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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 of the satellite component for the VHF data exchange system in the VHF maritime mobile band

1 Background

During the last WP 5B meeting, a working document towards a preliminary draft new Report ITU-R M.[VDES-SAT] has been developed, which is contained in document 5B/71 Annex 14.

During the previous study period IALA has studied a VDES satellite component in six channels of the Appendix 18.

IALA has noted the opportunity 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.

IALA has commenced studies on a new prospective MMSS (space-to-Earth) allocation in the frequency band 160.9625-161.4875MHz. This would simplify sharing considerations between the terrestrial and satellite components of VDES.

2 Discussion

In Annex A, IALA proposes two options for the satellite component of the VDES.

The first option is understood by WP5B and was presented during the last study period. This option uses the channels 24, 84, 25, 85, 26 and 86 for the satellite component (both downlink and uplink).

The second option identifies the satellite downlink in the range 160.9625-161.4875MHz. The satellite uplink is identified in the frequency range of the channels 24, 84, 25, 85, 26 and 86. The channels 26 and 86 will be the active uplink of the satellite component (VDE-SAT Uplink). It should be noted that the channels 24, 84, 25 and 85 are used by the terrestrial component of the VDES, and the VDE-SAT Uplink shall not impose constraints on VDES terrestrial operations on these channels.

IALA intends to continue to work on this Report and will provide an update at the next WP 5B in 2017.

3 Actions requested

IALA requests ITU-R WP 5B to take into account these proposals when developing the preliminary draft new Report ITU-R M.[VDES-SAT].

ANNEX

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

Technical characteristics 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 Appendix 18, to enable a new VDES satellite component, while ensuring that this component will not degrade the current terrestrial VDES components, ASM and 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.

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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 provides a summary of why a VDES satellite component is needed, spectrum requirements, technical description and the appropriate sharing and compatibility studies.

2 VDE-SAT, the essential supplement to coastal VDES

2.1 ~~To fill the geographical and operational gaps of the VDES coastal network~~Practical aspects of deploying coastal coverage

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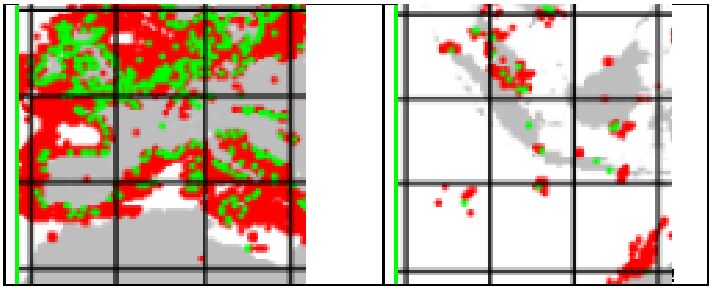
~~When analysing the~~Analysis of ship density at global scale ~~it clearly appears~~shows that coastal areas play a key role ~~.~~in ship traffic and safety management and the VDES terrestrial (VDE-TER) will always remain a key component a successful implementation of VDES for a competent authority.- ~~It is then of common understanding and evidence that the VDES via the coastal network is the appropriate solution for maritime data exchanges between shore to ships and vice versa.~~ However, ~~in parallel, it is very instructive to consider in detail the present status of the AIS terrestrial network. Marine traffic (can we quote that source?) is known as the most extended collaborative network with more than 2000 stations spread all over the World.~~ the current state of AIS-TER deployment shows that while ~~S~~some areas like Europe, the US and Japan ~~is~~are ~~are~~ largely covered, ~~but~~ others like the West of Africa or the South West of Asia ~~are much less covered.~~have much sparser coverage- Figure 2-1 illustrates this well.

FIGURE 2-1

AIS costal station locations (green points) and AIS data coverage (red points) ~~(derived from MarineTraffic).~~



Many countries with long coastlines are currently not able to ensure adequate terrestrial infrastructure to cover their coastlines. ~~It is difficult to imagine that, in the foreseeable future, such countries will be able to expand their terrestrial infrastructure to the same level as, for example, Europe.~~ There are numerous challenges, but one of the main difficulties is to find appropriate hosting sites, especially with a reliable power supply. Figure 2-2 ~~that~~ represents ~~the~~ a ~~10 minute~~10-minutes distribution of terrestrial AIS data over ~~3~~ three consecutive days in the Gulf of Guinea illustrates ~~ing~~ ~~some~~ critical gaps ~~on~~in routine operations.

FIGURE 2-2

Representation of the 10 minutes distribution of terrestrial AIS data over 3 consecutive days in the Gulf of Guinea.

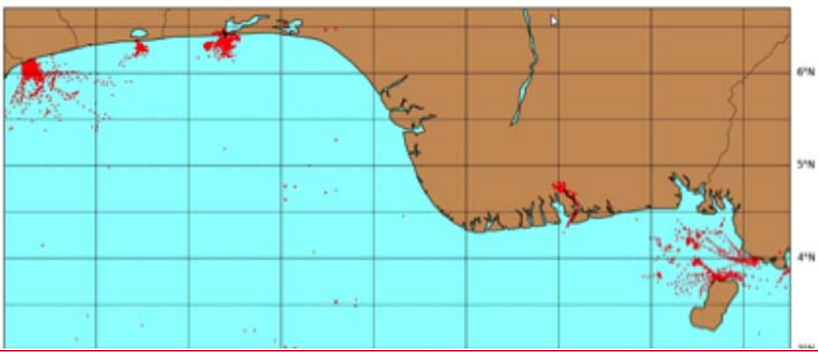


Figure 2-3 exemplifies the high variability observed on the temporal distribution of AIS messages collected from coastal stations. Such high variability indicates severe disruption to ship tracking and, ~~in the future, potential disruption to VDES terrestrial communications~~given that AIS is a component of VDES we can assume these same sites will be used, thus VDES will suffer the same

