Radiocommunication Study Groups

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International Association of Marine Aids to Navigation and Lighthouse Authorities

LIAISON NOTE TO ITU-R WORKING PARTY 5B
WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT ITU-R M.[VDES-SAT]

Technical characteristics and feasibility assessment of the satellite component for the VHF data exchange system in the VHF maritime mobile band

1 Background

At the last WP 5B meeting, the working document towards a Preliminary Draft New Report ITU-R M.[VDES-SAT] was further revised and is contained in Doc. 5B/195(Annex 26). WP 5B also noted further questions concerning compatibility with incumbent services in the same band. IALA has now studied these issues, and the proposed modifications of the PDN Report ITU-R M.[VDES-SAT] are contained in the annex.

During the previous study period IALA has considered a VDES satellite component in six channels of Appendix **18** of the Radio Regulations. IALA has now considered the possibility offered by Resolution **360 (Rev.WRC-15)** to study new spectrum allocations to the maritime mobile-satellite service (Earth-to-space and space-to-Earth), within the frequency bands 156.0125-157.4375 MHz and 160.6125-162.0375 MHz.

2 Discussion

IALA considers, from a technical point of view, frequency plan alternative 2, as proposed in Doc. 5B/195(Annex 26), to be a more favourable alternative to the original proposal in Recommendation ITU-R M.2092-0. Frequency plan alternative 2 would ease the sharing considerations between the terrestrial and satellite components of VDES.

IALA considers that all questions concerning compatibility with incumbent services in-band and in adjacent bands have been studied, and the results show that the satellite component of the VDES is compatible with incumbent services.

IALA is prepared to continue to work on this Report in the future, based on the outcome of the upcoming WP 5B meeting, and intends to update WP 5B at the next meeting in November 2017.

3 Actions requested

IALA requests ITU-R WP 5B to take into consideration these proposals when developing the PDN Report ITU-R M.[VDES-SAT].

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

Technical characteristics and feasibility assessment of the satellite component for the VHF data exchange system in the VHF maritime mobile band

1 Introduction

At the WRC-15, ITU-R Resolution **360** was revised and updated to invite the WRC-19 to consider, based on the results of ITU-R studies, modifications of the Radio Regulations, including new spectrum allocations to the maritime mobile-satellite service (MMSS) (Earth-to-space and space-to-Earth), preferably within the frequency bands 156.0125-157.4375 MHz and 160.6125-162.0375 MHz of RR Appendix **18**, to enable a new VHF data exchange system (VDES) satellite component, while ensuring that this component will not degrade the current terrestrial VDES components, ASM and automatic identification system (AIS) operations and not impose any additional constraints on existing services in these and adjacent frequency bands as stated in *recognizing d)* and *e)* of ITU-R Resolution **360**.

Furthermore, in preparation for WRC-19, ITU-R was invited to conduct, as a matter of urgency, and in time for WRC-19, sharing and compatibility studies between VDES satellite components and incumbent services in the same and adjacent frequency bands specified in *recognizing d)* and *e)* of ITU-R Resolution **360** to determine potential regulatory actions, including spectrum allocations to the MMSS (Earth-to-space and space-to-Earth) for VDES applications.

This report is the response from ITU-R to that invitation. ~~, and it~~This report provides a summary of why a VDES satellite component is ~~needed~~required, identifies the spectrum requirements, provides a technical description of the satellite component of VDES and the results of the appropriate sharing and compatibility studies.

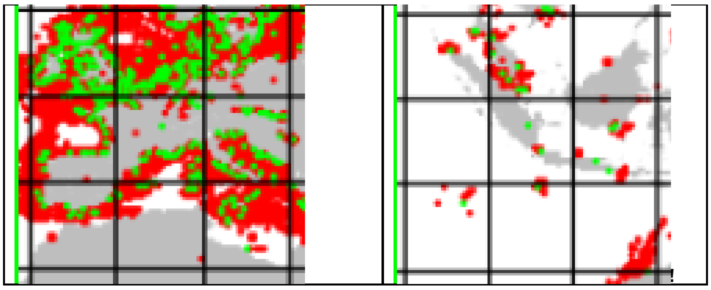
2 VHF data exchange-satellite, the essential supplement to ~~coastal~~ terrestrial VHF data exchange system

2.1 Practical aspects of deploying coastal coverage

Analysis of ship density at global scale shows that coastal areas play a key role in ship traffic and safety management and the VDES terrestrial (VDE-TER) will always remain a ~~key~~ vital component a successful implementation of VDES for a competent authority. However, the current state of AIS-TER deployment shows that, while some areas like Europe, the US and Japan are largely covered, others like the West of Africa or the South West of Asia have much sparser coverage. This is illustrated in Figure 2-1~~ illustrates this well~~.

FIGURE 2-1

Automatic identification system costal station locations (green points) and automatic identification service data coverage (red points)



Many countries with long coastlines are currently not able to ~~ensure adequate~~provide terrestrial infrastructure to cover their coastlines. There are numerous challenges, ~~but one of the main difficulties is to find~~ including finding appropriate hosting sites~~, especially~~ with access to a reliable power supply. Figure 2-2 represents a 10-minute distribution of terrestrial AIS data over three consecutive days in the Gulf of Guinea illustrating critical gaps in routine operations.

FIGURE 2-2

Representation of the 10 minute distribution of terrestrial automatic identification system data over 3 consecutive days in the Gulf of Guinea

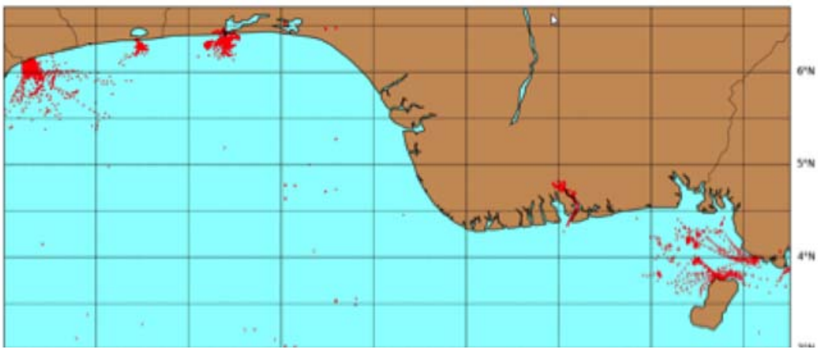
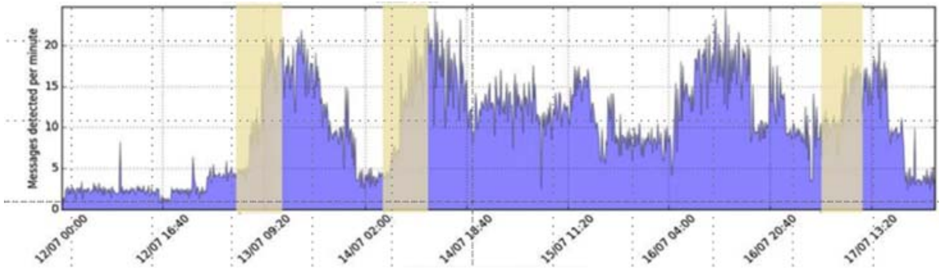


Figure 2-3 exemplifies the high variability observed on the temporal distribution of AIS messages collected from coastal stations. Such high variability indicates severe disruption to ship tracking. ~~and, given that~~ Since AIS is a component of VDES we can assume these same sites ~~will be~~are likely to be used for VDES~~ used~~, thus VDES will suffer ~~the~~ from similar ~~same~~ issues of~~. These problems of~~ infrastructure distribution;~~,~~ reliability and maintenance in remote and difficult to access areas; and~~,~~ ~~or operators with insufficient~~requirement for sufficient budget for technical support.~~ –, are difficult to solve and affects many maritime zones.~~

FIGURE 2-3

High variability observed on the distribution of automatic identification system messages collected from coastal stations in the Gulf of Guinea. The grey line corresponds to sunrise when power generators possibly are activated on some sites



VDE-SAT will provide an opportunity to fill the gaps in the coverage of coastal areas. VDE-SAT can also provide redundancy in operations in a situation where parts of the terrestrial infrastructure experience outages. VDE-SAT technical characteristics provide a flexible mode of operation, allowing VDE-SAT services to dynamically adapt to changes in the terrestrial VDE coverage.

~~1.1.1~~ 2.2 ~~To expand the~~Expanding VHF data exchange system from the coastal area to global coverage

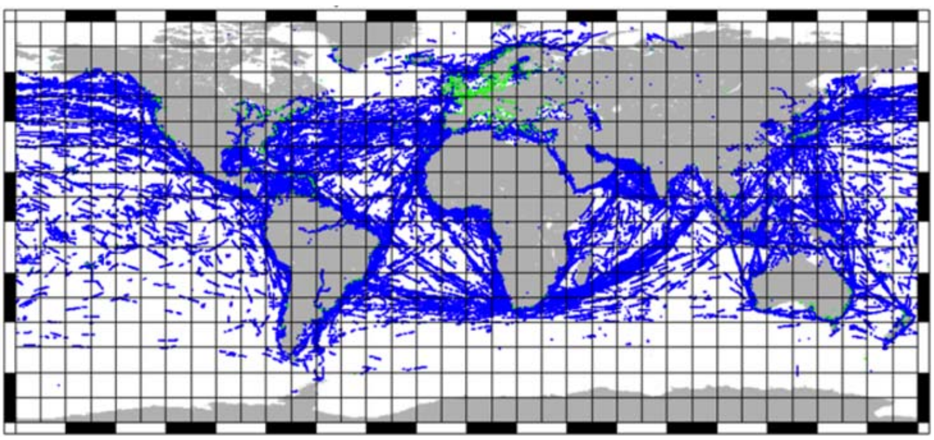
Mis en forme : Titre 2

Mis en forme : Anglais (Royaume-Uni)

The implementation of the SAT-AIS has already demonstrated how the capabilities of the terrestrial AIS can be extended to global coverage, this is illustrated in Figure 2-4. Like SAT-AIS, VDE-SAT, will enable the extension of terrestrial VDE capabilities to long-range communications on a global scale. With polar orbiting satellites, the Arctic and Antarctic will also be covered. ~~However, the~~ VDE-SAT is designed specifically for satellite services and thus it is not subject to some of the limitations experienced with SAT-AIS.

FIGURE 2-4

Comparison of one day of terrestrial automatic identification system data (green dots) to one day of satellite automatic identification system data (blue dots) - April 2015 [Source CLS]



2.3 Use case descriptions

~~The VDES is a complementary service to the AIS and is not a safety of life or safety of navigation service.~~ VDES has been developed to address emerging indications of overload of the AIS VHF Data Link (VDL) and also enable a wider, seamless, data exchange capability to support e-navigation. -VDES supports the increasing communications requirements identified through the development of e-Navigation and could potentially support the modernization of GMDSS.

A number of use cases for VDES have been developed, based on the work carried out on user need analysis for e-Navigation. -Seven high level use-cases (potential uses) have been identified for VDES[1]:

- Supporting communications during search and rescue operations (SAR Communications)
- Distribution of maritime safety information (MSI)
- Facilitating ship reporting
- Supporting vessel traffic services
- Providing updates for charts and publications
- Supporting exchange of ship route information (route exchange)
- Supporting additional communications requirements such as information to tugs (logistics).

Mis en forme : Anglais (États-Unis)
Mis en forme : Liste à puces
Mis en forme : Anglais (États-Unis)

The following sections provide further information on some of these use-cases.

2.3.1 Distribution of maritime safety information

~~The maritime~~Maritime safety information (MSI) consists of navigational and meteorological warnings, meteorological forecasts, and other urgent safety-related messages broadcasted to ships. VDE-SAT, as the only standard (non-proprietary) global communications link for the maritime community would provide for the global distribution of MSIs extending existing terrestrial coverage and providing coverage where a terrestrial infrastructure isn't practical such as the Arctic Sea. Maritime Safety Information may concern the following topics:

– warnings of severe live or forecasted weather conditions to make the trip as safe and comfortable (passengers' trip) as possible;

– warnings of navigation hazards like dangers at sea (floating objects like containers, offshore structures, drifting buoys or ships...) ~~(Figure 2-5);~~

– route information, protected marine environment areas, restricted navigation zones, under keel clearance ~~(Figure 2-6);~~

– piracy or armed robbery at sea information including scene identification, warnings, procedures for example with the schedule plans for convoys with security resources (to be discussed).

[1] Refer to IALA Guideline 1117 for further information on VDES use-cases.

Mis en forme : Anglais (Australie)

~~FIGURE 2-5~~

~~**Example of danger at sea caused when a ship capsizes in the Pacific Ocean**~~

Fishing ship Zhong Yang 26 capsized in South Pacific

BY VILIYANA FILIPOVA – AUGUST 7, 2013

POSTED IN: SHIPS ACCIDENTS

The fishing longliner Zhong Yang 26 capsized in South Pacific on 26 nautical miles off Rapa Iti island, French Polynesia. The accident happened during operations in bad weather and heavy winds, which caused 3-4 meters waves and swell. The vessel was operating in the vicinity and did not sent any distress signal before capsizing. The fishing longliner is still adrift over the water, but with reduced stability. On board of the ship there were 14 crew members, which condition in unknown. The local authorities started search end rescue operation for the missing crew men and will obtain the vicinity with helicopter and two

15 days later, the ship is still adrift

~~FIGURE 2-6~~

~~**Ex. AMSA/Torres Strait where under keel clearance information is essential for safe navigation**~~

~~1.1.2~~ 2.3.1.1 ~~2.3.4~~ Ice chart distribution

Information on sea ice conditions is important to help ensure safe passage ~~at sea~~. Knowledge of areas with sea ice along a ship's planned route allows the ship~~s~~ to find the most efficient route. Together with prognoses for expected ice movements, ice charts allow mariners to plan ahead and significantly reduce the risk of vessels becoming ice locked.

The Norwegian Meteorological Institute produces ice charts for the European part of the Arctic. Today ice charts and prognoses for the next 24 hours are generated on a daily basis. The ice charts are available as graphic files from the website of the Norwegian Meteorological Institute for free. An example ice chart showing the European part of the Arctic is provided in Figure 2-~~7~~5.

Commenté [A1]: Unless base image can be found, recommend removed

While it may be nice to have, I'm not convinced it is required.

