource sharing with frequency plan alternative 1

(… no changes …)

5.2.2 Resource sharing with frequency plan alternative 2

(… no changes …)

5.2.3 Resource sharing with frequency plan alternative 3

With frequency plan alternative 3, 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 signaling channels as described in Recommendation ITU-R M.2092-0. Other slot assignments in the exclusive VDE-SAT frequency bands are managed based on the content of the bulletin board and announcement signaling channels. The assignment may change dynamically (according to the satellite coverage or temporal demands).

The utilization of channels 2024, 2084, 2025 and 2085 is primary for VDE-SAT downlink. VDE-TER shore-to-ship is also possible in channels 2024, 2084, 2025 and 2085, but the VDE-TER shore-to-ship in these channels does not impose constraints on VDE-SAT downlink.

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 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 2026 and 2086 are exclusively used for VDE-SAT downlink, maintaining the original signaling assignment that was described above
– Channels 2024, 2084, 2025 and 2085 are primary used for VDE-SAT downlink

This resource sharing method should be used as a starting point for VDES resource sharing, or in the absence of coordination between the shore and satellite operation.

5.3 VHF data exchange-terrestrial and VHF data exchange-satellite uplink resource sharing

5.3.1 Resource sharing with frequency plan alternative 1

(… no changes …)

5.3.2 Resource sharing with frequency plan alternative 2

(… no changes …)

5.3.3 Resource sharing with frequency plan alternative 3

With frequency plan alternative 3, 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.).

There are dedicated time slots in channels 1024 and 1084 that are assigned to the terrestrial signaling channel and terrestrial bulletin board. These slots should not be used by the VDE-SAT uplink when a VDE shore station is within the satellite coverage area.

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 services 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 services
– 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.

Coordination of resource sharing between VDE ship-to-ship and VDE-SAT uplink for areas not controlled by a VDE shore station is managed by the VDE-SAT bulletin board, as described in Recommendation ITU-R M.2092-0. 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.

5.4 Resource sharing between multiple satellite VHF data exchange systems

(… no changes …)

6 Interference to incumbent services and those in adjacent frequency bands

6.1 In-band interference

6.1.1 Fixed services in-band

(… no changes …)

6.1.2 Land and aeronautical mobile services in-band

6.1.2.1 Analysis of the interference effect of the VHF data exchange-satellite uplink

(… no changes …)

6.1.2.2 Analysis of the interference effect of the VHF data exchange-satellite downlink

(… no changes …)

6.1.2.2.1 View 1 about power flux density mask

(… no changes …)

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

~~Editor's note:~~ Regarding the mobile station, this analysis ~~only takes into account~~considers the link between the base stations and the vehicular mobile stations. ~~The case of handheld mobile stations have not yet been evaluated.~~

Representative technical and operational characteristics of conventional and trunked land mobile systems operating in the mobile service in the frequency band 156-162 MHz are given in Recommendation ITU-R M.1808. Table 28 provides the technical characteristics of base stations and Table 29 provides technical characteristics of mobile stations as they are given in that Recommendation. Recommendation ITU-R P.372 provides additional relevant information regarding interference.

TABLE 28

Technical characteristics for base stations operating in the mobile service in the frequency band 138-174 MHz

Frequency band (MHz)	**138–174**	
Type of emission	**Analogue**	**Digital**
System-wide		

Frequency band (MHz)	**138–174**	
Type of emission	**Analogue**	**Digital**
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)
Receiver		
Noise figure (dB)	6–12 (7)	6–12 (7)
IF filter bandwidth (kHz)	8/11/12.5/16	5.5/5.5/5.5/5.5
Sensitivity (dBm)	−116 to −121 (−119)~~ensitivity (dBm)t~~	−116 to −121 (−119)~~ensitivity (dBm)t~~
Antenna gain (dBd)	0–9 (6)	0–9 (8)
Antenna height (m) (relative to ground level)	10–150 (60)	10–150 (65)
Radiation pattern	Omnidirectional	Omnidirectional
Antenna polarization	Vertical	Vertical
Total loss (dB)	0–6 (3)	0–6 (3)