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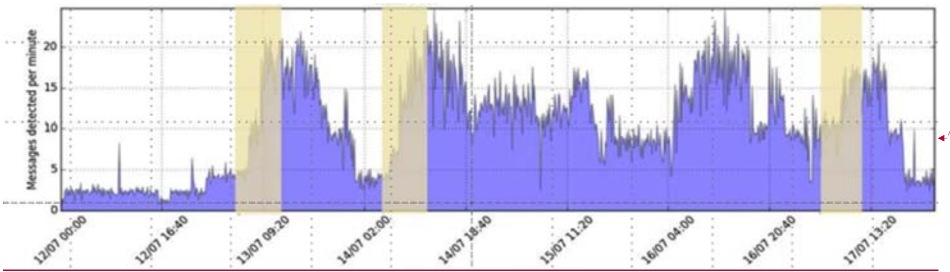
Mis en forme : Paragraphes solidaires issues. These problems of infrastructure distribution, reliability and maintenance in remote and difficult to access areas, or operators with insufficient budget for technical support, are difficult to solve and affects many maritime zones.

FIGURE 2-3

High variability observed on the distribution of AIS 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.



~~The above-mentioned examples show that the~~ VDE-SAT will provide an opportunity to fill the gaps in the coverage of ~~terrestrial VDE in~~ coastal areas ~~that are not in the range of the current AIS coastal stations network~~. VDE-SAT can also provide redundancy in ~~the~~ operations in a situation where parts of the terrestrial infrastructure experience outages. VDE-SAT technical characteristics provide a flexible mode of operations, allowing VDE-SAT services to dynamically adapt to changes in the terrestrial VDE coverage.

2.2 To expand ~~of~~ the VDES from the coastal area to global coverage

The implementation of the SAT-AIS has already demonstrated how the capabilities of the terrestrial AIS can be extended to global coverage~~. This~~ , this is illustrated in Figure 2-4. ~~The~~ Like SAT-AIS, VDE-SAT, ~~based on a constellation of LEO satellites,~~ will enable ~~for~~the extension of ~~the~~ terrestrial VDE capabilities to long-range communications on a global scale. With polar orbiting satellites ~~also~~ the Arctic and Antarctic will also be covered. ~~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. The intercontinental maritime lines are precisely drawn. The navigation in the Northern Arctic latitudes is also shown where the terrestrial network is lacking. As~~However, unlike SAT-AIS, the satellite operations have been carefully considered during the definition of the technical characteristics for VDE-SAT therefore it will certainly be even more effective than SAT-AIS.

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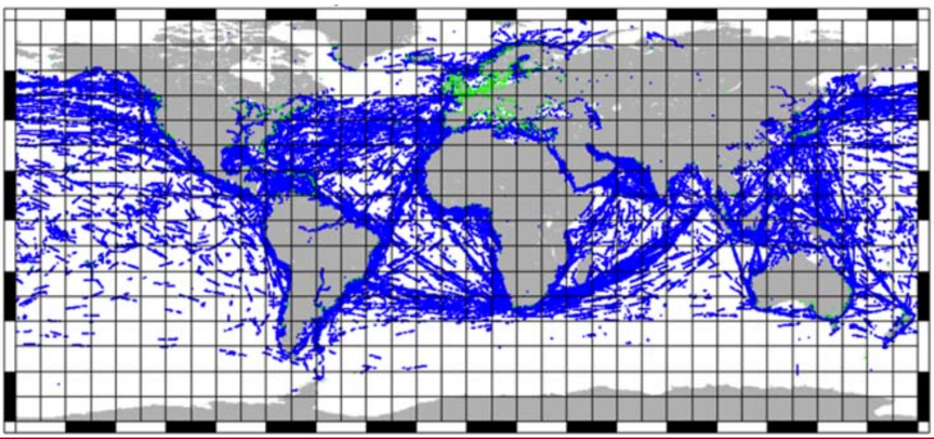
FIGURE 2-4

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



2.3 Use case descriptions

2.3.1 Distribution of maritime safety information

The MSI (Maritime Safety Information) 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 ~~T~~the global distribution of MSIs extending existing terrestrial coverage and providing coverage where a terrestrial infrastructure isn't practical such as the Arctic Sea. ~~can be realized using the VDE-SAT downlink to broadcast information from a LEO satellite to the vesselsnotices. The messages content shall mainly refer to what is applicable to the maritime areas included in the satellite footprint along its track. A priority is associated to each of the messages in order to allow the Captain, and members of the watch, to prioritize the type of information to be displayed according to their needs. Moreover, the on-board Electronic Chart Display and Information System (ECDIS) acts as an automatic filter in a way that the seafarer only visualizes the MSIs that are on its route plan. Useful safety~~Maritime Safety- ~~i~~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 (Figure2-6)~~....~~
- 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)...

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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

~~Some areas of navigation require specific dedicated information. It may be ice charts and bulletins in the polar region. It may also be tides, sea level, or current data forecast for port entrance or strait passages. The mariner can then take benefit of Under Keel Clearance 'gate' information to monitor the threat of grounding.~~

~~One can easily understand that theOf particular interest are areas where a terrestrial infrastructure isn't practical such as VDE-SAT is a perfect tool when considering the Arctic sea, which is far from any coastal infrastructure. However, even when the region of interest if close to the coast and possibly equipped with a VDES terrestrial station, the relevant data required for a safe navigation shall be available prior to the arrival to the dangerous area, typically 48 to 72 hours (TBC) in advance, that is to say out of the VHF range of this actual terrestrial station, which makes the use of VDE-SAT essential.~~

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FIGURE 2-6

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

2.3.2 Automated or on event ship reporting

In addition to supporting shore side services, VDE-SAT will also support ship services. -Ship reporting ~~is a relevant use case for. This reporting~~ may be mandatory, collaborative or of specific interest. For example, IMO has published guidelines for setting up a single window system in maritime transport with the aim to reduce the administrative burden and facilitate coordination between stakeholders. In particular, it includes reporting requirements for ships visiting foreign ports, the 96 hours pre-entry (IMO Fal forms). Before entering into the terrestrial VDES coverage, a ship can push its report via the VDE-SAT to the relevant authority~~. Encryption is applied to protect sensitive data and ensure its authenticity.~~ Similar procedures can also be used for mandatory reporting of fish catching.