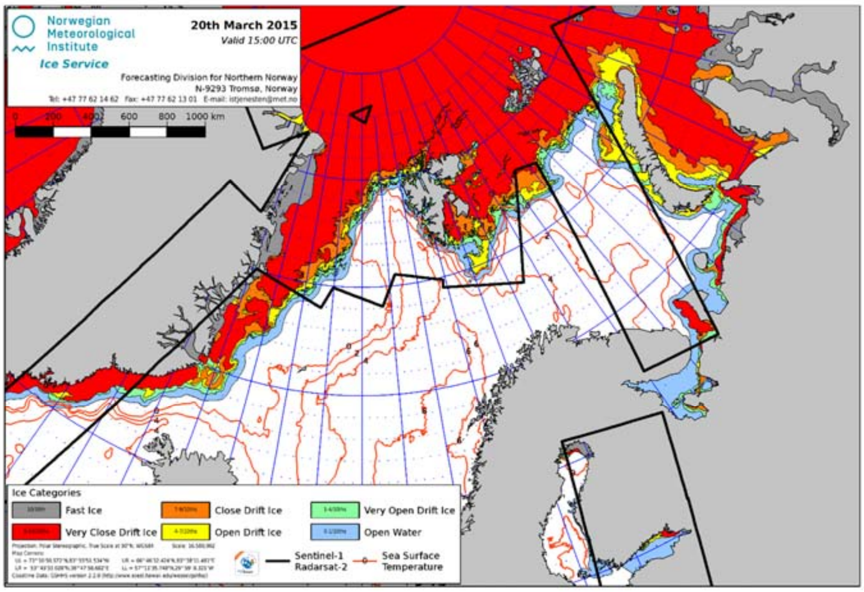
Commenté [A2]: As above – I have the base image, but I don't see how this image actually adds any value.

Mis en forme : Titre 4

Mis en forme : Anglais (Royaume-Uni)

FIGURE 2-~~7~~5

Example ice chart graphics showing the ~~e~~European part of the arctic, available online from the Norwegian Meteorological Institute



The ice information should also become available as a grid of geographical positions, with both the current ice situation and prognoses. It could then be formatted in a way suitable for distribution to electronic chart plotters. The amount of data to transfer depends on the size of the area and the geographical resolution of the ice information.

~~A future ice chart service should be expected to produce updated ice charts and prognoses every 6 hours.~~ The distribution systems currently in use are unnecessarily manual. With VDE-SAT the distribution systems should become more automated and user friendly. Ships should get access to the updated ice charts and prognoses as soon as possible, as well as upon request when needed by the navigator on-board.

Mis en forme : Normal

2.3.2 ~~Automated or on event ship reporting~~Ship reporting

~~In addition to supporting shore side services, VDE-SAT will also support ship services.~~ Ship reporting may be related to a mandatory requirement, a collaborative approach to collect and share information or of specific interest. VDE-SAT will facilitate ship reporting.

~~For example,~~ IMO has published guidelines ~~for setting~~on implementing ~~up~~ a single window system in maritime transport with the aim to reduce ~~the~~ administrative burden and facilitate coordination between stakeholders. In particular, ~~it~~ the guidelines include~~s~~ reporting requirements for ships visiting foreign ports, known as a notice of arrival. -This ~~the~~ 96 hour~~s~~ pre-entry report, and other reports identified within the guidelines, uses pre-determined templated forms (IMO Fal forms).

While static information may be provided from a ship's agent (shore / shore communications) more dynamic data, and updates on information previously provided, can be sent from the ship ~~Before entering into the terrestrial VDES coverage, a ship can push its report~~ via the VDE-SAT to the relevant authority. Similar procedures can also be used for mandatory reporting of specific items, for example, catch amounts for fishing vessels. ~~fish catching.~~

Another ship reporting case relevant for VDE-SAT is the Voluntary Observing Ship (VOS) program in which ships regularly report weather. ~~The~~ Using VDE-SAT the record and data transmission ~~is~~ could be ~~completely~~ automati~~c~~ed, providing data from ship sensors in a machine to machine format, -without ~~any~~ the requirement for manual ~~operation~~reporting. This data is critical for accurate weather forecasting and modelling.

2.3.3 ~~VHF data exchange-satellite opportunity for S~~small vessel~~s~~ fleets or developing areas

The VDE-SAT is designed for satellite communications and so will support a simplified low cost transceiver. This low cost, highly robust option will provide significant value for a large number of fishermen in developing areas. ~~They~~ VDE-SAT ~~will be able to receive~~could be used to provide weather warnings and alerts to small vessels, allowing them to seek a safe harbour.

~~In addition, the fishermen will be able to send a message to call for technical assistance to address incidents like an engine failure or a problem on the helm control.~~

Commenté [A3]: I believe we need to address VDES in SAR before stating this.

The VDE-SAT may also ~~be the~~provide a solution for developing countries to manage their EEZ where a terrestrial infrastructure is cost prohibitive or where the necessary power infrastructure ~~just doesn't~~doesn't exist.

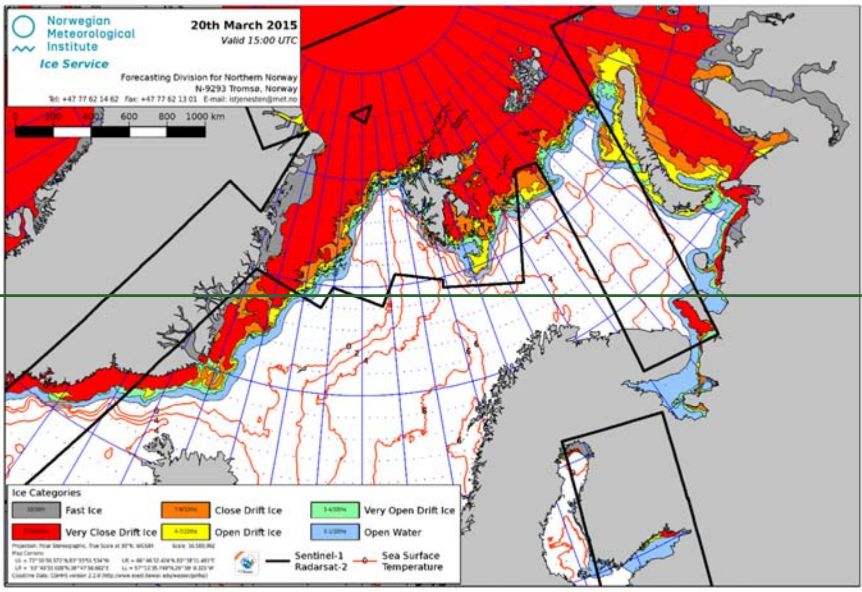
~~1.1.3 2.3.4 Ice chart distribution~~

~~Information on sea ice conditions is important to help ensure safe passage at sea. Knowledge of areas with sea ice along a ship's planned route allows ships to find the most efficient route. Together with prognoses for expected ice movements, ice charts allow mariners to plan ahead and significantly reduce the risk of vessels becoming ice locked.~~

~~The Norwegian Meteorological Institute produces ice charts for the European part of the Arctic. Today ice charts and prognoses for the next 24 hours are generated on a daily basis. The ice charts are available as graphic files from the website of the Norwegian Meteorological Institute for free. An example ice chart showing the European part of the Arctic is provided in Figure 2-7.~~

~~FIGURE 2-7~~

~~**Example ice chart graphics showing the european part of the arctic, available online from the Norwegian Meteorological Institute**~~



~~The ice information should also become available as a grid of geographical positions, both the current ice situation and prognoses. It could then be formatted in a way suitable for distribution to electronic chart plotters. The amount of data to transfer depends on the size of the area and the geographical resolution of the ice information.~~

~~A future ice chart service should be expected to produce updated ice charts and prognoses every 6 hours. The distribution systems currently in use are unnecessarily manual. With VDE-SAT the distribution systems should become more automated and user friendly. Ships should get access to the updated ice charts and prognoses as soon as possible, as well as upon request when needed by the navigator on-board.~~

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., ~~which~~ The shipborne VDES equipment will preferably ~~would~~ 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.

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

Note the organization and frequency use of RR Appendix **18**, channelized in two sections of 25 kHz channels, a lower section with center frequencies at 156.025 MHz to 157.425 MHz and an upper section with center frequencies at 160.625 MHz to 162.026 MHz, spaced 4.6 MHz apart. The channels are numbered in two groups, 60 numbers apart, 01 to 28 and 60 to 88. Some of the channels are duplex channels with paired frequencies that are 4.6 MHz apart, for example, channel 60 (156.025 MHz and 160.625 MHz) is followed by channel 01 (156.050 MHz and 160.650 MHz), then by channel 61 (156.075 MHz and 160.675 MHz), then by channel 02 (156.100 MHz and 160.700 MHz), etc., and this sequence continues to channel 07 (156.350 MHz and 160.950 MHz). But then the channels 67 to 77 are implemented as simplex channels, where only the lower side (156.375 MHz to 156.875 MHz) is used. The unused upper side of these 25 kHz channels with center frequencies at 160.975 MHz to 161.475 MHz comprises a 525 kHz bandwidth that may be considered as an alternative for the VDES satellite downlink, since it poses no conflict to incumbent maritime services and could be constrained with an appropriate pfd mask to protect incumbent terrestrial services. Utilization of this band could provide a very robust satellite-to-ship service.

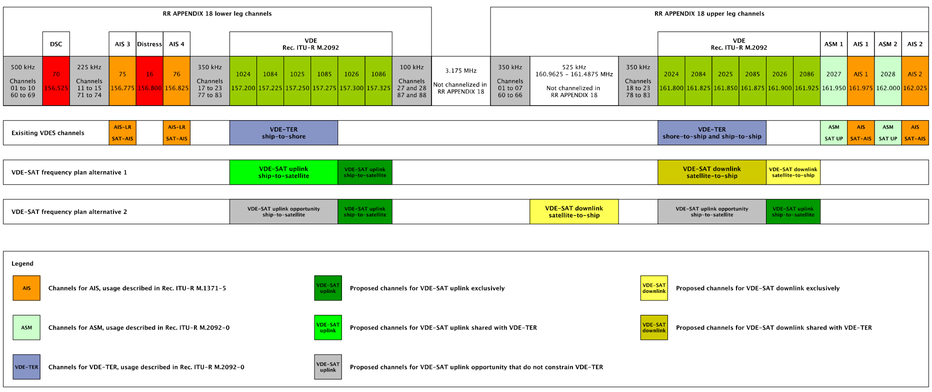
~~1.1.4~~ 3.3 Frequency plan alternatives

Mis en forme : Titre 2

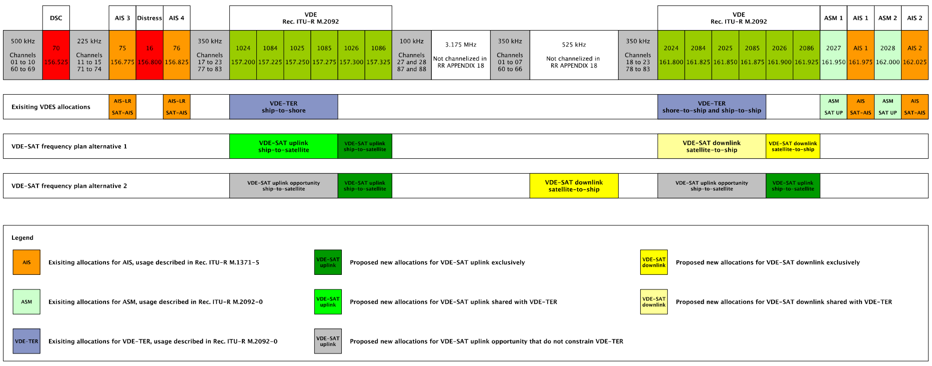
The channels 24, 84, 25, 85, 26 and 86 are allocated for VDE after WRC-15, with the lower leg frequencies used for ship-to-shore and the upper leg frequencies used for shore-to-ship and ship-to-ship. The channels 2027 (ASM 1) and 2028 (ASM 2) are allocated for ASM. Currently, 2 alternative frequency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

FIGURE 3-1

RR Appendix 18 and VHF data exchange system frequency utilization plans



~~[Editorial note: Clarify the colour scheme and more explanation of the figure]~~



3.3.1 Frequency plan alternative 1

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

– ~~The f~~Four channels 1024, 1084, 1025 and 1085 are shared between ship-to-shore and ship-to-satellite (VDE-SAT uplink) services

– ~~The t~~Two channels 1026 and 1086 are exclusively reserved for ship-to-satellite (VDE-SAT uplink) services

– ~~The f~~Four channels 2024, 2084, 2025 and 2085 are shared among shore-to-ship, ship-to-ship and satellite-to-ship (VDE-SAT downlink) services

– ~~The t~~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

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

– ~~The f~~Four channels 1024, 1084, 1025 and 1085 are reserved for ship-to-shore services, but ship-to-satellite (VDE-SAT uplink) services are possible without imposing constraints on ship-to-shore services.

– ~~The f~~Four channels 2024, 2084, 2025 and 2085 are reserved for shore-to-ship and ship-to-ship services, but ship-to-satellite (VDE-SAT uplink) services are possible without imposing constraints on shore-to-ship and ship-to-ship services.

– ~~The f~~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.

4 Technical description of the VHF data exchange-satellite

4.1 VDE-SAT key parameters

This section outlines key parameters regarding the VDE-SAT system ~~parameters~~ that are used in the various studies throughout this report and are common for uplink and downlink.

4.1.1 Satellite to surface distance range

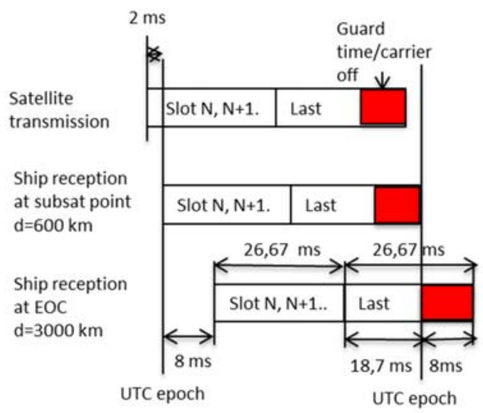
The orbit height determines the satellite range variations. For example, for a 600 km LEO the maximum range is 2 830 km. For timing purposes a maximum range of 3 000 km will be used.

The minimum range is equal to the orbit height. For a LEO satellite at 600 km altitude the minimum range will be 600 km. This value is used to determine the minimum propagation delay time. Considering these exemplary values for the minimum and maximum ranges, the path delay will vary from 2 ms to 10 ms, a variation of 8 ms as shown in Figure 4-1 and Figure 4-2.