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 29

Technical characteristics for mobile stations operating in the mobile service 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 to~~.~~ –18 (H: −3 V: 14, 16)	−3~~V~~ to –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~~nt~~ to–4 (H: −10, V: 0)	−10~~(H~~ to –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)
Receiver		
Noise figure (dB)	6–12 (7)	6–12 (7)
IF filter bandwidth (kHz)	8/11/12.5/16	5.5/5.5/5.5/5.5
Sensitivity (dBm)	−116 to −121 (−119)~~=ensi = nsitivity~~	−116~~-nsi-~~ to −121 (−119)
Antenna gain (dBd)	−10~~nt–~~ to 4 (H: −10, V: 0)	−10~~(H–~~ to 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).

For the studies of the compatibility of the VDE-SAT downlink with the land mobile service the typical values from Table 28 and Table 29 have been used. These technical characteristics and values are summarized in Table 30.

TABLE 30

Typical values for technical characteristics of land mobile service stations used in compatibility study

Station type	Base station	Mobile station
Necessary bandwidth (kHz)	16	16
Output power (W)	100	50
Output power (dBW)	20	17
Feed loss (dB)	2.0	1.0
Maximum antenna gain (dBd)	6.0	0.0
Maximum antenna gain (dBi)	8.2	2.2
Maximum e.r.p.	24.0	16.0
Maximum e.i.r.p.	26.2	18.2
Antenna height (m)	60	2
Distance to horizon from station (km)	27.7	5.1

Figure 16 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 31 and Table 32 for the base station and mobile station respectively. Table 31 and Table 32 also present the resulting e.i.r.p versus elevation angle for the two station types.