Another ship reporting case relevant for VDE-SAT is ~~collaborative contribution of high seas trip reporting. One example is~~ the Voluntary Observing Ship (VOS) program in which ships regularly report weather. The record and data transmission is completely automatic without any manual operation. ~~That kind of in-situ inputs~~This data is critical for accurate weather forecasting and modelling.~~— is of crucial interest for the weather forecast in open oceans, and its importance is increasing considering that the network of permanent weather stations tend to decrease. With easy ECDIS menus and standard message formats, the mariner will also be in position to report new dangers at sea, route status or extreme navigation conditions that may be collected by ship in the vicinity, by the shore but also the VDES satellites extending the possible benefit to a large area and other relevant maritime actors.~~

2.3.3 VDE-SAT opportunity for small vessels fleet or developing areas

The VDE-SAT ~~is also an opportunity for small ships that are not equipped with expensive communications equipment.~~is designed for satellite communications and so will support a~~— A~~ simplified low cost ~~VDES+AIS~~ transceiver.~~– designed to handle onlytake advantage of the most robust transmission schemes may~~This low cost highly ~~robost~~robust option will –provide significant ~~added~~ value for a large number of fishermen in developing areas. They will be able to receive

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weather warnings and alerts, allowing them too seek a safe harbour in time, and avoid adverse weather such as tsunamis or typhoons. With VDE-SAT such services can also be provided in areas without any terrestrial VDE infrastructure. . In addition, the fishermen will be able to send a message to call for a technical assistance in case they are faced to technicalto address- incidents like an engine failure or a problem on the helm control.

The VDE-SAT may also be the solution for developing countries to manage their EEZ where a terrestrial infrastructure is cost prohibitive or where the necessary power infrastructure just doesn't exist. to broadcast specific information to ships that navigate on their EEZ. Such a service will then be available independently to the implementation and maintenance of a terrestrial dedicated network.

2.3.4 Anti-piracy

2.3.5 VDES infrastructure for developing areas

2.3.6 High seas communications to small vessels, i.e. fishing vessels

2.3.74 Ice chart distribution

Information on sea ice conditions around a vessel 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. at an early stage. Together with prognoses for expected ice movements, ice charts allow mariners to plan ahead and significantly reduce the chance 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 graphics 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. In the future the update frequency is expected to increase to multiple updates per day. Currently, the ice chart graphics files have a size in the order of 100 kB to 1000 kB.

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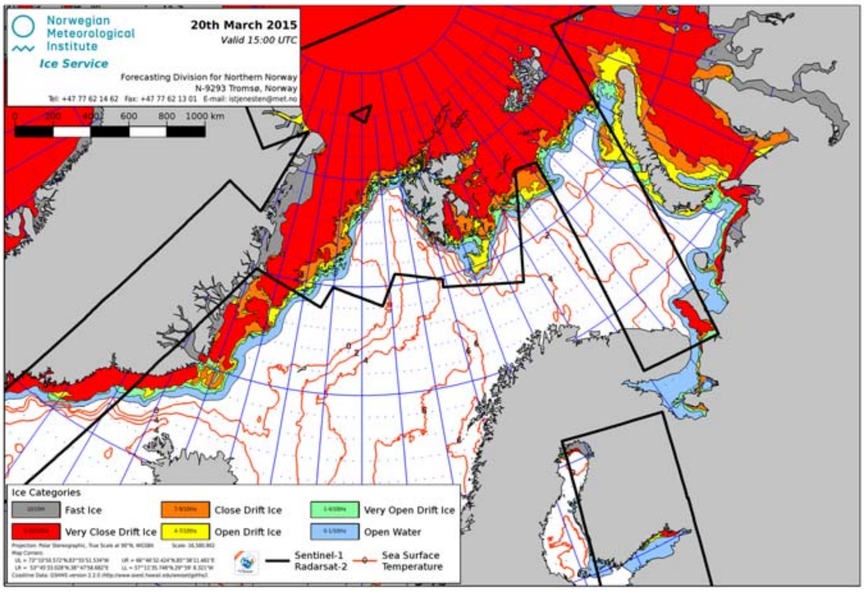
FIGURE 2-7

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. ~~It is estimated that it will be in the order of 10 kB to 100 kB.~~

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. ~~In the future~~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 ~~onboard~~on-board. ~~The service/information will typically be provided by a national Hydrographic or Meteorological Office, and should be available for free.~~

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

3.1 Spectrum requirement for the VDE - SAT

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-

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shore and shore-to-ship) in the shipborne VDES equipment, which 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

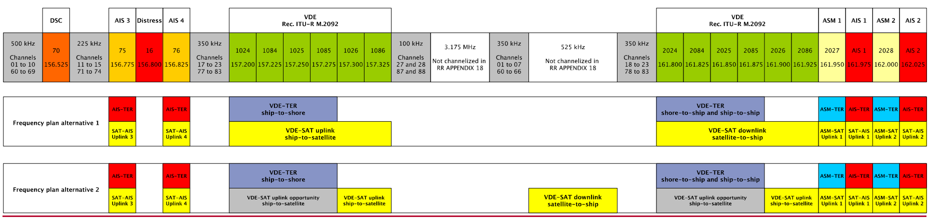
Note the organization and frequency use of RR Appendix 18, channelized in two sections of 25 kHz channels, a lower section with center frequencies at 156.025 MHz to 157.425 MHz and an upper section with center frequencies at 160.625 MHz to 162.026 MHz, spaced 4.6 MHz apart. The channels are numbered 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~~pfd mask to protect incumbent terrestrial services. Utilization of this band could provide a very robust satellite-to-ship service.