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

FIGURE 4-1

VDE-SAT downlink timing



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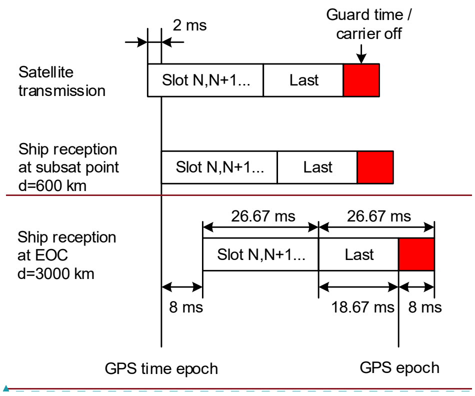
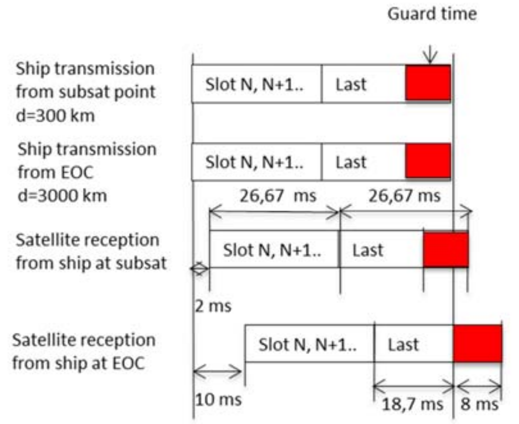


FIGURE 4-2

VDE-SAT Uplink timing



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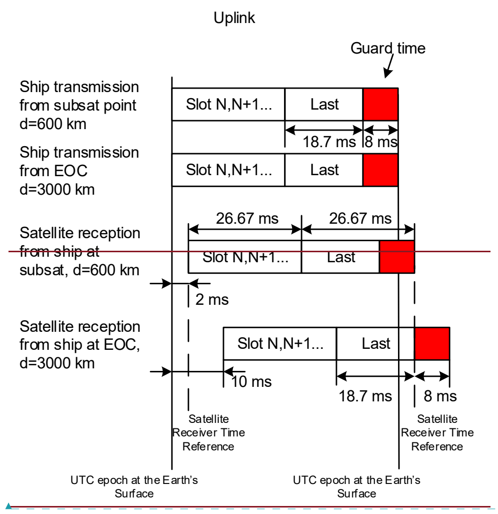

4.1.2 Satellite transmission carrier frequency error

The transmit frequency error at the satellite shall be less than 1 ppm, i.e. ±160 Hz.

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

4.1.3 Ship station antenna gain and transmitter requirements

Ship station antenna gain and transmitter requirements are defined in Annex 1 of Recommendation ITU-R M.2092. From that definition it is expected that a ship transmitter will have linear output power of at least 6 W.

The assumed ship antenna gain and minimum ship e.i.r.p. versus elevation angle is shown in Table 4-1. There are no minimum e.i.r.p. requirements above 80 degrees elevation. Table 4-1 is based on a linear transmitter ~~meeting~~that meets the maximum Adjacent Channel Interference levels defined in Annex 1 of Recommendation ITU-R M.2092, which is expected to provide an output power of at least 6 W. For saturated operation the e.i.r.p. shall be 3 dB higher.

TABLE 4-1

Ship antenna gain and minimum ship e.i.r.p. versus elevation angle

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

Code de champ modifié

Mis en forme : Normal

70	−4	3.8
80	−10	−2.2
90	−20	−12.2

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 Yagi antenna with the satellite pointed at the horizon. 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.

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, satellite antenna gain versus ship elevation and nadir offset angle are shown in Table 4-3.

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 ~~VHF date exchange satellite~~VDE-SAT downlink in the VHF maritime mobile frequency band

~~1.1.5~~ This section outlines key parameters and link budgets for the VDE-SAT system ~~parameters~~ that are used in the various studies of the downlink throughout this report.

~~*[Editorial note: new/updated Annex TBD]*~~**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 WP5A, WP5B and WP5C ahead of WRC-15. In a Liaison Statement to WP5B (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.

TABLE 4-4

Proposed power spectral and power flux density mask

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

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

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

Mis en forme : Anglais (Royaume-Uni)
Mis en forme : Normal
Mis en forme : Anglais (Royaume-Uni)
Mis en forme : Police :Non Italique, Couleur de police : Automatique, Anglais (États-Unis)
Mis en forme : Anglais (États-Unis)
Mis en forme : Police :Non Italique

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) 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 4-6.

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

The noise floor for a ship receiver is a function of many sources such as vessel electronics, other radio equipment, power supplies, etc. ~~, and sensitivity~~Sensitivity is also reduced by RF cabling losses and the LNA noise figure. Table 4-8 presents representative values for the receiver noise figure.

TABLE 4-8

Ship receiver noise figure calculations

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

* The galactic background antenna noise temperature is 245 K at 160 MHz according to Recommendation ITU-R P.372.

A typical ship station receiver is expected to observe an interference level of -116 dBm per 25 kHz at the antenna input.

4.2.3 VDE-SAT downlink 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

Tableau mis en forme
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and powerful FEC. The VDE-SAT uses the waveforms defined in Table 4-9 for downlink. The thresholds C/N_0 and $C/(N+I)$ on a Gaussian channel have been estimated.

TABLE 4-9

Estimated thresholds for the VDE-SAT downlink waveforms

Physical Layer Frame Format #	1	2	3	4	5	6	7
Channel bandwidth (kHz)	50	50	50	100	150	300	500
Occupied bandwidth (kHz)	42	42	42	90	141	291	492
CDMA chip rate (kcps)	33.6	NA	NA	72.0	112.8	232.8	393.6
Symbol rate (ksps)	4.2	33.6	33.6	18.0	28.2	58.2	98.4
Burst length (slots)	90	90	90	90	90	90	90
Modulation	BPSK/CDMA	π/4 QPSK	8PSK	BPSK/CDMA			
FEC rate	½	¼	½	½	½	½	½
Information rate (kbps)	2.1	16.8	50.4	9.0	14.1	29.1	49.2
Estimated threshold Es/N0 for a Gaussian channel (dB) (PER=10^{-2})	-2.0	-2.4	5.0	-2.0	-2.0	-2.0	-2.0
Estimated required C/N0 (dBHz)	34.2	42.9	50.3	40.6	42.5	45.6	47.9
Estimated required C/(N+I) (dB)	-11.0	-2.4	5.0	-8.0	-8.0	-8.0	-8.0

Tableau mis en forme

Mis en forme : Exposant

4.2.4~~3~~ VDE-SAT downlink link budget

The nominal signal level, $C/(N_0+I_0)$ and the link budget versus elevation for a 25 kHz channel are provided in Table 4-10 for a Yagi antenna and Table 4-11 for ~~Yagi and~~an Isoflux ~~on-board~~ antenna~~s~~. The assumed maximum ship antenna gain is 3 dBi and the system noise temperature is 30.2 dBK as shown in Table 4-2 in Section 4.1.4.

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

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

TABLE 4-10

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

Ship elevation angle	**Satellite e.i.r.p. in circular polarization**	**Satellite range**	**Path loss**	**Polarization loss**	**Ship antenna gain**	**Antenna signal level**	**C/N_0**	**Ship on-board interference level in 25 kHz**	**$C/(N_0+I_0)$**
(degrees)	**(dBW)**	**(km)**	**(dB)**	**(dB)**	**(dBi)**	**(dBm)**	**(dBHz)**	**(dBm)**	**(dBHz)**
0	−4.4	2 830	145.6	3	3	−120.0	48.4	−116	40.0
10	−4.4	1 932	142.2	3	3	−116.7	51.7	−116	43.3
20	−4.4	1 392	139.4	3	2.5	−114.3	54.1	−116	45.7
30	−4.6	1 075	137.2	3	1	−113.8	54.6	−116	46.2
40	−5.5	882	135.4	3	0	−114.0	54.4	−116	46.0
50	−6.9	761	134.2	3	−1.5	−115.6	52.8	−116	44.4
60	−8.8	683	133.2	3	−3	−118.0	50.4	−116	41.9
70	−11.7	635	132.6	3	−4	−121.3	47.1	−116	38.7

Tableau mis en forme

80	−14.6	608	132.2	3	−10	−129.8	38.6	−116	30.2
90	−17.9	600	132.1	3	−20	−143.0	25.4	−116	17.0

TABLE 4-11

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

Ship elevation angle	**Satellite e.i.r.p in circular polarization**	**Satellite range**	**Path loss**	**Polarization loss**	**Ship antenna gain**	**Antenna signal level**	***C/N₀***	**Ship on-board interference level in 25 kHz**	***C/(N₀+I₀)***
deg	**dBW**	**(km)**	**dB**	**dB**	**dBi**	**dBm**	**dBHz**	**dBm**	**dBHz**
0	−3.0	2 830	145.6	3	3	−118.6	49.8	−116	41.4
10	−3.5	1 932	142.2	3	3	−115.7	52.7	−116	44.2
20	−4.0	1 392	139.4	3	2.5	−113.9	54.5	−116	46.1
30	−5.5	1 075	137.2	3	1	−114.7	53.7	−116	45.3
40	−7.0	882	135.4	3	0	−115.4	53.0	−116	44.5
50	−9.0	761	134.2	3	−1.5	−117.7	50.7	−116	42.3
60	−10.0	683	133.2	3	−3	−119.2	49.2	−116	40.8
70	−12.0	635	132.6	3	−4	−121.6	46.8	−116	38.4
80	−13.0	608	132.2	3	−10	−128.2	40.2	−116	31.8
90	−13.5	600	132.1	3	−20	−138.6	29.8	−116	21.4

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

This section outlines key parameters and link budgets for the VDE-SAT system ~~parameters~~ that are used in the various studies of the uplink throughout this report.

~~1.1.6~~

~~*[Editorial note: new/update Annex to TBD]*~~ **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.

Mis en forme : Police :10 pt
Mis en forme : Retrait : Gauche : -0,1 cm, Droite : -0,1 cm
Tableau mis en forme
Mis en forme : Police :10 pt
Mis en forme : Police :10 pt, Italique
Mis en forme : Police :10 pt, Italique
Mis en forme : Police :10 pt
Mis en forme : Police :10 pt
Mis en forme : Police :10 pt, Non Italique
Mis en forme : Police :10 pt
Mis en forme : Police :10 pt
Mis en forme : Police :Non Gras, Non Italique, Couleur de police : Automatique
Mis en forme : Titre 2
Mis en forme : Anglais (Royaume-Uni)
Mis en forme : Normal

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 threshold Es/N0 for a Gaussian channel (dB) (PER=10^{-2})	-1.5	3.9	3.9	8.0	12.2
Estimated required C/N0 (dBHz)	31.7	49.2	49.2	53.3	57.5
Estimated required C/(N+I) (dB)	-13.5	2.9	2.9	7.0	11.2

[Editorial note: Table needs to be verified, especially the values for C/N and C/(N+I)]

4.3.2 VDE-SAT uplink receiver characteristics

Satellite noise levels at the receiver front end are presented in Table 4-13. The system noise temperature is taken to be 25.7 dBK assuming no external interference. The required *C*/(*N*+*I*) listed in Table 4-13 is for the most robust waveform, as given in Table 4-12. Adaptive coding and modulation allow the usage waveforms with higher throughput when the necessary link quality is available.

TABLE 4-13

Characteristics of the VDE-SAT receiver

Parameter	Value	Unit
Antenna noise temperature	200.0	K
Feed losses	1.0	dB
LNA noise figure	2.0	dB
LNA noise temperature	159.7	K
Feed loss noise temperature at LNA	56.1	K
Antenna noise temperature at LNA	158.9	K
System noise temperature at LNA	374.7	K
System noise temperature at LNA	25.7	dBK
Intrinsic noise power density	-202.9	dBW/Hz
Intrinsic noise power in 42 kHz bandwidth	-156.6	dBW
Required carrier-to-noise-plus-interference ratio (C/(N+I))	-13.5	dB

4.3.3 VDE-SAT uplink link budget

Tables 4-14 and 4-15 present link budgets for VDES up-link with a satellite receiver in a 600 km altitude orbit using Isoflux and Yagi antennas. A 6 W ship station transmitter is assumed. For the most robust waveform, the link margin is high for all elevation angles and both satellite antenna types. Furthermore, in an interference free environment all ~~the~~ five waveforms given in Table 4-12

Mis en forme : Centré
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will be usable up to 70 degrees elevation angle for the isoflux antenna and up to 80 degrees elevation angle for the Yagi-antenna.

TABLE 4-14

Worst-case link budget for the VDE-SAT~~F~~ uplink with 6 W ship transmitter, Isoflux satellite receiving antenna without interference.

Ship elevation angle	**Ship antenna gain**	**Ship e.i.r.p.**	**Polarization loss**	**Path length**	**Path loss**	**Satellite antenna gain**	**Carrier level at LNA, including feed loss**	***C/N₀***	***C/N***	**Link margin for waveform 1**
deg	dBi	dBW	dB	km	dB	dBi	dBW	dBHz	dB	dB
0.0	3.0	10.8	3.0	2 830	145.4	2.0	–136.6	66.2	20.0	33.5
10.0	3.0	10.8	3.0	1 932	142.1	1.5	–133.8	69.0	22.8	36.3
20.0	2.5	10.3	3.0	1 392	139.3	1.0	–132.0	70.9	24.7	38.2
30.0	1.0	8.8	3.0	1 075	137.0	–0.5	–132.7	70.1	23.9	37.4
40.0	0.0	7.8	3.0	882	135.3	–2.0	–133.5	69.4	23.1	36.6
50.0	–1.5	6.3	3.0	761	134.0	–4.0	–135.7	67.1	20.9	34.4
60.0	–3.0	4.8	3.0	683	133.1	–5.0	–137.3	65.6	19.3	32.8
70.0	–4.0	3.8	3.0	635	132.4	–7.0	–139.7	63.2	17.0	30.5
80.0	–10.0	–2.2	3.0	608	132.1	–8.0	–146.3	56.6	10.4	23.9
90.0	–20.0	–12.2	3.0	600	131.9	–8.5	–156.7	46.2	0.0	13.5

TABLE 4-15

Worst-case link budget for the VDE-SAT uplink with 6 ~~w~~W ship transmitter, Yagi satellite receiving antenna without interference.

Ship elevation angle	Ship antenna gain	Ship e.i.r.p.	Polarization loss	Path length	Path loss	Satellite antenna gain	Carrier level at LNA, including feed loss	C/N_0	C/N	Link margin for waveform 2
deg	dBi	dBW	dB	km	dB	dBi	dBW	dBHz	dB	dB
0.0	3.0	10.8	3.0	2 830	145.4	8.0	–130.6	72.2	26.0	39.5
10.0	3.0	10.8	3.0	1 932	142.1	8.0	–127.3	75.5	29.3	42.8
20.0	2.5	10.3	3.0	1 392	139.3	8.0	–125.0	77.7	31.7	45.2
30.0	1.0	8.8	3.0	1 075	137.0	7.8	–124.4	78.4	32.2	45.7
40.0	0.0	7.8	3.0	882	135.3	6.9	–124.6	78.3	31.2	45.5
50.0	–1.5	6.3	3.0	761	134.0	5.5	–126.2	76.6	30.4	43.9
60.0	–3.0	4.8	3.0	683	133.1	3.6	–128.7	74.2	27.9	41.4
70.0	–4.0	3.8	3.0	635	132.4	0.7	–132.0	70.9	24.7	38.2
80.0	–10.0	–2.2	3.0	608	132.1	–2.2	–140.5	62.4	16.2	29.7
90.0	–20.0	–12.2	3.0	600	131.9	–5.5	–153.7	49.2	3.0	16.5

Mis en forme : Police :Non Italique, Couleur de police : Automatique

~~**1.1.7 4.3 Resource sharing method for VHF data exchange-terrestrial and VHF data exchange-satellite services**~~

~~*[Editorial note: new/update Annex TBD]*~~

5 Interoperability and resource sharing with ~~the terrestrial VHF data exchange systems~~ VDE-TER and between ~~satellite VHF data exchange~~ VDE-SAT systems

5.1 Resource sharing method for V~~HF data exchange-terrestrial~~ DE-TER and ~~VHF~~ VDE-SAT~~data exchange-satellite~~ services

Mis en forme : Titre 2

~~1.1.8~~

Mis en forme : Anglais (Royaume-Uni)

The VDES resource assignment between the VDE-TER and the VDE-SAT services is outlined in the following sections. ~~4.3 Resource sharing method for VDE-TER and VDE-SAT services.~~ 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 satellite bulletin board (SSB) and announcement signalling channels (ASC), as described in Recommendation ITU-R M.2092-0~~defined section 4.1~~, 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 ~~which~~ what extent, resources are shared between VDE-TER and VDE-SAT are closely linked to the frequency utilization plan selected for VDES. Section~~ 4.~~ 3 currently discuss two alternative frequency plans and their implications on resource sharing between VDE-TER and VDE-SAT. Methods for resource sharing are ~~also~~ discussed in the following sections~~ 4.3.~~, ~~thus further detail can be found there.~~

~~Methods for resource sharing between VDE-TER and VDE-SAT depend on the frequency plan and the methods are different for VDE-SAT uplink and downlink.~~

Commenté [A4]: Appears to be redundant, as the same concept is already identified in the paragraph above.