FIGURE 16

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

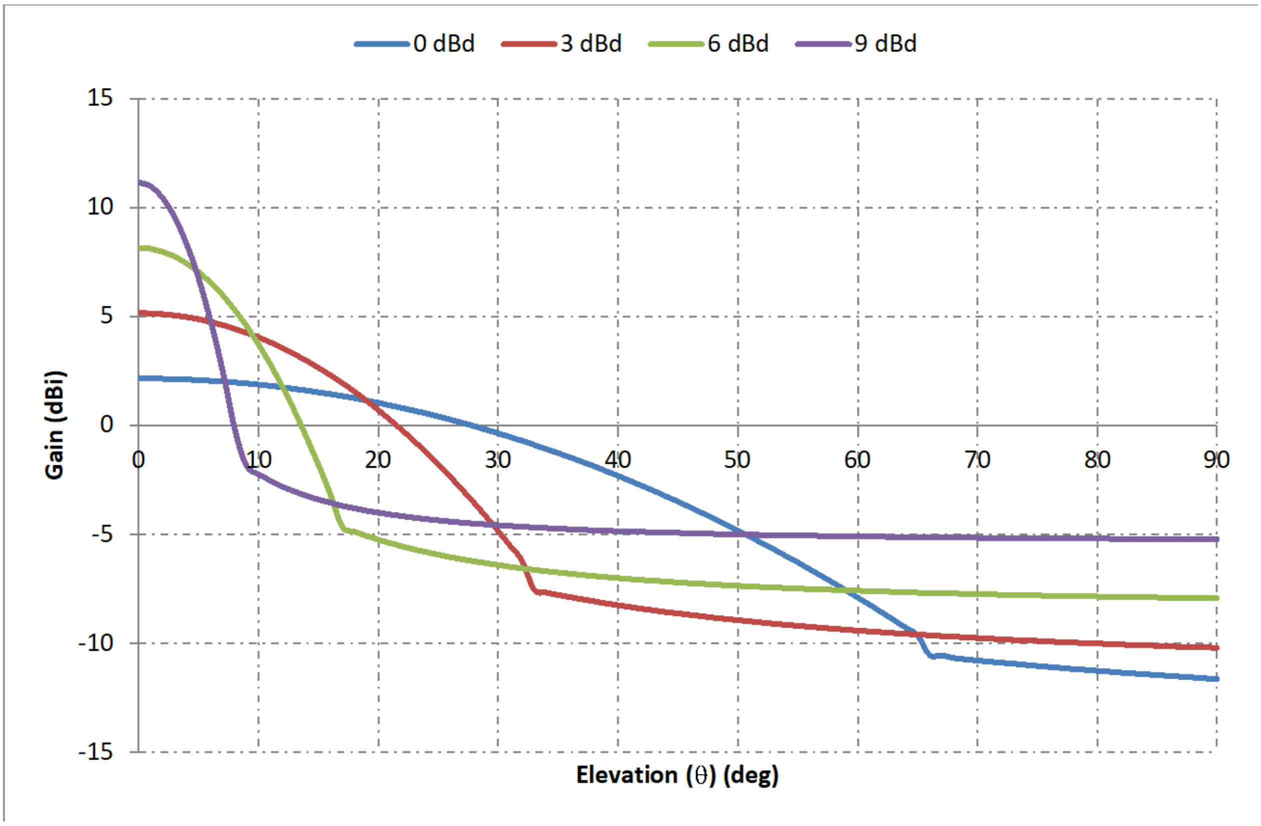


TABLE 31

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

Elevation angle	**Antenna gain**	**e.i.r.p.**
degrees	dBi	dBW
0	8.2	26.2
10	3.7	21.7
20	−0.7	12.8
30	−0.8	11.6
40	−0.6	11.0
50	−0.0	10.6
60	−0.6	10.4
70	−0.4	10.3
80	−0.3	10.1
90	−0.1	10.1

TABLE 32

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

Elevation angle	Antenna gain	e.i.r.p.
degrees	dBi	dBW
0	2.2	18.2
10	1.9	17.9
20	1.0	17.0
30	−0.0	15.6
40	−0.6	13.7
50	−0.7	11.2
60	−0.2	8.1
70	−012e	5.2
80	−022e	4.7
90	−072e	4.4

6.1.2.2.1.2 Link budget calculations for transmission from base station to mobile station

(… no changes …)

6.1.2.2.1.3 C/I analysis for the interference level from the VDE-SAT downlink into a base station

(… no changes …)

6.1.2.2.1.4 Conclusions

As shown in Table 36, the carrier to interference ratio (C/I) for the mobile station to base station link with interference from the VDE-SAT downlink will be between 28.1 dB and 40.2 dB. For the base station to mobile station link the C/I with interference from the VDE-SAT downlink will be between 33.1 and 38.0 dB, as shown in Table 37.

Recommendation ITU-R M.1808, section 2.2 of Annex 1, provide SINAD ratio values of 12 dB to 20 dB for establishing degradation protection for land mobile systems. ~~These SINAD values correspond to C/I values of 6 dB to 10 dB.~~ The C/N required to achieve these SINAD ratio values can be derived from the FM improvement formulae, which calculates the audio S/N as a function of C/N in FM systems operating above the detection threshold. The detection threshold can also be referred to as the minimum discernible signal level. The FM improvement formulae is as follows:

$$\left(\frac{S}{N}\right)_{FM} = \left(\frac{C}{N}\right) \cdot \frac{3}{2} \cdot \frac{BW_{FM}}{B_m} \cdot \left(\frac{\Delta f}{B_m}\right)^2$$

where BW_{FM} is the bandwidth of the FM signal obtained using Carson's rule, Δf is the peak frequency deviation and B_m is the bandwidth of the information signal.

The FM improvement formulae can be expressed in dB form as follows:

$$\left(\frac{S}{N}\right)_{FM} = \left(\frac{C}{N}\right) + 1.8 + 10log_{10}\left(\frac{BW_{FM}}{B_m}\right) + 20log_{10}\left(\frac{\Delta f}{B_m}\right)$$

Table XX shows the C/N values required to achieve SINAD ratio values of 12 dB and 20 dB, respectively for FM system with 12.5 kHz and 25 kHz channel spacing.