3.3 Frequency plan alternatives

The channels 24, 84, 25, 85, 26 and 86 are allocated for VDE after WRC-15, with the lower leg frequencies used for ship-to-shore and the upper leg frequencies used for shore-to-ship and ship-to-ship. The channels 2027 (ASM 1) and 2028 (ASM 2) are allocated for ASM. Currently, 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 VDES frequency utilization plans



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 four channels 1024, 1084, 1025 and 1085 are shared between ship-to-shore and ship-to-satellite (VDE-SAT uplink) services

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– The two channels 1026 and 1086 are exclusively reserved for ship-to-satellite (VDE-SAT uplink) services
– The four channels 2024, 2084, 2025 and 2085 are shared among shore-to-ship, ship-to-ship and satellite-to-ship (VDE-SAT downlink) services
– The two channels 2026 and 2086 are exclusively reserved for satellite-to-ship (VDE-SAT downlink) services.
– Two channels 2027(ASM 1) and 2028 (ASM 2) are shared between ship-to-shore, ship-to-ship, shore-to-ship and ship-to-satellite services

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 four channels 1024, 1084, 1025 and 1085 are reserved for ship-to-shore services, but ship-to-satellite (VDE-SAT uplink) services are possible without imposing constraints on ship-to-shore services
– The four channels 2024, 2084, 2025 and 2085 are reserved for shore-to-ship and ship-to-ship services, but ship-to-satellite (VDE-SAT uplink) services are possible without imposing constraints on shore-to-ship and ship-to-ship services
– The four channels 1026, 1086, 2026 and 2086 are exclusively reserved for ship-to-satellite (VDE-SAT uplink) services.
– Frequencies are exclusively reserved for satellite-to-ship (VDE-SAT downlink) services within the frequency range 160.9625 MHz to 161.4875 MHz, which is not channelized in RR Appendix 18
– Two channels 2027(ASM 1) and 2028 (ASM 2) are shared between ship-to-shore, ship-to-ship, shore-to-ship and ship-to-satellite services

4 Technical description of the VDE-SAT

4.1 Technical characteristics of the VDE-SAT Downlink in the VHF Maritime Mobile band

[Editorial note: ~~(~~new/updated Annex ~~to Rec. ITU-R M.2092TBD)~~*]*

~~4.1.1 Antenna noise levels on-board ships~~

4.2 Technical characteristics of the VDE-SAT Uplink in the VHF Maritime Mobile band

[Editorial note: ~~(~~new/update Annex to ~~Rec. ITU-R M.2092TBD~~*]*~~)~~

4.3 Resource sharing method for VDE-TER and VDE-SAT services

[Editorial note: new/update Annex ~~to Rec. ITU-R M.2092TBD~~]

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5 Interoperability and resource sharing with the terrestrial VDES and between VDES satellite systems

5.1 Resource sharing method for VDEES terrestrial -TER and satellite VDE-SAT services

The VDES resource assignment between the VDE-TER and the VDE-SAT services is outlined in Section 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 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 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 three alternative frequency plans and their implications on resource sharing between VDE-TER and VDE-SAT. Methods for resource sharing are also discussed in Section 4.3, thus further detail can be found there.

5.2 Resource sharing between multiple VDES satellite systems

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.

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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]

6.1 In-band interference

6.1.16 Fixed services in-band

6.1.2 Land and aeronautical mobile services in-band

[Editorial note: A PFDpfd mask was agreed upon during the previous study period. The studies leading up to that PFDpfd 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 has been imposed a pfd mask, as specified in Section 4, which was coordinated and agreed between all relevant ITU Study Groups. This pfd mask ensures that VDE-SAT downlink will not cause harmful interference to land and aeronautical mobile services.

6.2 Out-of-band interference

6.2.1 Maritime Distress and voice services (see Report ITU-R M.2371)

[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 4.6MHz frequency separation between VDE-SAT downlink and these services ensure that they can be protected from harmful interference.

6.2.2 Satellite AIS

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.

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In a system scenario where the VDE-SAT transmission and SAT-AIS reception are hosted on different satellites 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, 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 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 increase the detection of ships by SAT-AIS even if some AIS messages are lost to interference from VDE-SAT transmissions *[Editorial note: this effect should be studied]*. The time that a VDE-SAT satellite is within interference range of a SAT-AIS satellite will not be continuous, and in most circumstances limited to only a few minutes.

The co-location of SAT-AIS receiver and 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 the complexity of the on-board transceivers. However, also in this case, the high repetition rate for AIS transmissions from ships also increase the detection of ships by SAT-AIS even if some AIS messages are lost to interference from VDE-SAT transmissions *[Editorial note: this effect should be studied]*.

6.2.3 Radiolocation service in the 154-156 MHz band (See No 5.225A)

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6.2.3.1 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 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.

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

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Table 6-1 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

Radiolocation service systems characteristics

	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

Tableau mis en forme

	Radar A (narrow-band radar)	**Radar B (wideband radar)**
Duty cycle	0.322	
Modulation type	pulse	
Altitude above the ground level (m)	19	
Antenna type	Phased array	
Maximum antenna gain (dB) – transmitter – receiver	 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, degree – horizontal plane (Rx/Tx) – vertical plane (Rx/Tx)	 2.6/5.2 2.6/2.6	
Receiver noise temperature (K)	800	
Operational receiver passband (kHz) (−3 dB level)	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 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 to the technical characteristics of the radiolocation service as presented in Table 6-1, 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)

6.2.3.3 VDE-SAT downlink proposed power spectral and ~~PFD~~pfd mask

In Section 4.1 a power spectral and ~~PFD~~pfd mask is proposed for the VDE-SAT downlink in band signal. This mask is presented in Table 6-2.

TABLE 6-2

Proposed power spectral and ~~PFD~~pfd mask

$$\theta° = earth - satellite\ elevation\ angle$$

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

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

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6.2.3.4 VDE-SAT downlink out of band noise

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

TABLE 6-3

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

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

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

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

6.2.3.5 Conclusions

According to Section 7.4.6, the radiolocation service in the 154-156 MHz frequency band operates in an elevation span from 2-70 degrees. The interference ~~PFDpfd mask presented in Table 6-3 provide~~pfd mask presented in Table 6-3 provides a maximum interference ~~PFD~~pfd at 70 degrees of -239.0 dBW/(Hz*m^2). This is 3.7 dB below the protection criteria level calculated in Section 6.3.2.