5.2 VDE-TER and VDE-SAT downlink resource sharing

Mis en forme : Titre 2

5.2.1 Resource sharing with frequency plan alternative 1

With frequency plan alternative 1, the channels 2026 and 2086 are dedicated to VDE-SAT downlink. Within these exclusive VDE-SAT channels, there are dedicated time slots that are assigned to the satellite bulletin board and announcement signalling channels as described in 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 signalling channels. The assignment may change dynamically (according to the satellite coverage or temporal demands).

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

There are dedicated time slots in channel 2024 and 2084 that are assigned to the terrestrial signalling channel and terrestrial bulletin board, as described in Recommendation ITU-R M.2092-0. These slots should not be used by the VDE-SAT downlink when a VDE shore station is within the satellite coverage area.

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

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

– Channels 2024 and 2084 are exclusively used for terrestrial VDE, maintaining the original signalling assignment that was described above

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

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

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

Coordination of resource sharing between VDE ship-to-ship and VDE-SAT downlink for areas not controlled by a VDE shore station is managed by the VDE-SAT bulletin board, as described in 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.

5.2.2 Resource sharing with frequency plan alternative 2

With frequency plan alternative 2, the frequency band from 160.9625 MHz to 161.4875 MHz is dedicated to VDE-SAT downlink. The frequencies in this band are not channelized in RR APPENDIX 18. Within this exclusive VDE-SAT band, there are dedicated channels and time slots that are assigned to the satellite bulletin board and announcement signalling channels as described in Recommendation ITU-R M.2092-0. Other slot assignments in this exclusive VDE-SAT frequency band are managed based on the content of the bulletin board and announcement signalling channels. The assignment may change dynamically (according to the satellite coverage or temporal demands).

5.3 VDE-TER and VDE-SAT uplink resource sharing

Mis en forme : Titre 2

5.3.1 Resource sharing with frequency plan alternative 1

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

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

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

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

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

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

5.3.2 Resource sharing with frequency plan alternative 2

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

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

~~1.1.9~~ 5.4 Resource sharing between multiple satellite VHF data exchange systems

Mis en forme : Titre 2

The sharing between two or more satellite systems is coordinated between the satellite operators and organized through the bulletin board, delivered by satellites in the VDE-SAT downlink band, as described in Recommendation ITU-R M.2092-0. Ships use the satellite bulletin boards for channel and resource configuration.

The waveform used for the bulletin board should allow for detection of overlapping signals received from multiple satellites. The use of direct sequence spreading as defined in Recommendation ITU-R M.2092-0 allows for detection of up to 8 overlapping satellite signals.~~The sharing of VDE-SAT resources between two or more satellite systems is envisaged in section 4 by means of signalling that can be implemented in the SBB and ASC. The bulletin board, transmitted frequently on the VDE-SAT Downlink, provides the necessary information on how resources should be utilized for any given satellite. Sharing of resources between satellites are coordinated between satellite service operators.~~

~~The physical channel used for the bulletin board should allow for detection of overlapping signals received from multiple satellites. The use of direct sequence spreading as defined in section 4 allows for detection of up to 8 overlapping signal. The waveform definition for VDE-SAT transmission as defined in section 4, allows sharing of different time slots for different VDE-SAT downlink services.~~

~~The transmission timing of all VDES components (i.e. AIS, ASM, VDE-SAT and VDE terrestrial), is defined based on a common frame structure that is synchronized in time on the earth's surface to the UTC. This will allow multiple satellite systems to coordinate the transmission of data services in a time-sharing manner within common coverage areas.~~

6 Interference to incumbent services and those in adjacent frequency bands

~~*[Editorial note: at a future meeting the studies for in bands interference and out of bands interference should be clearly separated]*~~

~~1.1.10~~ 6.1 In-band interference

Mis en forme : Titre 2

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 WP5A, WP5B and WP5C ahead of WRC-15. In a Liaison Statement to WP5B (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.

~~1.1.11~~

6.1.2 Land and aeronautical mobile services in-band

~~*[Editorial note: A pfd mask was agreed upon during the previous study period. The studies leading up to that pfd mask should be included here either directly or incorporated by reference]*~~

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 ~~has been imposed a~~ pfd mask~~, as~~ specified in Recommendation ITU-R M.2092-0 and provided in Section 4.2.1~~section 4, which was coordinated and agreed between all relevant ITU Study Groups.~~. 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 WP5A, WP5B and WP5C ahead of WRC-15. In a Liaison Statement to WP5B (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.

~~1.1.12~~ 6.2 Out-of-band interference

6.2.1 Maritime distress and voice services

~~*[Editorial note: See Report ITU-R M.2371]*~~

The impact of introducing VDE-SAT services into channels 24, 84, 25, 85, 26 and 86 of RR Appendix **18** was addressed in Report ITU-R M.2371, along with introduction of terrestrial VDES in channel 24, 84, 25 and 85 of RR Appendix **18**.

The VDE-SAT uplink has common characteristics with VDE terrestrial ship-to-shore. Therefore, VDE-SAT uplink will not create any additional interference to maritime distress and voice services.

The VDE-SAT downlink is located in the upper leg channels of RR Appendix **18**, while maritime distress services and ship-to-ship and ship-to-shore voice is located in the lower leg channels. The 4.6 MHz frequency separation between VDE-SAT downlink and these services ensure that they can be protected from harmful interference.

6.2.2 Satellite automatic identification system

The impact of introducing VDE-SAT services into channels 24, 84, 25, 85, 26 and 86 of RR Appendix **18** was addressed in Report ITU-R M.2371, along with introduction of terrestrial VDES in channel 24, 84, 25 and 85 of RR Appendix **18**.

The VDE-SAT uplink has common characteristics with VDE terrestrial ship-to-shore. Therefore, VDE-SAT uplink will not create any additional interference to satellite AIS.

The impact of the VDE-SAT transmission on the AIS1, AIS2, ASM1, ASM2 and LR-AIS reception by satellite has been highlighted in Report ITU-R M.2371. Due to a large frequency separation between VDE-SAT transmission frequencies and LR-AIS frequencies, ~~there is~~ no impact on the satellite detection of LR-AIS is expected. The impact of VDE-SAT transmission on the reception of AIS1, AIS2 and ASM1 and ASM2 depends on the system scenarios.

In a system scenario where the VDE-SAT transmission and SAT-AIS reception are hosted on different satellites the impact will be reduced by the ~~space~~ separation between the satellite orbits and their coverage ~~will reduce the impact~~. In this case, when the two satellites are close together, the use of bulletin boards and the announcement channels as specified in ~~section 4~~Recommendation

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ITU-R M.2092-0, provides a practical solution to coordinate and control the duty cycle of the VDE-SAT transmission. Using this mechanism, system operators can schedule the VDE-SAT transmission ~~on~~ in a dynamic manner (with a repetitive control as frequent as every minute) to avoid the interference of the VDE-SAT on the detection of SAT-AIS. The high repetition rate for AIS transmissions from ships also increases the detection of ships by SAT-AIS, even if some AIS messages are lost to interference from VDE-SAT transmissions. The time that a VDE-SAT satellite is within interference range of a SAT-AIS satellite will not be continuous, and in most ~~circumstances~~circumstances, will be limited to only a few minutes.

The co-location of a SAT-AIS receiver and a VDE-SAT transmission may require a more sophisticated solution on board of the satellite. One such solution can be a full-duplex radio design that would allow for the cancellation of interference caused by the transmitted signal. This may ~~impact~~ have an effect on the complexity of the on-board transceivers. However, ~~also in this case,~~ the high repetition rate for AIS transmissions from ships also increases the detection of ships by SAT-AIS even if some AIS messages are lost due to interference from VDE-SAT transmissions.

6.2.2.1 SAT-AIS receiver blocking analysis

Reception of a strong signal on a nearby channel will result in compression in the SAT-AIS receiver, which can result in blocking of the SAT-AIS receiver. The blocking performance of a radio receiver is typically described as the input level of the unwanted signal where it will generate a 1 dB compression of the wanted signal. A 1 dB compression level result in an insignificant impact on the receiver performance.

SAT-AIS receivers, commercially available, typically have a 1 dB compression level of -48 dBm, for the most sensitive receiver setting. To ensure that the VDE-SAT downlink is ~~are~~ operating within the mask defined in Recommendation ITU-R M.2092-0 and provided in Section 4.2.1, the maximum output power of a VDE-SAT transceiver is 22.0 dBm in a 50 kHz channel. This also assumes Yagi antenna case. With frequency plan alternative 1, up to 150 kHz will be available for the VDE-SAT downlink, while with frequency plan alternative 2 up to 525 kHz will be available for the VDE-SAT downlink. If the full VDE-SAT downlink band is used by a satellite, either as single or multi-carrier, the total output power of the VDE-SAT transceiver will be then be either 26.8 dBm or 32.2 dBm. These two output power levels are the basis for the analysis of required separation distance presented in Table 6-1.

TABLE 6-1

SAT-AIS receiver blocking analysis

	Units	**Frequency plan alternative 1**	**Frequency plan alternative 2**
VDE-SAT tx output power	dBm	26.8	32.2
Feed loss	dB	1.1	1.1
Max VDE-SAT tx antenna gain (RHCP)	dBi	8.0	8.0
SAT-AIS rx antenna gain (LP)	dBi	0.0	0.0
Polarization loss	dB	3.0	3.0
Max acceptable SAT-AIS rx input level	dBm	-48	-48
Required free space loss	dB	78.7	84.1
Required separation distance	km	1.3	2.4

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From Table 6-1 it can be observed that even in ~~the~~a ~~worst case~~worst-case ~~situation~~scenario, with full output power from the VDE-SAT transceiver using frequency plan alternative 2, the required separation distance to avoid blocking of a SAT-AIS receiver on another satellite is only 2.4 km. Such proximity between two satellites occurs very rarely. Furthermore, given that satellites travel at a speed of about 7.5 km/s, if such proximity between two satellites occurs it will only last for a fraction of a second~~, if they occur~~. Thus, it can be concluded that AIS receiver blocking on other satellites by a VDE-SAT transceiver is not a problem, and no mitigation measures are needed.

6.2.2.2 SAT-AIS receiver front end burnout analysis

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Reception of a very strong signal within the operating frequency range of a SAT-AIS receiver may cause receiver front end burnout~~, if the signal is strong enough~~. A burn out protection level typically defines the receiver front end input level that can be sustained over a longer period of time without damaging the receiver front end. SAT-AIS receivers, commercially available, typically have front end burnout protection level of 8 dBm. This value is used in the nominal case analysis of required separation distance for avoiding SAT-AIS receiver front end burnout. Assuming there are SAT-AIS receivers on the commercial market of lower quality, a ~~worst case~~worst-case analysis using a ~~front end~~front-end burnout protection level of 0 dBm has also been performed. The two analysis cases also assume the same two VDE-SAT transceiver output power levels as those used in the AIS receiver blocking analysis discussed in Section 6.2.2.1. Table 6-2 presents the analysis of the separation distance required for avoiding SAT-AIS receiver front end burnout.

TABLE 6-2

SAT-AIS receiver front end burnout analysis

	Units	**Worst case**	**Nominal case**
VDE-SAT tx output power	dBm	32.2	26.8
Feed loss	dB	1.1	1.1
Max VDE-SAT tx antenna gain (RHCP)	dBi	8.0	8.0
SAT-AIS rx antenna gain (LP)	dBi	0.0	0.0
Polarization loss	dB	3.0	3.0
Max acceptable SAT-AIS rx input level	dBm	0.0	8.0
Required free space loss	dB	36.1	22.7
Required separation distance	km	0.009	0.002

From Table 6-2 it can be observed that even in ~~the~~a ~~worst case~~worst-case ~~situation~~scenario, with full output power from the VDE-SAT transceiver using frequency plan alternative 2 and a very sensitive AIS receiver, the required separation distance to avoid AIS receiver front end burnout on another satellite is only 0.009 km. Such proximity between two satellites occurs extremely rarely. Furthermore, given that satellites travel at a speed of about 7~~,~~.5 km/s, if such proximity between two satellites occurs it will only last for a fraction of a second~~, if they occur~~. Also, such proximity events do not happen without ample warning, allowing a planned shutdown of the VDE-SAT transceiver if so deemed necessary. ~~However, the main conclusion is~~Thus, it can be concluded that SAT-AIS receiver front end burnout on other satellites by a VDE-SAT transceiver is not a problem, and no mitigation measures are needed.

6.2.3 Radiolocation service in the frequency band 154-156 MHz

~~1.1.13~~ 6.2.3.1 Introduction

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Radio regulations (RR) No. **5.225A** specifies that in certain countries of Region 1 the frequency band 154-156 MHz is allocated to the radiolocation service on the primary basis. Application of the radiolocation service in those frequency bands is limited to the space surveillance radars. Study results reflected in Report ITU-R M.2172-1 show that the mentioned radars could operate in a shared manner with the maritime mobile service (MMS) ground systems operating in the adjacent frequency band 156-174 MHz.

A sharing study has been performed to ascertain if the potential VDE-SAT downlink service will generate harmful interference into the radiolocation service.

~~1.1.14~~ 6.2.3.2 Transmitter and receiver characteristics of the radiolocation service used for the sharing study

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Table 6-~~1~~ 3 presents characteristics of the space surveillance radars operating in the frequency band 154-156 MHz. The characteristics were taken from Report ITU-R M.2172-1 and were used in the compatibility studies.