TABLE XX

C/N required for audio SINADs of 12 dB and 20 dB in FM systems with 12.5 and 25 kHz channel spacings

Channel spacing	12.5	25	kHz
SINAD	12	20	dB
S/N_{FM}	11.7	20	dB
B_m	3	3	kHz
Δf	2.5	5	kHz
BW_{FM}	11	16	kHz
C/N	7.8	6.4	dB

A C/I level of more than 28.1 dB for the mobile station to base station link with interference from the VDE-SAT downlink is negligible relative to the C/N values of 7.8 dB and 6.4 dB required to meet the SINAD degradation protection values for land mobile systems provided in Recommendation ITU-R M.1808, Annex 1. When, considering the actual realizable pfd level, the situation will improve even further.

~~*[Editor's note: The link between SINAD values and C/I values should be provided]*~~

Furthermore, Report ITU-R M.1021 provides equipment characteristics for digital transmission in the land mobile service, including a bit energy to noise density ratio (E_b/N_0) reference sensitivity of 12 dB corresponding to a bit error ratio (BER) of 1%. According to Recommendation ITU-R M.1808, digital land mobile systems use C4FM modulation and a BER threshold of 5%. C4FM modulation has two bits per symbol. Given that C/I corresponds to symbol energy to noise density ratio (E_s/N_0), digital land mobile systems have a typical C/(N+I) threshold of 15 dB. A C/I level of more than 28.1 dB for the mobile station to base station link with interference from the VDE-SAT downlink is negligible relative to the reference sensitivity provided in Report ITU-R M.1021. When, considering the actual realizable pfd level, the situation will improve even further.

Therefore, it can be concluded that the land mobile service will not experience harmful interference from the VDE-SAT downlink with the pfd-mask specified in Recommendation ITU-R M.2092-0.

6.1.2.2.2 View 2 about the power flux density mask

(… no changes …)

6.1.2.2.3 View 3 about power flux density mask

(… no changes …)

6.2 Out-of-band interference

(… no changes …)

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

(… no changes …)

8 Testing, demonstrations and measurements

(… no changes …)

~~9 Future demonstrations and measurements~~

~~[*Editorial note: This section is intended only as information on planned and on-going demonstration and measurement projects and should be removed from the final report.*~~

[*Editorial note: Additional demonstration and measurement projects/activities should be included as they become public*.]

9.1 EfficienSea 2 coordination

EfficienSea2 is a European Community project for a safer and more efficient waterborne operation through new technologies and smarter traffic management. This 3-year project is entering its second year, running from mid-2015 to mid-2018. The project is in the scope of the Horizon 2020, the biggest EU Research and Innovation programme. Lead by the DMA, 33 entities are contributors. One of activities is dedicated to novel maritime communications and among them the VDES. One aspect of the project was to develop VDES hardware prototypes in a lab environment which take into account the radio technical standards and specifications under construction in the International Association of Marine Aids to Navigation and Lighthouse Authorities and the resolution adopted in November 2015 by ITU during the WRC-15. In addition, live sea trials for testing exchanges of ship-to-ship and ship-to-shore data with real-life e-navigation scenarios are underway. EfficienSea 2 is also coordinating terrestrial VDES activities with satellite VDES activities.

The satellite VDES are lead by ESA under the ARTES program dedicated to research on the telecommunications systems. One of these activities is focussed on the VDE-SAT user needs and requirements to derive the system design. Another is aimed at the realisation of a test satellite with a flight demonstration within the EfficienSea 2 timeframe. A liaison between ESA, the main actors of the VDE-SAT activities and the EfficienSea 2 terrestrial VDES actors permits the inclusion of the satellite VDES downlink component into overall VDES testbed activities.

APPENDIX 1

Considerations for the power flux density mask for the VHF data exchange - satellite downlink (Rec. ITU-R M.2092-0 Annex 4)

(… no changes …)

APPENDIX 2

Carrier to interference analysis of power flux density masks for the VDE-SAT downlink

A2.1 VHF data exchange satellite downlink

(… no changes …)

A2.2 Consideration of an alternative power flux density mask based on available land mobile service characteristics in Recommendation ITU-R M.1808-0

(… no changes …)

A2.2.1 VHF data exchange system satellite downlink *C/N* performance assessment of the proposed alternative power flux density mask to ensure the protection of the land mobile service

(… no changes …)

A2.2.2 Carrier to interference (*C/I*) performance comparison of the current pfd mask and the alternative pfd mask to ensure the protection of the land mobile service