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 will not cause harmful interference to the radiolocation service in the 154-156 MHz frequency band as it is characterized in Report ITU-R M.2172-1 and Recommendation ITU-R M1802-1.

6.2.4 Broadcasting service in the 162-164 MHz band

[Editorial note: See RR No 5.229] ~~(See No 5.229)~~

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

[Editorial note: See No 5.230 ~~(See No 5.230)~~]

~~6.6 Fixed service in-band~~

6.2.~~7~~6 Land and aeronautical mobile services ~~in-band and~~ in adjacent frequency bands ~~(154-164 MHz)~~

[Editorial note: A ~~PFD~~pfd mask was agreed upon during the previous study period. The studies leading up to that ~~PFD~~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]

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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 has been imposed a pfd mask, as specified in Section 4, which was coordinated and agreed between all relevant ITU Study Groups. This pfd mask ensures that VDE-SAT downlink will not cause harmful interference to land and aeronautical mobile services.

6.2.87 Radio astronomy out of band pfd mask

6.9 PFD limit calculations, averaging time, polarization, required signal characteristics

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

7.1 Link budget analysis for the VDE-SAT uplink

7.1.1 VDES ship terminal transmission characteristics

7.1.2 Propagation model

7.1.3 Noise level at VDE-SAT satellite receiver

7.1.24 Link budget simulations based on noise measurementsanalysis and link margin discussions

7.31.5 Performance degradation estimatesConclusions

7.42 Compatibility of a new VHF data exchange system (VDES) satellite component with radars operating in the frequency band 154-156 MHz

7.42.1 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 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 EIRP 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 frequency bands related to provisions of RR Appendix 18 contain no constrains imposed on 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 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.

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7.42.2 Characteristics of space surveillance radars operating in the 154-156 MHz

Table 7-1 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 7-1

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

Parameter	**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 (dB): – transmitter – receiver	 25 30	
Max antenna gain into horizon (dB)	9	12
Main beam pattern (degrees) – horizontal plane (Rx/Tx) – vertical plane (Rx/Tx)	 2.6/5.2 2.6/2.6	
Scan angle ranges (degrees): – horizontal plane – vertical plane	 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[1]	

[1] Values of unwanted emissions in the VDES receiver frequency band are described in section 6 herein.

7.42.3 Characteristics of VDES satellite link (ship-to-satellite)

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[2]. 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 EIRP as a function of elevation angle. Patterns for Yagi-antenna and Isoflux antenna are shown in Tables 7-3 and 7-4 accordingly. Satellite noise levels at the receiver front end are presented in Table 5. The system noise temperature is taken to be 25.7 dBK assuming no external interference.

TABLE 7-2

Minimum ship station EIRP vs. elevation angle

Ship elevation angle	Ship antenna gain	Minimum ship EIRP 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: Saturation mode operation requires EIRP by 3 dB as muchMultilevel 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).

2 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 M.2092-0, uses the waveforms defined in Table 7-5 for uplink. The thresholds C/N_0 and C/(N+I) on a Gaussian channel have been estimated.

TABLE 7-5

Estimated thresholds for the VDE-SAT 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 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 7-56

Characteristics of VDES 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 in 25 kHz bandwidth density	-158.9-202.9	dBW/Hz
Intrinsic noise power in 15042 kHz bandwidth	-1516.16	dBW
Required carrier-to-noise ratio (C/N)	TBD	dB
Required carrier-to-noise-plus-interference ratio (C/(N+I))	TBD-12.3	dB
Interference-to-noise protection ratio (I/N) with Isoflux antenna	11.9 (10.0)[-6][3]	dBdB
Interference-to-noise protection ratio (I/N) with Yagi antenna	20.8 (20.0)	dB

[Editorial note: Estimation of the link implementation feasibility as well as assessment of electromagnetic compatibility requires clarification of appropriate link carrier-to-noise (C/N) ratio and protection criteria, including maximum interference level potentially capable to destroy satellite receiver.]

7.42.4 Scenario of interference from unwanted emissions by radars operating in the frequency band 154-156 MHz on VDES 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.

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[3] Since currently a protection criterion has not been specified for the VDES satellite receiver it is proposed to use a commonly accepted interference-to-noise ratio (I/N) equal to minus 6 dB for that purpose.

FIGURE 7-1

Scenario of radar unwanted emission interference effect on VDES satellite receiver

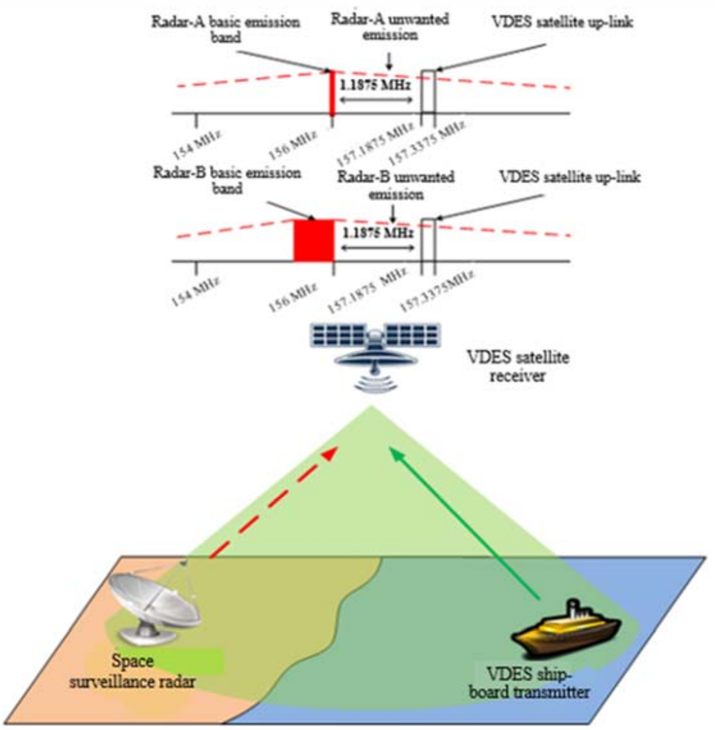

Figure 7-1 depicts scenario of effect caused by interference from space surveillance radar emissions on the VDES satellite receivers. A wanted signal from the ship transmitter is shown as a solid green arrow whereas interference from the space surveillance radar is reflected as a dashed red arrow.