TABLE 6-~~1~~3

Radiolocation service systems characteristics

	Units	Radar A (narrow-band radar)	Radar B (wideband radar)
Frequency band	MHz	154-156	
Output pulse power (min/max)	dBW	27/46	40/46
Mean output power (min/max)	dBW	22/41	35/41
Polarization		Linear	
Pulse duration	µs	13 000	3 200
Duty cycle		0.322	
Modulation type		pulse	
Altitude above the ground level	m	19	
Antenna type		Phased array	
Maximum antenna gain – transmitter – receiver	dB	 25 30	
Maximum antenna gain on the horizon	dB	9	
Antenna pattern		See § 1.1 in Appendix 1 of Report ITU-R M.2172-1	
Main beam pattern, – horizontal plane (Rx/Tx) – vertical plane (Rx/Tx)	degrees	 2.6/5.2 2.6/2.6	
Receiver noise temperature	K	800	
Operational receiver passband (−3 dB level)	kHz	0.132	625
Receiver thermal noise	dBW	−178.4	−141.6

In Recommendation ITU-R M.1802-1 the protection criteria for the radiolocation service is given as *I/N*=-6 for both radar types. When converting the receiver thermal noise level stated for Radar A and Radar B in Table 6-~~1~~ 3 to receiver thermal noise density, they both end up with a receiver thermal noise density level of -199.6 dBW/Hz. To ensure the protection of the radiolocation service, any interference must be at least 6 dB below that noise level. That corresponds to an I_0 of -205.6 dBW/Hz.

According to the technical characteristics of the radiolocation service as presented in Table 6-~~1~~3, the maximum receiver gain is 30 dB. It is assumed this is the gain at 156 MHz. The effective aperture area of the receiver antenna is then $A_{eff} = (G*c^2)/(f^2*4\pi) = 24.7$ dBm^2. Thus, to ensure protection of the radiolocation service, the interference power flux density in the 154-156 MHz band must be less than -230.3 dBW/(Hz*m^2)

~~1.1.15~~ 6.2.3.3 VHF data exchange-satellite downlink proposed power spectral and power flux density mask

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The VDE-SAT downlink has been imposed a pfd mask, as specified in Recommendation ITU-R M.2092-0 and provided in Section 4.2.1 for the ~~in bandin~~-band signal. ~~In section 4.1 a power spectral and pfd mask is proposed for the VDE-SAT downlink in band signal.~~ This mask is presented in Table 4-4 and again here in Table 6-~~2~~4.

TABLE 6-~~2~~ 4

Proposed power spectral and power flux density mask

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

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

$$PFD(\theta^\circ)_{\ (\mathrm{dBW/(m^2 * Hz)})} = \begin{cases} -185 + 0.16 * \theta^\circ & 0^\circ \leq \theta < 45^\circ; \\ -178 + 0.53 * (\theta^\circ - 45^\circ) & 45^\circ \leq \theta < 60^\circ; \\ -170 + 0.1 * (\theta^\circ - 60^\circ) & 60^\circ \leq \theta \leq 90^\circ. \end{cases}$$

~~1.1.16~~ 6.2.3.4 VDE-SAT downlink out of band noise

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Without additional filtering of the spectral side lobes, the noise generated by a VDE-SAT transmitter in the frequency band 154-156 MHz be will more than ~~25~~ 50 dB below that of the in-band signal. Appropriate filtering can ensure an additional ~~40~~ 15 dB of reduction of the out of band noise. Table 6-~~3~~ 5 presents the resulting interference pfd mask for the 154-156 MHz frequency band.

TABLE 6-~~3~~ 5

Proposed interference pfd mask for the frequency band 154-156 MHz

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

$$PFD(\theta^\circ)_{\ (\mathrm{dBW/(m^2 * Hz)})} = \begin{cases} -250 + 0.16 * \theta^\circ & 0^\circ \leq \theta < 45^\circ; \\ -243 + 0.53 * (\theta^\circ - 45^\circ) & 45^\circ \leq \theta < 60^\circ; \\ -235 + 0.1 * (\theta^\circ - 60^\circ) & 60^\circ \leq \theta \leq 90^\circ. \end{cases}$$

The significant frequency separation between the radiolocation service in the frequency band 154-156 MHz and the upper leg of the RR Appendix **18** frequencies starting at 160.625 MHz ensures that this interference pfd mask will be the ~~worst case~~worst-case interference level in the frequency band 154-156 MHz.

~~1.1.17~~ 6.2.3.5 Conclusions

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According to section 7.4~~2~~.~~6~~5, the radiolocation service in the frequency band 154-156 MHz operates in an elevation span from 2-70 degrees. The proposed interference pfd mask presented in Table 6-~~3~~ 5 provides a maximum interference pfd at 70 degrees of -239.0 dBW/(Hz*m^2). This is 3.7 dB below the protection criteria level calculated in section 6.2.3.2.

The VDE-SAT downlink uses circular polarisation, while the radiolocation service uses linear polarisation. This results in a 3 dB reduction in interference from the VDE-SAT downlink to the radiolocation service due to polarisation loss. The additional 3 dB of margin ensure an *I/N* of less than -12.7 dB.

Based on these calculations it is concluded that the VDE-SAT downlink, in compliance with the proposed interference mask, will not cause harmful interference to stations operating in the radiolocation service in the 154-156 MHz frequency band according to ~~if the proposed interference mask is implemented for systems characterized in~~ Report ITU-R M.2172-1 and Recommendation ITU-R M.1802-1 ~~(note delete it's confusing)~~.

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~~6.2~~4.42 Broadcasting service in the frequency band 162-164 MHz

*[Editorial note: See RR No. **5.229**]*

No. 5.229 of the Radio Regulations (Volume I, page 84), stipulates an alternative allocation in Morocco in the band 162-174 MHz to the broadcasting service on a primary basis. The use of this band for this allocation shall be subject to agreement with administrations having services, operating or planned, in accordance with the Table of Frequency Allocations in Article 5 of the Radio Regulations which are likely to be affected. Thus, outside of Morocco, any changes to the VDE-SAT downlink to avoid interference to the broadcasting service in this band requires agreement between relevant administrations.

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

*[Editorial note: See No. **5.230**]*

No. 5.230 of the Radio Regulations (Volume I, page 84), stipulates an alternative allocation in China in the band 163-167 MHz to the space operation service (space-to-Earth) on a primary basis, subject to agreement obtained under RR Nos. 9.21. RR Nos. 9.21 stipulates the requirement to seek agreement of other administrations to use this service. Thus, outside of China, any changes to the VDE-SAT downlink to avoid interference to the space operations service (space-to-Earth) in this band requires agreement between relevant administrations.

6.2.6 Land and aeronautical mobile services in adjacent frequency bands

~~*[Editorial note: A pfd mask was agreed upon during the previous study period. The studies leading up to that pfd mask should be included here either directly or incorporated by reference]*~~

*[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 ~~has been imposed a~~ pfd mask~~, as~~ specified Recommendation ITU-R M.2092-0 and provided in Section 4.2.1~~in section 4.~~, ~~which was coordinated and agreed between all relevant ITU Study Groups.~~ 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 WP5A, WP5B and WP5C ahead of WRC-15. In a Liaison Statement to WP5B (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. 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.

6.2.7 Radio astronomy out of band power flux density mask

~~*Note: see liaison statement from WP 7D (5B/177)*~~Ahead of the WRC-15 studies were performed and a power flux density mask was defined for the satellite downlink emissions and for the protection of the RAS operating in the nearby band 150.05-153.00 MHz. This mask is included and described in Recommendation ITU-R M.2092-0, and it specifies that the VDE-SAT downlink emissions not to exceed -238 dBW/m^2 in a 2.95 MHz bandwidth centered around 152 MHz. Application of this pfd mask will ensure the protection of the RAS band 150.05-153.00 MHz. In a Liaison Statement to WP5B (Doc. 5B/177), WP7D confirmed that this mask still is sufficient and valid for protection of the RAS, also after WRC-15.

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

[Editorial note: Address the mitigation of interference from terrestrial services to the VDE-SAT uplink]

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

7.1.1 Introduction

The two frequency plan alternatives currently under consideration, as discussed in Section 3, propose ~~both~~ to use frequencies for the VDE-SAT uplink that are allocated to the mobile service (except aeronautical mobile in Region 1) subject to the Radio Regulations. It is therefore necessary to study the potential impact of the mobile service into the VDE-SAT uplink.

This Section presents results of studies of the compatibility of the VDE-SAT uplink in the frequency bands 157.1875 to 157.2275 MHz and 161.7875 to 161.9375 MHz with the land mobile service operating in the 156 to 162 MHz band.

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

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 7-1 provides the technical characteristics of base stations and Table 7-2 provides technical characteristics of mobile stations as they are given in that Recommendation.

TABLE 7-1

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		
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)

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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 – −121 (−119)	−116 – −121 (−119)
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 7-2

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)

Mis en forme : Police :Anglais (Royaume-Uni)

Mis en forme : Table_No, Gauche

Mis en forme : Police :Anglais (Royaume-Uni)

Mis en forme : Police :Anglais (Royaume-Uni)

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)
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 – −121 (−119)	−116 – −121 (−119)
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).

For the studies of the compatibility of the VDE-SAT uplink with the land mobile service the typical values from Table 7-1 and Table 7-2 have been used. These technical characteristics and values are summarized in Table 7-3.

TABLE 7-3

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	1

Mis en forme : Normal

Mis en forme : Police :Anglais (Royaume-Uni)

Mis en forme : Police :Anglais (Royaume-Uni)

Mis en forme : Table_No, Gauche

Mis en forme : Police :Non Gras, Anglais (Royaume-Uni)

Maximum antenna gain (dBd)	6	0
Maximum antenna gain (dBi)	8	2
Maximum e.r.p.	24	16
Maximum e.i.r.p.	26	18

Figure 7-1 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 7-4 and Table 7-5 for the base station and mobile station respectively. Table 7-4 and Table 7-5 also present the resulting e.i.r.p versus elevation angle for the two station types.

Mis en forme : Anglais (États-Unis)

Mis en forme : Normal

FIGURE 7-1

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

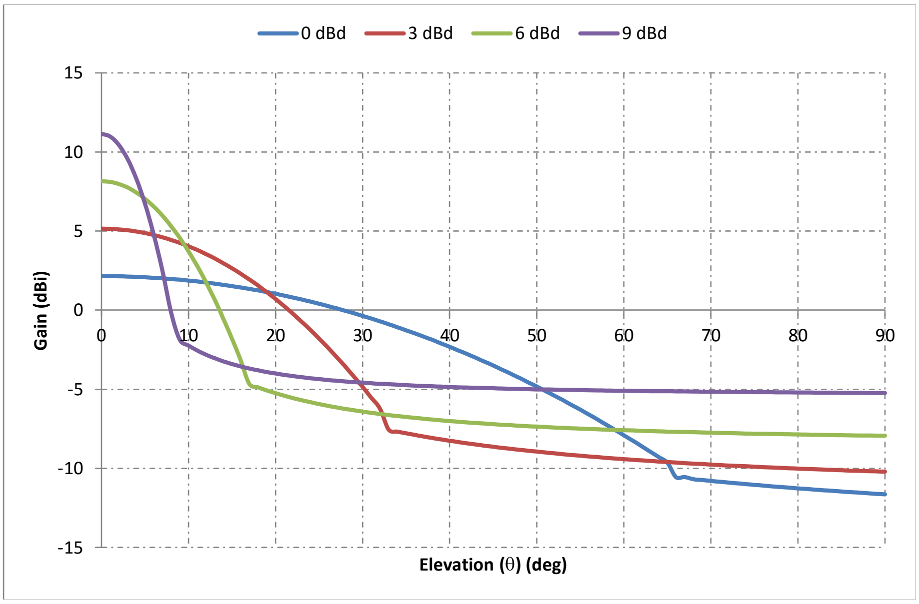

TABLE 7-4

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 7-5

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

7.1.3 Characteristics of the VDE-SAT uplink

The technical characteristics of the VDE-SAT uplink are described in Sections 4.1 and 4.3 and summarized in Table 7-6.

Mis en forme : Normal

TABLE 7-6

Characteristics of VHF data exchange system satellite receiver

Parameter	Value	Unit
Antenna noise temperature	200.0	K
Feed losses	1.0	dB
LNA noise figure	2.0	dB
LNA noise temperature	159.7	K
Feed loss noise temperature at LNA	56.1	K
Antenna noise temperature at LNA	158.9	K
System noise temperature at LNA	374.7	K
System noise temperature at LNA	25.7	dBK
Intrinsic noise power density	-202.9	dBW/Hz
Intrinsic noise power in 42 kHz bandwidth	-156.6	dBW
Required carrier-to-noise-plus-interference ratio (C/(N+I))	-13.5	dB

Mis en forme : Normal

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

Based on the technical characteristics for base stations and mobile stations in the land mobile service and the VDE-SAT uplink receiver characteristics, the level of interference to the VDE-SAT uplink can be estimated. Tables 7-7 to 7-10 provides estimate of the interference level from base and mobile station at the satellite receiver input for both isoflux and Yagi antenna. The analysis shows that the maximum interference level at elevation angles of more than 10 degrees will be equal to:

– Interference from base station:

-123.1 dBW to satellite receiver with isoflux antenna

-116.6 dBW to satellite receiver with Yagi antenna

– Interference from mobile station:

-125.3 dBW to satellite receiver with isoflux antenna

-117.7 dBW to satellite receiver with Yagi antenna

TABLE 7-7

Estimate of interference from base station to VDE-SAT uplink receiver with isoflux antenna

Radar elevation angle	**Base station e.i.r.p.**	**Polarisation loss**	**Path length**	**Path loss**	**Satellite antenna gain**	**Interference level at LNA, including feed loss**
deg	dBW	dB	Km	dB	dBi	dBW
0.0	26.0	3.0	2 830	145.4	2.0	-121.4
10.0	21.5	3.0	1 932	142.1	1.5	-123.1
20.0	12.5	3.0	1 392	139.3	1.0	-129.8
30.0	11.5	3.0	1 075	137.0	-0.5	-130.0
40.0	11.0	3.0	882	135.3	-2.0	-130.3
50.0	10.5	3.0	761	134.0	-4.0	-131.5
60.0	10.0	3.0	683	133.1	-5.0	-132.1
70.0	10.0	3.0	635	132.4	-7.0	-133.4
80.0	10.0	3.0	608	132.1	-8.0	-134.1
90.0	10.0	3.0	600	131.9	-8.5	-134.4

TABLE 7-8

Estimate of interference from base station to VDE-SAT uplink receiver with Yagi antenna

Radar elevation angle	**Base station e.i.r.p.**	**Polarisation loss**	**Path length**	**Path loss**	**Satellite antenna gain**	**Interference level at LNA, including feed loss**
deg	dBW	dB	Km	dB	dBi	dBW
0.0	26.0	3.0	2 830	145.4	8.0	-115.4
10.0	21.5	3.0	1 932	142.1	8.0	-116.6
20.0	12.5	3.0	1 392	139.3	8.0	-122.8
30.0	11.5	3.0	1 075	137.0	7.8	-121.7

40.0	11.0	3.0	882	135.3	6.9	-121.4
50.0	10.5	3.0	761	134.0	5.5	-122.0
60.0	10.0	3.0	683	133.1	3.6	-123.5
70.0	10.0	3.0	635	132.4	0.7	-125.7
80.0	10.0	3.0	608	132.1	-2.2	-128.3
90.0	10.0	3.0	600	131.9	-5.5	-131.4