(… no changes …)

A2.2.2.1 Characteristics of land mobile systems operating in the 156 to 162 MHz band

(… no changes …)

A2.2.2.2 Link budget calculations for transmissions between base stations and mobile stations

(… no changes …)

A2.2.2.3 *C/I* analysis for the interference levels from the VDE-SAT downlink into communications links between base stations and mobile stations

(… no changes …)

A2.2.2.4 Conclusions

As shown in Tables A2-14 and A2-15, the carrier to interference ratios (*C/I*) for the mobile station to base station links with interference from the VDE-SAT downlinks will be significantly better, by at least 3.8 dB, when the alternative pfd mask for ensuring the protection of the land mobile service is used. For the base station to mobile station links, Tables A2-16 and A2-17 show that the *C/I* with interference from the VDE-SAT downlink is also significantly better when this alternative pfd mask is used.

Annex 1 of Recommendation ITU-R M.1808~~, section 2.2 of Annex 1,~~ provides SINAD ratio values of 12 dB to 20 dB for establishing degradation protection for land mobile systems~~, which corresponds to *C/(N+I)* levels of 6 dB to 10 dB~~. The C/N required to achieve these SINAD ratio values can be derived from the FM improvement formulae, which calculates the audio S/N as a function of C/N in FM systems operating above the detection threshold. The detection threshold can also be referred to as the minimum discernible signal level. The FM improvement formulae is as follows:

$$\left(\frac{S}{N}\right)_{FM} = \left(\frac{C}{N}\right) \cdot \frac{3}{2} \cdot \frac{BW_{FM}}{B_m} \cdot \left(\frac{\Delta f}{B_m}\right)^2$$

where BW_{FM} is the bandwidth of the FM signal obtained using Carson's rule, Δf is the peak frequency deviation and B_m is the bandwidth of the information signal.

The FM improvement formulae can be expressed in dB form as follows:

$$\left(\frac{S}{N}\right)_{FM} = \left(\frac{C}{N}\right) + 1.8 + 10log_{10}\left(\frac{BW_{FM}}{B_m}\right) + 20log_{10}\left(\frac{\Delta f}{B_m}\right)$$

Table XX shows the C/N values required to achieve SINAD ratio values of 12 dB and 20 dB, respectively for FM system with 12.5 kHz and 25 kHz channel spacing.

TABLE XX

C/N required for audio SINADs of 12 dB and 20 dB in FM systems with 12.5 and 25 kHz channel spacings

Channel spacing	**12.5**	**25**	**kHz**
SINAD	12	20	dB
S/N_{FM}	11.7	20	dB
B_m	3	3	kHz
Δf	2.5	5	kHz
BW_{FM}	11	16	kHz
C/N	7.8	6.4	dB

Therefore, a worst-case *C/I* level of more than 31.9 dB (Table A2-15) for the mobile station to base station link with interference from the VDE-SAT downlink provides considerable margin to the C/N values of 7.8 dB and 6.4 dB required to meet the SINAD degradation protection values for land mobile systems provided in Annex 1 of Recommendation ITU-R M.1808.for SINAD ratio.

Also, according to section 2.2 of Annex 1 of Recommendation ITU-R M.1808, digital land mobile systems use C4FM modulation and a BER threshold of 5%. C4FM modulation has two bits per symbol. Given that *C/I* corresponds to symbol energy to noise density ratio (E_s/N_0), digital land mobile systems have a typical *C/(N+I)* threshold of 15 dB. A *C/I* level of more than 31.9 dB (Table A2-15) for the mobile station to base station link with interference from the VDE-SAT downlink provides considerable margin for BER.

[*Editor's note: to provide references explaining the connection between SINAD and C/I*]

Therefore, based on the results of this *C/I* analysis, it can be concluded:

1 That a *C/I* level of better than 31.9 dB can be achieved and an improvement of 3.8 dB or better can be realized if the alternative pfd mask is used, and

2 That this *C/I* level provides considerable margin for land mobile systems to satisfy the performance criteria specified in Annex 1 of Recommendation ITU-R M.1808, section 2.2, Annex 1