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

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 EIRP in 42 kHz of -3.4 dBW

The obtained result meet 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.

A satellite with a VDES on-board receiver is in a circular orbit of 600 km in altitude. Interference-to-noise (I/N) and 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 vertical plane within angle sector of 2-70 degrees the estimation assumes that a receiving antenna onboard a satellite be aligned with the space surveillance radar main lobe. Table 7-7 and Table 7-8 show the resulting the I/N using the satellite isoflux antenna and the 8 dBi Yagi antenna as defined in M.2092-0. These calculations are worst case in that they assume that the radar and satellite antenna boresigths are aligned, a rare occurrence. It can be seen that the worst-case interference level is 11.9 dB above the noise level for the isoflux case. The worst case I/N for the Yagi is 20.8 dB for a radar elevation angle to the satellite of 40 degrees.

TABLE 7-7

Radar emissions into a 600 km LEO satellite using isoflux antenna.

Radar elevation angle	Radar peak EIRP in 50 kHz at 157 MHz	Polarisation loss	Path length	Path loss	Satellite antenna gain	Interference level at LNA, including feed loss	I/N0	I/N
deg	dBW	dB	km	dB	dBi	dBW	dBHz	dB
0,0	-3.4	3.0	2830.0	145.4	2.0	-150,9	52,0	5,8
10.0	-3.4	3.0	1932.0	142.1	1.5	-148,0	54,8	8,6
20.0	-3.4	3.0	1392.0	139.3	1.0	-145,7	57,2	10,9
30.0	-3.4	3.0	1075.0	137.0	-0.5	-145,0	57,9	11,7
40.0	-3.4	3.0	882.0	135.3	-2.0	-144,7	58,1	11,9
50.0	-3.4	3.0	761.0	134.0	-4.0	-145,5	57,4	11,2
60.0	-3.4	3.0	683.0	133.1	-5.0	-145,5	57,4	11,1
70.0	-3.4	3.0	635.0	132.4	-7.0	-146,9	56,0	9,8
80.0	-3.4	3.0	608.0	132.1	-8.0	-147,5	55,4	9,1
90.0	-3.4	3.0	600.0	131.9	-8.5	-147,9	55,0	8,7

TABLE 7-8

Radar emissions into a 600 km LEO satellite using 8 dBi Yagi antenna.

Radar elevation angle	Radar peak EIRP in 50 kHz at 157 MHz	Polarisation loss	Path length	Path loss	Satellite antenna gain	Interference level at LNA, including feed loss	I/N0	I/N
deg	dBW	dB	km	dB	dBi	dBW	dBHz	dB
0.0	-3.4	3.0	2830.0	145.4	8.0	-144,9	58,0	11,8
10.0	-3.4	3.0	1932.0	142.1	8.0	-141,5	61,3	15,1
20.0	-3.4	3.0	1392.0	139.3	8.0	-138,7	64,2	17,9
30.0	-3.4	3.0	1075.0	137.0	7.8	-136,7	66,2	20,0
40.0	-3.4	3.0	882.0	135.3	6.9	-135,8	67,0	20,8
50.0	-3.4	3.0	761.0	134.0	5.5	-136,0	66,9	20,7
60.0	-3.4	3.0	683.0	133.1	3.6	-136,9	66,0	19,7
70.0	-3.4	3.0	635.0	132.4	0.7	-139,2	63,7	17,5
80.0	-3.4	3.0	608.0	132.1	-2.2	-141,7	61,2	14,9
90.0	-3.4	3.0	600.0	131.9	-5.5	-144,9	58,0	11,7

7.42.56 Estimation of link budget for VDES up-link with a satellite receiver in a 600 km altitude orbit

Tables 7-6 9 and 7-7 10 presents estimates worst caseof link budgets for VDES up-link with a satellite receiver in a 600 km altitude orbit using Yagi Isoflux and Isoflux Yagi antennas accordingly assuming 6 W ship station transmitter and the interference level from unwanted emissions by radars operating in the frequency band 154-156 MHz as calculated in Table 7-7 and Table 7-8.

Table 7-9 and Table 7-10 show that formats 1 and 2 will ensure link availability with substantial margins under the worst case radar interference condition for ship elevation angles up to 80 degrees, Format 3 will be available for ship elevation angles up to 60 degrees and Formats 4 and 5 will require additional discrimination or mitigation techniques. Table 7-11 summaries a few potential discrimination factors and mitigation techniques..

[Editorial note: Estimation of the link implementation feasibility requires defining a necessary link carrier-to-noise (C/N) ratio with subsequent calculation of link budget.]

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TABLE 7-69

Worst-case Llink budget for VDE-SAT uplink with 6 W ship transmitter, and YagiIsoflux satellite receiving antenna and interference from unwanted emissions by radars.