TABLE 7-9

Estimate of interference from mobile station to VDE-SAT uplink receiver with isoflux antenna

Radar elevation angle	**Mobile station e.i.r.p.**	**Polarisation loss**	**Path length**	**Path loss**	**Satellite antenna gain**	**Interference level at LNA, including feed loss**
deg	dBW	dB	Km	dB	dBi	dBW
0.0	18.0	3.0	2 830	145.4	2.0	-129.4
10.0	18.0	3.0	1 932	142.1	1.5	-126.6
20.0	17.0	3.0	1 392	139.3	1.0	-125.3
30.0	15.5	3.0	1 075	137.0	-0.5	-126.0
40.0	13.5	3.0	882	135.3	-2.0	-127.8
50.0	11.0	3.0	761	134.0	-4.0	-131.0
60.0	8.0	3.0	683	133.1	-5.0	-134.1
70.0	5.0	3.0	635	132.4	-7.0	-138.4
80.0	4.5	3.0	608	132.1	-8.0	-139.6
90.0	4.0	3.0	600	131.9	-8.5	-140.5

TABLE 7-10

Estimate of interference from mobile station to VDE-SAT uplink receiver with Yagi antenna

Radar elevation angle	**Mobile station e.i.r.p.**	**Polarisation loss**	**Path length**	**Path loss**	**Satellite antenna gain**	**Interference level at LNA, including feed loss**
deg	dBW	dB	Km	dB	dBi	dBW
0.0	18.0	3.0	2 830	145.4	8.0	-123.4
10.0	18.0	3.0	1 932	142.1	8.0	-120.1
20.0	17.0	3.0	1 392	139.3	8.0	-118.3
30.0	15.5	3.0	1 075	137.0	7.8	-117.7
40.0	13.5	3.0	882	135.3	6.9	-118.9
50.0	11.0	3.0	761	134.0	5.5	-121.5
60.0	8.0	3.0	683	133.1	3.6	-125.5
70.0	5.0	3.0	635	132.4	0.7	-130.7
80.0	4.5	3.0	608	132.1	-2.2	-133.8
90.0	4.0	3.0	600	131.9	-5.5	-137.5

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

The most robust waveform format defined for the VDE-SAT uplink is waveform 1, as provided in Section 4.3 and Table 4-12. This waveform is used in the analysis of the effect on VDE-SAT uplink link budget from interference from a single base or mobile station operating in the land mobile service in the 156 to 162 MHz band. An additional interfering land mobile base station 10 degree away from worst case position will increase the I+N level by approximately 0.9 dB. The analysis is based on the interference free link budgets provided in Section 4.3. Tables 7-11 to 7-14 present link budgets for VDE-SAT up-link when interference from a base station or mobile station in the land mobile service is present. The tables show that the VDE-SAT uplink waveform format 1 will ensure link availability with margins with interference from base station and mobile station for the most relevant ship elevation angles. The VDE-SAT uplink will be available for ship elevation angles between 10 and 60 degrees with Yagi antenna on the satellite and between 10 and 50 degrees with isoflux antenna on the satellite. Furthermore, Table 7-15 summaries ~~a few~~some potential discrimination factors and mitigation techniques.

TABLE 7-11

Link budget for VDE-SAT uplink with isoflux antenna and interference from base station.

Ship elevation angle	**Carrier level at LNA, including feed loss**	***C/N₀***	***C/N***	**Interference level at LNA, including feed loss**	**C/(N+I)**	**Link margin for waveform 1**
deg	dBW	dBHz	dB	dBW	dB	dB
0.0	–136.6	66.2	20.0	-123.1	-13.5	0.0
10.0	–133.8	69.0	22.8	-123.1	-10.7	2.8
20.0	–132.0	70.9	24.7	-123.1	-8.9	4.6
30.0	–132.7	70.1	23.9	-123.1	-9.6	3.9
40.0	–133.5	69.4	23.1	-123.1	-10.4	3.1
50.0	–135.7	67.1	20.9	-123.1	-12.6	0.9
60.0	–137.3	65.6	19.3	-123.1	-14.2	-0.7
70.0	–139.7	63.2	17.0	-123.1	-16.6	-3.1
80.0	–146.3	56.6	10.4	-123.1	-23.2	-9.7
90.0	–156.7	46.2	0.0	-123.1	-33.6	-20.1

TABLE 7-12

Link budget for VDE-SAT uplink with Yagi antenna and interference from base station.

Ship elevation angle	**Carrier level at LNA, including feed loss**	***C/N₀***	***C/N***	**Interference level at LNA, including feed loss**	**C/(N+I)**	**Link margin for waveform 1**
deg	dBW	dBHz	dB	dBW	dB	dB
0.0	–130.6	72.2	26.0	-116.6	-14.0	-0.5
10.0	–127.3	75.5	29.3	-116.6	-10.7	2.8
20.0	–125.0	77.9	31.7	-116.6	-8.4	5.1

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30.0	–124.4	78.4	32.2	-116.6	-7.8	5.7
40.0	–124.6	78.3	32.0	-116.6	-8.0	5.5
50.0	–126.2	76.6	30.4	-116.6	-9.6	3.9
60.0	–128.7	74.2	27.9	-116.6	-12.1	1.4
70.0	–132.0	70.9	24.7	-116.6	-15.4	-1.9
80.0	–140.5	62.4	16.2	-116.6	-23.9	-10.4
90.0	–153.7	49.2	3.0	-116.6	-37.1	-23.6

TABLE 7-13

Link budget for VDE-SAT uplink with isoflux antenna and interference from mobile station.

Ship elevation angle	**Carrier level at LNA, including feed loss**	***C/N₀***	***C/N***	**Interference level at LNA, including feed loss**	**C/(N+I)**	**Link margin for waveform 1**
deg	dBW	dBHz	dB	dBW	dB	dB
0.0	–136.6	66.2	20.0	-125.3	-11.4	2.1
10.0	–133.8	69.0	22.8	-125.3	-8.6	4.9
20.0	–132.0	70.9	24.7	-125.3	-6.7	6.8
30.0	–132.7	70.1	23.9	-125.3	-7.5	6.0
40.0	–133.5	69.4	23.1	-125.3	-8.2	5.3
50.0	–135.7	67.1	20.9	-125.3	-10.5	3.0
60.0	–137.3	65.6	19.3	-125.3	-12.0	1.5
70.0	–139.7	63.2	17.0	-125.3	-14.4	-0.9
80.0	–146.3	56.6	10.4	-125.3	-21.0	-7.5
90.0	–156.7	46.2	0.0	-125.3	-31.4	-17.9

TABLE 7-14

Link budget for VDE-SAT uplink with Yagi antenna and interference from mobile station.

Ship elevation angle	**Carrier level at LNA, including feed loss**	***C/N_0***	***C/N***	**Interference level at LNA, including feed loss**	**C/(N+I)**	**Link margin for waveform 1**
deg	dBW	dBHz	dB	dBW	dB	dB
0.0	–130.6	72.2	26.0	-117.7	-12.9	0.6
10.0	–127.3	75.5	29.3	-117.7	-9.6	3.9
20.0	–125.0	77.9	31.7	-117.7	-7.3	6.2
30.0	–124.4	78.4	32.2	-117.7	-6.7	6.8
40.0	–124.6	78.3	32.0	-117.7	-6.9	6.6
50.0	–126.2	76.6	30.4	-117.7	-8.5	5.0
60.0	–128.7	74.2	27.9	-117.7	-11.0	2.5
70.0	–132.0	70.9	24.7	-117.7	-14.2	-0.7
80.0	–140.5	62.4	16.2	-117.7	-22.8	-9.3

90.0	–153.7	49.2	3.0	-117.7	-35.9	-22.4

TABLE 7-15

Summary of a few potential discrimination factors and mitigation techniques for VDE-SAT uplink against interference from base and mobile stations in the land mobile service

Factor	Description	Effect
Range	Base and mobile stations are below horizon	No interference
Land mobile station operating mode	Land mobile systems typically operate in simplex mode without continuous transmission	In the gaps between transmissions from a land mobile station VDE-SAT uplink transmissions can be received, and intermittent interference blocking can be handled by FEC and/or ARQ
Frequency diversity	Both frequency plan alternative 1 and 2 provide multiple VDE-SAT uplink channels	In case of interference from a land mobile station on one VDE-SAT uplink channel, the satellite can move traffic to a different VDE-SAT uplink channel without interference from base or mobile station
Yagi antenna isolation	The Yagi antenna provides better spatial selectivity than the isoflux antenna when pointed away from areas with land mobile stations	The Yagi antenna provides discrimination when pointed away from areas with land mobile stations. Figure 7-~~3~~23 shows typical Yagi isolation of 10 dB, 60 degrees off boresight and 20 dB 75 degrees off boresight.

7.1.7 Conclusions

Based on the calculations and estimations presented above it is clear that the most robust waveforms defined for the VDE-SAT uplink is resilient to harmful interference from base and mobile stations operating in the land mobile service in the band 156-162 MHz for all elevation angles between 0 and 60 degrees, depending on waveform used, without any additional interference discrimination or mitigation techniques. Allowing for potential discrimination factors and mitigation techniques discussed above, ~~also~~ the less robust waveforms are expected to perform as stipulated in Section 4. The adaptive modulation and coding scheme defined for VDE-SAT can be utilized to ensure the link is closed.

~~7.1.1 Link budget analysis for the VHF data exchange satellite uplink~~

~~7.1.2 7.1.1 VHF data exchange system ship terminal transmission characteristics~~

~~7.1.3 7.1.2 Propagation model~~

~~7.1.4 7.1.3 Noise level at VHF data exchange-satellite satellite receiver~~

~~7.1.5 7.1.4 Link budget analysis and link margin discussions~~

~~7.1.6 7.1.5 Conclusions~~

~~7.1.7~~ 7.2 Compatibility of ~~a new VHF data exchange system satellite component~~ VDE-SAT with the radiolocation service ~~radars~~ operating in the frequency band 154-156 MHz

7.2.1 Introduction

Radio regulations (RR) No. **5.225A** specifies that in certain countries of Region 1 the frequency band 154-156 MHz is allocated to the radiolocation service on the primary basis. Application of the

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radiolocation service in those frequency bands is limited to the space surveillance radars. Study results reflected in Report ITU-R M.2172-1 show that the mentioned radars could operate in a shared manner with the maritime mobile service (MMS) ground systems operating in the adjacent frequency band 156-174 MHz. At the same time to provide protection for the MMS stations in the frequency bands 156.5125-156.5375 MHz, 156.7625-156.8375 MHz, 161.9625-161.9875 MHz and 162.0125-162.0375 MHz additional constrains specifying that e.i.r.p. of out-of-band emissions produced by the space surveillance radars should not exceed the level of –16 dBW was imposed by RR No. **5.225A**. The ~~mentioned~~ requirement is met by integrating additional notch filters into radar transmitting circuits for the mentioned frequency bands. The rest of the frequency bands related to provisions of RR Appendix **18** contain no constraints ~~imposed~~ on the operation of the space surveillance systems, and no specific measures are applied to reduce out-of-band emissions.

Recommendation ITU-R M.2092-0 specifies that the VDES up-link should be established in the frequency band 157.1875-157.3375 MHz by combining channels 1024, 1084, 1025, 1085, 1026, 1086 of RR Appendix **18** into a single channel of 150 kHz.

This ~~Report~~ Section presents results of studies in compatibility of a new VHF data exchange system (VDES) satellite component up-link in the frequency band 156.0125-157.4375 MHz with space surveillance radars operating in the frequency band 154-156 MHz.

7.2.2 Characteristics of space surveillance radars operating in the frequency band 154-156 MHz

Table 7-16 presents characteristics of the space surveillance radars operating in the frequency band 154-156 MHz. The characteristics were taken from Recommendation ITU-R M.1802-1 and were used in the compatibility studies.

TABLE 7-16

Characteristics of radars operating in the frequency band 154-156 MHz

Parameter	Units	Value	
		Radar A	**Radar B**
Radar type		Primary ranging radar	
Radar function		Space objects recognition and trackinge	
Frequency band	MHz	154–156	
Relative frequency instability		10^{-11}	
Output pulse power (min/max)	dBW	27/46	40/46
Mean output power (min/max)	dBW	22/41	35/41
Polarization		Linear	
Pulse length	µs	13 000	3 200
Duty cycle		0.322	
Modulation type		Pulse	
Altitude above the ground level	m	19	
Antenna type		Phased array	
Maximum antenna gain: – transmitter – receiver	dB	 25 30	
Max antenna gain into horizon	dB	9	12
Main beam pattern – horizontal plane (Rx/Tx) – vertical plane (Rx/Tx)	degrees	 2.6/5.2 2.6/2.6	
Scan angle ranges: – horizontal plane – vertical plane	degrees	0–360	

		2–70	
Receiver noise temperature	K	800	
Operation receiver passband	kHz	0.132	625
Required frequency band	kHz	0.132	625
Emission class		P0N	MXN
I/N protection ratio	dB	−6	
Level of unwanted emissions		Complies with provisions of RR Appendix **3**[2]	

7.2.3 Characteristics of ~~VHF data exchange system satellite~~VDE-SAT uplink (ship-to-satellite)

The technical characteristics of the VDE-SAT uplink are described in Sections 4.1 and 4.3 and summarized in Table 7-17.~~*[Editorial note: this section should be moved to section 7.1]*~~

~~VDES system ship-to-satellite link is described in Recommendation ITU-R M.2092-0 which assumes a low-Earth orbit (LEO) satellite system with altitude of 600 km[3]. It is also assumed that such satellite system could use antennas of two types, i.e. Yagi antenna and Isoflux isotropic antenna. Technical characteristics of VDES system up-link taken from Recommendation ITU-R M.2092-0 are described below.~~

~~Table 7-2 depicts minimum transmitting ship station e.i.r.p. as a function of elevation angle. Patterns for Yagi antenna and Isoflux antenna are shown in Tables 7-3 and 7-4 accordingly.~~

~~TABLE 7-2~~

~~**Minimum ship station effective isotropic radiated power vs. elevation angle**~~

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

~~* Note: Multilevel and filtered modulation is used, and 3 dB back-off from saturation is assumed. Transmit average power shall be at least 1.0 watts and not exceed 25 watts as declared by the manufacturer. The ship stations may be equipped with antennas having patterns different from that shown in Table 2 (see Recommendation ITU-R M.2092-0 § 3.7.1).~~

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2 Values of unwanted emissions in the VDES receiver frequency band are described in section 6 ~~herein~~.

~~3 Due to unavailability of relevant data for the VDES satellite receiver characteristics the low-Earth orbit system described in Recommendation ITU-R M.2092-0 is used herein. But it is to note that Report ITU-R M.2084 deals with different characteristics of AIS satellite receivers.~~

~~TABLE 7-3~~

~~Satellite Yagi-antenna gain vs. nadir offset angle~~

~~Satellite 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 7-4~~

~~Satellite Isoflex-antenna gain vs. nadir offset angle~~

~~Satellite 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~~

~~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 defined in Recommendation ITU-R M.2092-0, uses the waveforms defined in Table 7-5 for uplink. The thresholds~~ $\cancel{C/N_0}$ ~~and~~ $\cancel{C/(N+I)}$ ~~on a Gaussian channel have been estimated.~~

~~TABLE 7-5~~

~~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~~	~~33.6~~	~~NA~~	~~NA~~	~~NA~~
~~Symbol rate (ksps)~~	~~2.4~~	~~2.4~~	~~33.6~~	~~33.6~~	~~33.6~~
~~Packet size (ms)~~	~~133.3~~	~~133.3~~	~~26.7~~	~~26.7~~	~~800~~
~~Modulation~~	~~BPSK~~	~~CPM/QPSK~~	~~QPSK~~	~~16APSK~~	~~16APSK~~
~~FEC rate~~	~~1/2~~	~~1/4~~	~~3/4~~	~~3/4~~	~~3/4~~
~~Information rate (kbps)~~	~~2.1~~	~~2.1~~	~~50.4~~	~~100.8~~	~~100.8~~
~~Estimated threshold Es/N0 for a Gaussian channel (dB) (BER=1E-5)~~	~~0.1~~	~~0.1~~	~~4.4~~	~~11.4~~	~~11.4~~
~~Symbol error rate at threshold (%)~~	~~30~~	~~30~~	~~10~~	~~2~~	~~2~~
~~Estimated required C/N0 (dBHz)~~	~~34.2~~	~~33.9~~	~~51.4~~	~~61.4~~	~~61.4~~
~~Estimated required C/(N+I) (dB)~~	~~-12.0~~	~~-12.3~~	~~5.2~~	~~15.2~~	~~15.2~~

~~*[Editorial note: Table needs to be verified, especially the values for C/N and C/(N+I)]*~~

~~Satellite noise levels at the receiver front end are presented in Table 7-6. The system noise temperature is taken to be 25.7 dBK assuming no external interference.~~ The required $C/(N+I)$ listed in Table 7-~~6~~ 17 is for the most robust waveform. Adaptive coding and modulation allow the usage waveforms with higher throughput when the necessary link quality is available.

TABLE 7-~~6~~17

Characteristics of VHF data exchange system satellite receiver

Antenna noise temperature	200.0	K
Feed losses	1.0	dB
LNA noise figure	2.0	dB
LNA noise temperature	159.7	K
Feed loss noise temperature at LNA	56.1	K
Antenna noise temperature at LNA	158.9	K
System noise temperature at LNA	374.7	K
System noise temperature at LNA	25.7	dBK
Intrinsic noise power density	-202.9	dBW/Hz
Intrinsic noise power in 42 ~~[50]~~ kHz bandwidth	-156.6	dBW
Required carrier-to-noise-plus-interference ratio (C/(N+I))	-~~12~~13.~~3~~5	dB

7.2.4 Scenario of interference from unwanted emissions by radars operating in the frequency band 154-156 MHz on VHF date exchange system satellite receiver

Subject to Recommendation ITU-R M.2029-0, the VDES up-link should be established in the frequency band 157.1875–157.3375 MHz by combining channels 1024, 1084, 1025, 1085, 1026, 1086 of RR Appendix **18** into a single channel of 150 kHz.

Mis en forme : Non Surlignage

FIGURE 7-~~1~~2

Scenario of radar unwanted emission interference effect on CHF data exchange system satellite receiver

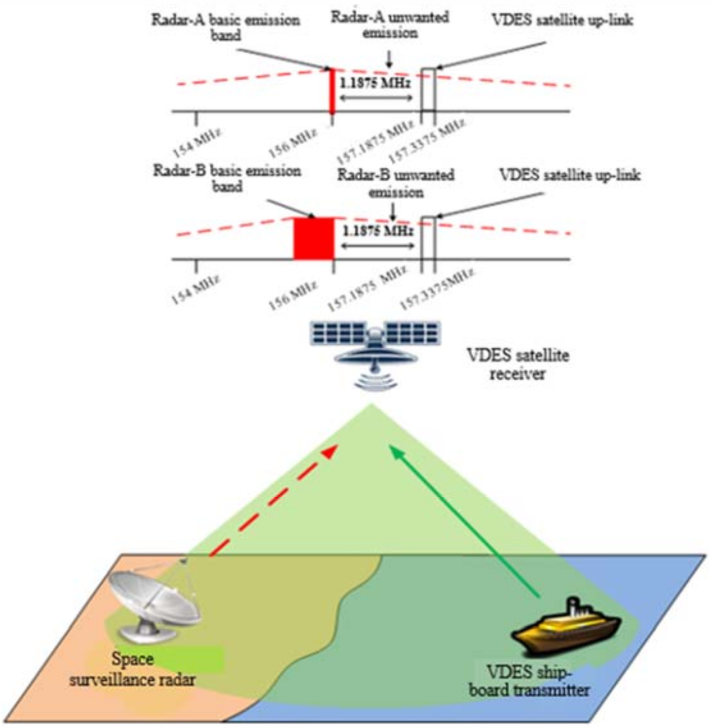


Figure 7-~~1~~ 2 depicts scenario of effect caused by interference from space surveillance radar emissions on the VDES satellite receivers. A wanted signal from the ship transmitter is shown as a solid green arrow whereas interference from the space surveillance radar is reflected as a dashed red arrow.

7.2.5 Estimation of interference level from unwanted emissions by radars operating in the frequency band 154-156 MHz on VHF data exchange system satellite receiver

~~Methodology~~ The methodology described in Report ITU-R M.2172-1 was used for estimating the levels of unwanted emissions from Radar A in the band of the VDES satellite receiver. Assuming frequency separation of 1.2 MHz it was found that the unwanted emission power at the radar antenna front end in 25 kHz bandwidth would be minus 30.7 dBW and that in 150 kHz bandwidth would be minus 22.9 dBW. Given the 25 dB transmit gain of the radar, this is equal to a peak e.i.r.p. in 42 kHz of -3.4 dBW

The ~~obtained~~ result meets the RR Appendix **3** provisions for spurious emissions as specifying that, for radars of the given type, the level power delivered to the antenna feed shall not exceed minus 21.3 dBW in 77 Hz reference band.

For Radar B, unwanted emissions level is a function of modulation parameters. Therefore, for Radar B, in accordance with requirements of RR Appendix **3**, the value of its unwanted emissions at the radar antenna front end would be minus 33 dBW in the bandwidth of 25 kHz and minus 25.2 dBW in the bandwidth of 150 kHz. This radar ~~is less of a~~ contribut~~or~~es less ~~to~~ interference than radar A, so the ~~worst~~ worst-case ~~condition~~ scenario of radar A is used to assess feasibility in this report.

A satellite with a VDES on-board receiver is in a circular orbit of 600 km in altitude. Carrier-to-interference (*C/I*) ratios are estimated using satellite elevation angle steps of 10 degrees for the angles of satellite visibility by the ship station from 0 to 90 degrees corresponding to appropriate angles of satellite visibility by the radar. Since space surveillance radar scans in a vertical plane within an angle sector of 2-70 degrees, the estimation assumes that a receiving antenna onboard a satellite will be aligned with the space surveillance radar main lobe. Table 7-~~7~~ 18 and Table 7-~~8~~ 19 show the resulting received interference power using the satellite isoflux antenna and the 8 dBi Yagi antenna as defined in M.2092-0. These calculations ~~are~~ present the ~~worst~~ worst-case in that they assume that the radar and satellite antenna boresigths are aligned, which is a rare occurrence. It can be seen that the worst-case interference level is -144.7 dBW for the isoflux case. The ~~worst~~ worst-case interference level for the Yagi is -135.8 dBW for a radar elevation angle to the satellite of 40 degrees.

TABLE 7-~~7~~18

Radar emissions into a 600 km low earth orbit satellite using isoflux antenna

Radar elevation angle	Radar peak e.i.r.p. in 42 kHz at 157 MHz	Polarisation loss	Path length	Path loss	Satellite antenna gain	Interference level at LNA, including feed loss
deg	dBW	dB	Km	dB	dBi	dBW
0.0	-3.4	3.0	2 830	145.4	2.0	-150.9
10.0	-3.4	3.0	1 932	142.1	1.5	-148.0
20.0	-3.4	3.0	1 392	139.3	1.0	-145.7
30.0	-3.4	3.0	1 075	137.0	-0.5	-145.0
40.0	-3.4	3.0	882	135.3	-2.0	-144.7
50.0	-3.4	3.0	761	134.0	-4.0	-145.5
60.0	-3.4	3.0	683	133.1	-5.0	-145.5
70.0	-3.4	3.0	635	132.4	-7.0	-146.9
80.0	-3.4	3.0	608	132.1	-8.0	-147.5
90.0	-3.4	3.0	600	131.9	-8.5	-147.9

TABLE 7-~~8~~19

Radar emissions into a 600 km low earth orbit satellite using 8 dBi Yagi antenna

Radar elevation angle	Radar peak e.i.r.p. in 42 kHz at 157 MHz	Polarisatio n loss	Path length	Path loss	Satellite antenna gain	Interference level at LNA, including feed loss
deg	dBW	dB	km	dB	dBi	dBW
0.0	-3.4	3.0	2 830.0	145.4	8.0	-144.9
10.0	-3.4	3.0	1 932.0	142.1	8.0	-141.5
20.0	-3.4	3.0	1 392.0	139.3	8.0	-138.7

30.0	-3.4	3.0	1 075.0	137.0	7.8	-136.7
40.0	-3.4	3.0	882.0	135.3	6.9	-135.8
50.0	-3.4	3.0	761.0	134.0	5.5	-136.0
60.0	-3.4	3.0	683.0	133.1	3.6	-136.9
70.0	-3.4	3.0	635.0	132.4	0.7	-139.2
80.0	-3.4	3.0	608.0	132.1	-2.2	-141.7
90.0	-3.4	3.0	600.0	131.9	-5.5	-144.9

7.2.6 Estimation of link budget for VHF data exchange system up-link with a satellite receiver in a 600 km altitude orbit

The most robust waveform format defined for the VDE-SAT uplink is waveform 1, as provided in Section 4.3 and Table 4-12. This waveform is used in the analysis of the effect on VDE-SAT uplink link budget from interference from radars operating in the 154-162 MHz band. The analysis is based on the interference free link budgets provided in Section 4.3. ~~Tables 7-9 and 7-10 present link budgets for VDES up-link with a satellite receiver in a 600 km altitude orbit using Isoflux and Yagi antennas. A 6 W ship station transmitter is assumed. The link margin is high for all elevation angles.~~ Tables 7-~~11~~ 20 and 7-~~12~~ 21 present the resulting ~~worst~~ worst-case C/N and C/(N+I), when the interference level from unwanted emissions by radars operating in the frequency band 154-156 MHz as calculated in Table 7-~~7~~ 18 and Table 7-~~8~~ 19 is included.

Table 7-~~11~~ 20 and Table 7-~~12~~ 21 show that waveform format~~s~~ 1 ~~and 2~~ will ensure link availability with substantial margins under the ~~worst~~ worst-case radar interference condition for all ship elevation angles~~ up to 80 degrees,~~. Formats 2 and 3 will be available for ship elevation angles up to 7~~6~~0 degrees. ~~and~~ Formats 4 will be available for ship elevation angles up to 60 degrees, but~~and~~ format 5 will require additional discrimination or mitigation techniques. Table 7-~~13~~ 22 summaries ~~a few~~some potential discrimination factors and mitigation techniques.

Mis en forme : Autoriser lignes veuves et orphelines

~~TABLE 7-9~~

~~**Worst-case link budget for VHD data exchange-satellite uplink with 6 W ship transmitter, Isoflux satellite receiving antenna without interference.**~~

~~Ship elevation angle~~	~~Ship antenna gain~~	~~Ship e.i.r.p.~~	~~Polarization loss~~	~~Path length~~	~~Path loss~~	~~Satellite antenna gain~~	~~Carrier level at LNA, including feed loss~~	~~C/N0~~	~~C/N~~	~~Link margin for waveform 1~~
~~deg~~	~~dBi~~	~~dBW~~	~~dB~~	~~km~~	~~dB~~	~~dBi~~	~~dBW~~	~~dBHz~~	~~dB~~	~~dB~~
~~0.0~~	~~3.0~~	~~10.8~~	~~3.0~~	~~2 830~~	~~145.4~~	~~2.0~~	~~–136.6~~	~~66.2~~	~~20.0~~	~~32.3~~
~~10.0~~	~~3.0~~	~~10.8~~	~~3.0~~	~~1 932~~	~~142.1~~	~~1.5~~	~~–133.8~~	~~69.0~~	~~22.8~~	~~35.1~~
~~20.0~~	~~2.5~~	~~10.3~~	~~3.0~~	~~1 392~~	~~139.3~~	~~1.0~~	~~–132.0~~	~~70.9~~	~~24.7~~	~~37.0~~
~~30.0~~	~~1.0~~	~~8.8~~	~~3.0~~	~~1 075~~	~~137.0~~	~~–0.5~~	~~–132.7~~	~~70.1~~	~~23.9~~	~~36.2~~
~~40.0~~	~~0.0~~	~~7.8~~	~~3.0~~	~~882~~	~~135.3~~	~~–2.0~~	~~–133.5~~	~~69.4~~	~~23.1~~	~~35.4~~
~~50.0~~	~~–1.5~~	~~6.3~~	~~3.0~~	~~761~~	~~134.0~~	~~–4.0~~	~~–135.7~~	~~67.1~~	~~20.9~~	~~33.2~~
~~60.0~~	~~–3.0~~	~~4.8~~	~~3.0~~	~~683~~	~~133.1~~	~~–5.0~~	~~–137.3~~	~~65.6~~	~~19.3~~	~~31.6~~
~~70.0~~	~~–4.0~~	~~3.8~~	~~3.0~~	~~635~~	~~132.4~~	~~–7.0~~	~~–139.7~~	~~63.2~~	~~17.0~~	~~29.3~~
~~80.0~~	~~–10.0~~	~~–2.2~~	~~3.0~~	~~608~~	~~132.1~~	~~–8.0~~	~~–146.3~~	~~56.6~~	~~10.4~~	~~22.7~~

~~90.0~~	~~–20.0~~	~~–12.2~~	~~3.0~~	~~600~~	~~131.9~~	~~–8.5~~	~~–156.7~~	~~46.2~~	~~0.0~~	~~12.3~~

~~TABLE 7-10~~

~~**Worst-case link budget for VHF data exchange-satellite uplink with 6 w ship transmitter, Yagi satellite receiving antenna without interference.**~~