Ship elevation angle	Ship antenna gain	Ship EIRP	Polarization loss	Path length	Path loss	Satellite antenna gain	Carrier level at LNA, including feed loss	C/N0	C/N	I/N	C/(I+N)
deg	dBi	dBW	dB	km	dB	dBi	dBW	dBHz	dB	dB	dB
0,0	3,0	10,8	3,0	2830,0	145,4	2,0	-136,6	66,2	20,0	11,9	7,8
10,0	3,0	10,8	3,0	1932,0	142,1	1,5	-133,8	69,0	22,8	11,9	10,6
20,0	2,5	10,3	3,0	1392,0	139,3	1,0	-132,0	70,9	24,7	11,9	12,5
30,0	1,0	8,8	3,0	1075,0	137,0	-0,5	-132,7	70,1	23,9	11,9	11,7
40,0	0,0	7,8	3,0	882,0	135,3	-2,0	-133,5	69,4	23,1	11,9	11,0
50,0	-1,5	6,3	3,0	761,0	134,0	-4,0	-135,7	67,1	20,9	11,9	8,7
60,0	-3,0	4,8	3,0	683,0	133,1	-5,0	-137,3	65,6	19,3	11,9	7,2
70,0	-4,0	3,8	3,0	635,0	132,4	-7,0	-139,7	63,2	17,0	11,9	4,8
80,0	-10,0	-2,2	3,0	608,0	132,1	-8,0	-146,3	56,6	10,4	11,9	-1,8
90,0	-20,0	-12,2	3,0	600,0	131,9	-8,5	-156,7	46,2	0,0	11,9	-12,2

Ship elevation angle	**Ship antenna gain**	**Ship EIRP**	**Path loss**	***C/N*, in 25-kHz channel**	***C/N*, in 150-kHz channel**
degrees	**dBi**	**dBW**	**dB**	**dB**	**dB**
0	3	10.8	145.56	29.14	21.34
10	3	10.8	142.25	32.45	24.65
20	2.5	10.3	139.40	34.8	27
30	1	8.8	137.16	35.34	27.54
40	0	7.8	135.44	35.16	27.36
50	-1.5	6.3	134.16	33.54	25.74
60	-3	4.8	133.22	31.08	23.28
70	-4	3.8	132.58	27.82	20.02
80	-10	-2.2	132.21	19.29	11.49
90	-20	-12.2	132.09	6.11	-1.69

TABLE 7-710

Worst-case Llink budget for VDE-SAT uplink with 6 w ship transmitter, and IsoflexYagi satellite receiving antenna and interference from unwanted emissions by radars.

Ship elevation angle	Ship antenna gain	Ship EIRP	Polarization loss	Path length	Path loss	Satellite antenna gain	Carrier level at LNA, including feed loss	C/N0	C/N	I/N	C/(I+N)
deg	dBi	dBW	dB	km	dB	dBi	dBW	dBHz	dB	dB	dB
0,0	3,0	10,8	3,0	2830,0	145,4	8,0	-130,6	72,2	26,0	20,8	5,2
10,0	3,0	10,8	3,0	1932,0	142,1	8,0	-127,3	75,5	29,3	20,8	8,5
20,0	2,5	10,3	3,0	1392,0	139,3	8,0	-125,0	77,7	31,7	20,8	10,8
30,0	1,0	8,8	3,0	1075,0	137,0	7,8	-124,4	78,4	32,2	20,8	11,4
40,0	0,0	7,8	3,0	882,0	135,3	6,9	-124,6	78,3	31,2	20,8	11,2
50,0	-1,5	6,3	3,0	761,0	134,0	5,5	-126,2	76,6	30,4	20,8	9,6
60,0	-3,0	4,8	3,0	683,0	133,1	3,6	-128,7	74,2	27,9	20,8	7,1
70,0	-4,0	3,8	3,0	635,0	132,4	0,7	-132,0	70,9	24,7	20,8	3,8
80,0	-10,0	-2,2	3,0	608,0	132,1	-2,2	-140,5	62,4	16,2	20,8	-4,7
90,0	-20,0	-12,2	3,0	600,0	131,9	-5,5	-153,7	49,2	3,0	20,8	-17,9

Ship elevation angle	Ship antenna gain	Ship EIRP	Path loss	C/N, in 25 kHz channel
degrees	dBi	dBW	dB	dB
0	3	10.8	145.56	23.14
10	3	10.8	142.25	25.95
20	2.5	10.3	139.40	27.8
30	1	8.8	137.16	27.04
40	0	7.8	135.44	26.26
50	-1.5	6.3	134.16	24.04
60	-3	4.8	133.22	22.48
70	-4	3.8	132.58	20.12
80	-10	-2.2	132.21	13.49
90	-20	-12.2	132.09	3.11

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TABLE 7-11

Summary of a few potential discrimination factors and mitigation techniques for VDE-SAT uplink against interference from unwanted emissions by radars.

Factor	Description	Effect
Range	Radars more than 2800 km from sub-satellite point 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 1863 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. This reduce the interference level down from the worst case situation.
Yagi antenna isolation	The Yagi antenna provides discrimination when pointed away from the radar	Figure 7-2 shows typical Yagi isolation of 10 dB, 60 degrees off boresight and 20 dB 75 degrees off boresight

FIGURE 7-2

Typical Yagi gain pattern as a function of boresight offset angle.

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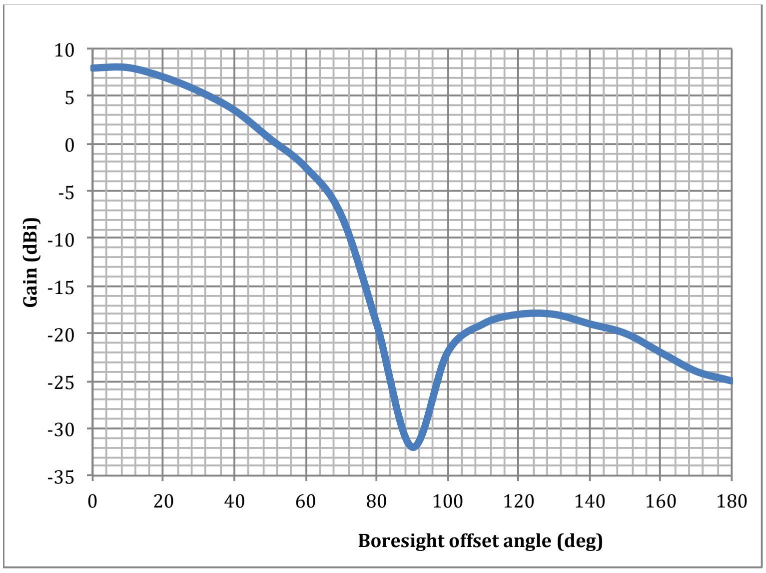