~~**Ship elevation angle**~~	~~**Ship antenna gain**~~	~~**Ship e.i.r.p.**~~	~~**Polarization loss**~~	~~**Path length**~~	~~**Path loss**~~	~~**Satellite antenna gain**~~	~~**Carrier level at LNA, including feed loss**~~	~~***C/N₀***~~	~~***C/N***~~	~~**Link margin for waveform 1**~~
~~deg~~	~~dBi~~	~~dBW~~	~~dB~~	~~km~~	~~dB~~	~~dBi~~	~~dBW~~	~~dBHz~~	~~dB~~	~~dB~~
~~0.0~~	~~3.0~~	~~10.8~~	~~3.0~~	~~2 830~~	~~145.4~~	~~8.0~~	~~–130.6~~	~~72.2~~	~~26.0~~	~~38.3~~
~~10.0~~	~~3.0~~	~~10.8~~	~~3.0~~	~~1 932~~	~~142.1~~	~~8.0~~	~~–127.3~~	~~75.5~~	~~29.3~~	~~41.6~~
~~20.0~~	~~2.5~~	~~10.3~~	~~3.0~~	~~1 392~~	~~139.3~~	~~8.0~~	~~–125.0~~	~~77.7~~	~~31.7~~	~~44.0~~
~~30.0~~	~~1.0~~	~~8.8~~	~~3.0~~	~~1 075~~	~~137.0~~	~~7.8~~	~~–124.4~~	~~78.4~~	~~32.2~~	~~44.5~~
~~40.0~~	~~0.0~~	~~7.8~~	~~3.0~~	~~882~~	~~135.3~~	~~6.9~~	~~–124.6~~	~~78.3~~	~~31.2~~	~~44.3~~
~~50.0~~	~~–1.5~~	~~6.3~~	~~3.0~~	~~761~~	~~134.0~~	~~5.5~~	~~–126.2~~	~~76.6~~	~~30.4~~	~~42.7~~
~~60.0~~	~~–3.0~~	~~4.8~~	~~3.0~~	~~683~~	~~133.1~~	~~3.6~~	~~–128.7~~	~~74.2~~	~~27.9~~	~~40.2~~
~~70.0~~	~~–4.0~~	~~3.8~~	~~3.0~~	~~635~~	~~132.4~~	~~0.7~~	~~–132.0~~	~~70.9~~	~~24.7~~	~~37.0~~
~~80.0~~	~~–10.0~~	~~–2.2~~	~~3.0~~	~~608~~	~~132.1~~	~~–2.2~~	~~–140.5~~	~~62.4~~	~~16.2~~	~~28.5~~
~~90.0~~	~~–20.0~~	~~–12.2~~	~~3.0~~	~~600~~	~~131.9~~	~~–5.5~~	~~–153.7~~	~~49.2~~	~~3.0~~	~~15.3~~

TABLE 7-~~11~~20

Worst-case link budget for VHF data exchange-satellite uplink with 6 W ship transmitter, Isoflux satellite receiving antenna with interference radar type A.

Ship elevation angle	**Carrier level at LNA, including feed loss**	***C/N₀***	***C/N***	**Interference level at LNA, including feed loss**	**C/I**	**C/(N+I)**	**Link margin for waveform ~~1~~1**
deg	dBW	dBHz	dB	dBW	dB	dB	dB
0.0	–136.6	66.2	20.0	-144.7	8.1	7.8	~~20~~21.~~1~~3
10.0	–133.8	69.0	22.8	-144.7	10.9	10.6	~~22~~24.~~9~~1
20.0	–132.0	70.9	24.7	-144.7	12.7	12.5	~~24~~26.~~8~~0
30.0	–132.7	70.1	23.9	-144.7	12.0	11.7	~~24~~25.~~0~~2
40.0	–133.5	69.4	23.1	-144.7	11.2	11.0	~~23~~24.~~3~~5
50.0	–135.7	67.1	20.9	-144.7	9.0	8.7	~~21~~22.~~0~~2
60.0	–137.3	65.6	19.3	-144.7	7.4	7.2	~~19~~20.~~5~~7
70.0	–139.7	63.2	17.0	-144.7	5.0	4.8	~~17~~18.~~1~~3
80.0	–146.3	56.6	10.4	-144.7	-1.6	-1.8	~~10~~11.~~5~~7
90.0	–156.7	46.2	0.0	-144.7	-12.0	-12.2	~~0~~1.~~1~~3

TABLE 7-~~12~~21

Worst-case link budget for VHF data exchange-satellite uplink with 6 w ship transmitter, Yagi satellite receiving antenna with interference radar type A.

Ship elevation angle	Carrier level at LNA, including feed loss	C/N_0	C/N	Interference level at LNA, including feed loss	C/I	C/(N+I)	Link margin for waveform ~~1~~1
deg	dBW	dBHz	dB	dBW	dB	dB	dB
0.0	–130.6	72.2	26.0	-135.8	5.2	5.2	~~17~~18.~~5~~7
10.0	–127.3	75.5	29.3	-135.8	8.5	8.5	~~20~~22.~~8~~0
20.0	–125.0	77.7	31.7	-135.8	10.8	10.8	~~23~~24.~~1~~3
30.0	–124.4	78.4	32.2	-135.8	11.4	11.4	~~23~~24.~~7~~9
40.0	–124.6	78.3	31.2	-135.8	11.2	11.2	~~23~~24.~~5~~7
50.0	–126.2	76.6	30.4	-135.8	9.6	9.6	~~21~~23.~~9~~1
60.0	–128.7	74.2	27.9	-135.8	7.1	7.1	~~19~~20.46
70.0	–132.0	70.9	24.7	-135.8	3.8	3.8	~~16~~17.~~1~~3
80.0	–140.5	62.4	16.2	-135.8	-4.7	-4.7	~~7~~8.~~6~~8
90.0	–153.7	49.2	3.0	-135.8	-17.9	-17.9	-~~5~~4.~~6~~4

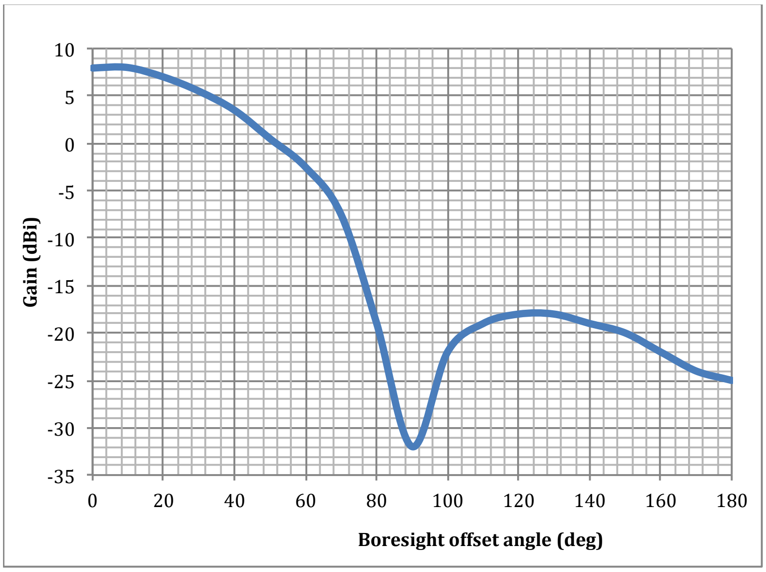
TABLE 7-~~13~~22

Summary of a few potential discrimination factors and mitigation techniques for VHF data exchange-satellite uplink against interference from unwanted emissions by radars

Factor	Description	Effect
Range	Radars that are below horizon	No interference
Radar operating mode	When the radar is operating in a scan mode, it will only affect the satellite for the short time it points directly at it.	There are approximately 69 horizontal beam positions and 27 vertical beam positions, or a total of 1 863 beam positions. Assuming a beam offset of 2 beamwidths provides sufficient discrimination, the probability that transmission in one of the seven possible beams is 0~~,~~.4 %. This level of interference blocking can be handled by FEC and/or ARQ
Radar scan loss	Planar phased array radars have a scan loss when not pointing orthogonal to the flat surface.	The scan loss depends on the number of planar arrays used. A horizontal scan of 60 degrees will cause a 3 dB loss, a vertical scan of 35 degrees will cause a scan loss of 0.9 dB. The ~~worst~~ worst-case condition when the main beam is orthogonal to the array is considered.
Yagi antenna isolation	The Yagi antenna provides better spatial selectivity than the isoflue antenna when pointed away from the radar	The Yagi antenna provides discrimination when pointed away from the radar. Figure 7-~~2~~ 3 shows typical Yagi isolation of 10 dB, 60 degrees off boresight and 20 dB 75 degrees off boresight.

FIGURE 7-~~2~~3

Typical Yagi gain pattern as a function of boresight offset angle



~~7.1.8~~7.1.1 7.2.7 Potential for burnout and blocking of the VHF data exchange-satellite receiver caused by unwanted emissions from the radar

Table 7-~~14~~ 23 and Table 7-~~15~~ 24 show the radar levels at the antenna for both the isoflux and Yagi antennas, with peak output e.i.r.p. from the radar of 71 dBW at 156 MHz. It can be seen that the maximum level is less than -61 dBW. This is more than 30 dB below expected burnout levels. Thus, the VDE-SAT receiver will not be exposed to an interference level from the radar that potentially can be capable of destroying the satellite receiver.

The presence radar signal between 154 and 156 MHz will add a blocking performance requirement for the VDE-SAT receiver. This requirement is not expected to be a concern.

TABLE 7-~~14~~23

Maximum signal level of unwanted emissions from radar with Isoflux antenna onboard the satellite

Elevation angle	Radar e.i.r.p.	Polarisation loss	Range	Pathloss	Satellite antenna gain	Received signal level
Degrees	dBW	dB	km	dB	dBi	dBW
0	71.0	3.0	2 830.0	–145.3	2.0	–76.3
10	71.0	3.0	1 932.0	–142.0	1.5	–73.5
20	71.0	3.0	1 392.0	–139.2	1.0	–71.2
30	71.0	3.0	1 075.0	–136.9	–0.5	–70.4
40	71.0	3.0	882.0	–135.2	–2.0	–70.2
50	71.0	3.0	761.0	–133.9	–4.0	–70.9
60	71.0	3.0	683.0	–133.0	–5.0	–71.0
70	71.0	3.0	635.0	–132.4	–7.0	–72.4
80	71.0	3.0	608.0	–132.0	–8.0	–73.0
90	71.0	3.0	600.0	–131.9	–8.5	–73.4

TABLE 7-~~15~~24

Maximum signal level of unwanted emissions from radar with Yagi antenna onboard the satellite

Elevation angle	Radar e.i.r.p.	Polarization loss	Range	Pathloss	Satellite antenna gain	Received signal level
deg	dBW	dB	km	dB	dBi	dBW
0.0	71.0	3.0	2 830.0	–145.3	8.0	–70.3
10.0	71.0	3.0	1 932.0	–142.0	8.0	–67.0
20.0	71.0	3.0	1 392.0	–139.2	8.0	–64.2
30.0	71.0	3.0	1 075.0	–136.9	7.8	–62.1
40.0	71.0	3.0	882.0	–135.2	6.9	–61.3
50.0	71.0	3.0	761.0	–133.9	5.5	–61.4
60.0	71.0	3.0	683.0	–133.0	3.6	–62.4
70.0	71.0	3.0	635.0	–132.4	0.7	–64.7
80.0	71.0	3.0	608.0	–132.0	–2.2	–67.2
90.0	71.0	3.0	600.0	–131.9	–5.5	–70.4

~~7.1.9~~ 7.2.~~9~~8 Conclusions

Mis en forme : Sans numérotation ni puces

[Editorial note: The conclusion is reserved for finalization of the contents of this report and for confirmation in liaison exchanges with appropriate working parties.]

[Based on the calculations and estimations presented above, it is clear that most robust waveforms defined for the VDE-SAT uplink is resilient to harmful interference from radars operating in the frequency band 154-156 MHz for all elevation angles up to 60-80 degrees, depending on waveform used, without any additional interference discrimination or mitigation techniques. Allowing for potential discrimination factors and mitigation techniques discussed above, ~~also the~~even the less robust waveforms are expected to perform as stipulated in section 4. The adaptive modulation and coding scheme defined for VDE-SAT can be utilized to ensure the link is closed.

These calculations and estimations also show that the VDE-SAT receiver will not be exposed to an interference level from the radar that potentially can be capable of destroying the satellite receiver.]

8 Testing, demonstrations and measurements

Mis en forme : Hiérarchisation + Niveau : 1 + Style de numérotation : 1, 2, 3, … + Commencer à : 1 + Alignement : Gauche + Alignement : 0 cm + Retrait : 0,76 cm

[Editorial note: This section is intended to provide results from demonstration and measurement projects involving VDE-SAT.]

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

Mis en forme : Normal

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. As results from these projects are available they should be summarised and moved to section 8.

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

~~7.1.10~~ 9.1 NORSAT-2 (European Space Agency ~~VHF data exchange satellite~~ VDE-SAT downlink verification planned H~~1~~2 2017)

Mis en forme : Titre 2

The objective of the ESA VDE-SAT Downlink Verification is to demonstrate the feasibility of the VHF data exchange via satellite in a real operating environment. The feasibility of VDE-SAT will be demonstrated by a test campaign as well as a VDE-SAT service demonstration.

The main purpose of the test campaign is to assess the performance of the waveforms considered, enabling standardisation of a suitable set of waveforms and corresponding parameters. Based on these results, recommendations regarding the downlink physical layer will be given.

Two test receivers, one on-board a Norwegian Coast Guard vessel and a reference receiver at Andoya in northern ~~FFI premises at Kjeller (~~Norway~~)~~, will be used during the test campaign. The Coast Guard vessel will receive VDE-SAT transmissions at sea. The terminal at ~~the FFI premises~~Andoya will be used as reference, for satellite transmitter (Tx) and ship terminal receiver (Rx) verification, and debugging if necessary.

The specification and performance figures are derived from the Recommendation ITU-R M.2092-0 and subsequent work in IALA. The activity shall demonstrate the functionality and performance of VDE-SAT Downlink waveforms and data link protocols that are currently being consolidated by international working groups in IALA and ITU for data exchange via satellite in VHF maritime bands.

~~7.1.11~~ 9.2 Efficiensea 2 coordination

Mis en forme : Titre 2

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 ~~, which is planned for a 3-year period~~ 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 ~~Taking~~ which take into account the radio technical standards and specifications under construction at IALA and the resolution adopted in November 2015 by ITU during the WRC-15. ~~, the first initiative to develop VDES hardware prototypes in a lab environment will be lead.~~ In addition, live sea trials ~~are planned~~ for testing exchanges of ship-to-ship and ship-to-shore data with real-life e-navigation scenarios are underway. EfficienSea 2 is also ~~intends to coordinate~~coordinating ~~the~~ terrestrial VDES activities with satellite VDES activities. ~~that are fortunately also envisaged during the same period of time.~~

The satellite VDES ~~They~~ 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 ~~(Figure 6)~~. A liaison between ESA, the main actors of the VDE-SAT activities and the EfficienSea 2 terrestrial VDES actors ~~will permit~~permits ~~to include~~the inclusion of the satellite VDES downlink component into ~~the~~ overall VDES testbed activities.