7.2.8 Potential for burnout and blocking of the VDE-SAT receiver caused by unwanted emissions from the radar

Erreur ! Source du renvoi introuvable. Table 7-12 and Table 7-13 show the radar levels at the antenna for both the isoflux and Yagi antennas, with peak output EIRP 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 7-12

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

Elevation angle	Radar EIRP	Polarisation loss	Range	Pathloss	Satellite antenna gain	Received signal level
Degrees	dBW	dB	km	dB	dBi	dBW
0	71,0	3,0	2830,0	-145,3	2,0	-76,3
10	71,0	3,0	1932,0	-142,0	1,5	-73,5
20	71,0	3,0	1392,0	-139,2	1,0	-71,2
30	71,0	3,0	1075,0	-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 7-13

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

Elevation angle	Radar EIRP	Polarization loss	Range	Pathloss	Satellite antenna gain	Received signal level
deg	dBW	dB	km	dB	dBi	dBW
0,0	71,0	3,0	2830,0	-145,3	8,0	-70,3
10,0	71,0	3,0	1932,0	-142,0	8,0	-67,0
20,0	71,0	3,0	1392,0	-139,2	8,0	-64,2
30,0	71,0	3,0	1075,0	-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

7.4.6 Estimation of effect by radar unwanted emissions on VDES satellite receivers

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.

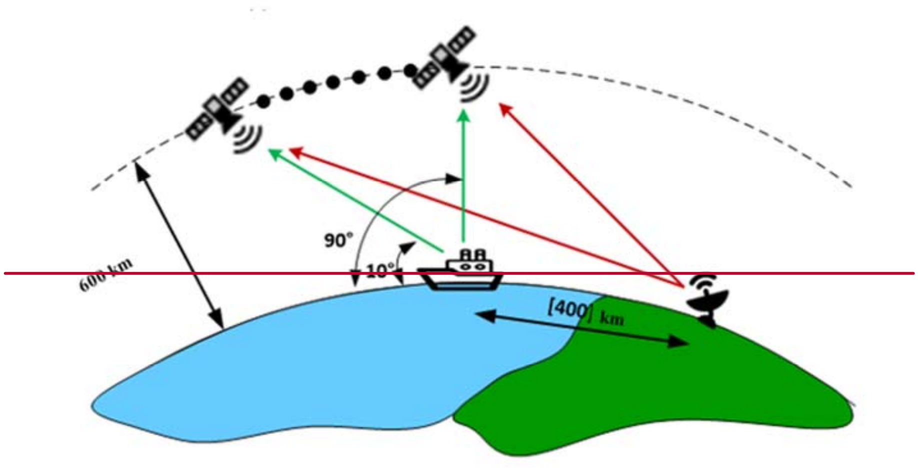
The obtained result meet the RR Appendix ***3*** *provisions for spurious emissions as specifying that for radars of the given type the level power delivered to the antenna feed shall not exceed minus 21.3 dBW in 77 Hz reference band.*

Radar B unwanted emissions level is a function of modulation parameters. For Radar B signal characteristics shown in Table the value of its unwanted emissions would be [TBD] dBW.

For estimation of effect caused by space surveillance radar unwanted emissions on the VDES satellite receivers the scenario shown in Figure 2 was addressed.

FIGURE 2

Scenario of radar unwanted emission interference effect on VDES satellite receiver



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A satellite with a VDES on-board receiver is in a circular orbit of 600 km in altitude. A VDES ship-borne transmitting station and a radar are separated by [400] km. Interference-to-noise (I/N) and carrier-to-interference (C/I) ratios are estimated using satellite elevation angle step of 10 degrees for the angles of satellite visibility by the ship station from 10 to 90 degrees corresponding to appropriate angles of satellite visibility by the radar from 5 to 53 degrees. Since space surveillance radar scans in vertical plane within angle sector of 2-70 degrees the estimation assumes that a satellite receiving antenna would fall into a space surveillance radar main lobe.

[TBD]

[Editorial note: Results of estimating the carrier-to-interference ratio at the satellite receiver front end would be presented on having agreed the scenario shown in Fig. 2.]

7.42.79 Conclusions

[TBD]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 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.

[Editorial note: Estimation of effect caused by space surveillance radar unwanted emissions on VDES satellite receivers would require clarification of relevant satellite link parameters including a protection criterion and a maximum acceptable interference level potentially capable of destroying the satellite receiver.]

8 Testing, demonstrations and measurements

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.]

9.1 NorsatNORSAT-2 (ESA VDE-SAT downlink verification planned H1 2017)

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 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 will be used as reference, for 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. 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.

9.2 Uplink measurements campaigns?

9.3 Global spectrum sweeps for interference mapping?

9.4 Two-way test/demo VDE-SAT system including protocols?

9.52 Efficiensea 2 coordination

EfficienSea2 is a European Community project for a safer and more efficient waterborne operation through new technologies and smarter traffic management. This project, which is planned for a 3-year period from mid-2015 to mid-2018, 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. Taking into account the radio technical standards and specifications under construction at IALA and the resolution adopted in November 2015 by ITU during the WRC15, 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. EfficienSea 2 also intends to coordinate the terrestrial VDES activities with satellite VDES activities that are fortunately also envisaged during the same period of time. 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

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activities and the EfficienSea 2 terrestrial VDES actors will permit to include the satellite VDES downlink component into the testbed.

9.6 Other test satellites planned?

9.7 Norsat 2 and other satellites sharing?

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Page 28 : [51] Mis en forme	Auteur

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Page 28 : [52] Mis en forme	Auteur

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Page 28 : [56] Mis en forme	Auteur

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