**Technical Guidelines for VDES Implementation**

1. **The History of Data Transmission in the VHF Marine Band**

The VHF marine band (Appendix 18 of the International Radio Regulations) was initially used for transmission of voice communications by FM (frequency modulation of the carrier) on 25 kHz channels, which is the most-inefficient means of communications in the international maritime service because voice speech is slow and lacks intelligibility, especially with varying languages and accents in the noisy marine radio environment. For this reason, the ITU (International Communications Union) introduced the first marine data transmission system, DSC (Digital Selective Calling) in accordance with Recommendation ITU-R M.493, to help ensure that calling and distress communications attempts were successful. VHF DSC transmits data at 1200 bits per second using digital two-tone FSK modulation, slow by modern data standards, but very robust. At the request of the IMO (International Maritime Organization), to improve safety of navigation, ITU introduced another VHF data transmission system, the AIS (Automatic Identification System) in accordance with Recommendation ITU-R M.1371, which provides navigation and identification data for ships, shore stations, aids to navigation and search and rescue devices at 9600 bits per second using digital GMSK modulation. At the request of some Administrations, to improve spectrum efficiency for VHF Data Exchange (VDE), ITU introduced a standard, Recommendation ITU-R M.1842, with options for 25 kHz, 50 kHz and 100 kHz channels at data rates up to 307.2 kbps using digital modulation waveforms that had been proven by ETSI (European Technical Standards Institute). Appendix 18, in its current revision by the World Radio Conference 2012 (WRC-12), approves all three data transmission methods in accordance with the approved ITU standards (Recommendations ITU-R M.493, M.1371 and M.1842) and designates channels for their use. Consequentially, both voice and data communications now coexist in the VHF marine band.

1. **The Introduction and Purpose for the VDES (VHF Data Exchange System)**

In the May 2013 meeting of ITU-R Working Party 5B (WP5B), several Administrations and IALA introduced and proposed the concept of VDES, which is intended to address AIS VDL loading problems, future data communications requirements identified by IMO and agreed agenda items for the future WRC-15 and WRC-18. The VDES was envisioned to operate as an integrated system (to include AIS, Application Specific Messages (ASM) and VHF Data Exchange (VDE), in ship-ship and ship-shore communications, including satellite uplink and downlink) that would utilize the resources and provisions of Appendix 18 and the applicable ITU standards. WP5B agreed, sent affirmative liaison statements to IMO, IALA and other affected ITU-R Working Parties and produced working documents on VDES to carry forward to its next meeting in November 2013.

1. **Technical Considerations for Successful VDES Implementation**

It should be noted that the ITU standards for data transmission in Appendix 18 identify the specific channels for data transmission and specify the timing of and maximum time durations for data transmissions. This level of specificity, e.g., the selection of the channels, the timing for the transmissions and the maximum durations of the transmissions, etc., is needed to preserve the integrity of both the data service and the other services in Appendix 18, including the GMDSS. Noting that AIS, DSC and voice communications have been successfully operating in Appendix 18 along with the GMDSS for many years, it is expected that VDES will also be successful if it is implemented in accordance with ITU standards. For example, the current working document toward a preliminary draft revision of Recommendation ITU-R M.1842-1 provides a draft new Annex 5 to specify the channel access scheme, transmission timing and maximum transmission duration on the channels specified for VDE in Appendix 18. These specifications are designed to ensure that GMDSS VHF voice radio communications[[1]](#footnote-1), DSC calls[[2]](#footnote-2) and DSC distress alerts[[3]](#footnote-3) are successful during VDES transmissions. To mitigate consequential instantaneous receiver desensitization from each opposite VHF transmitter, it is important to follow the installation guidelines provided by IMO, e.g., COMSAR/Circ.32 for antenna installations. For example, one manufacturer who supplies both GMDSS VHF voice radios and AIS specifies a minimum separation of 4m vertical distance between the two VHF antennas at the same horizontal position or more than 17m separation when the antennas are at the same horizontal level, which provides about 41 dB of isolation between the two VHF antennas. By contrast, a separation of only 1.5m provides only 20 dB of isolation.

1. **Selection and Use of Frequencies for VDES**

At its meeting in May 2013 (Document 5B/304, Annex 5, Section 3/1.16/3.3), WP5B provided the following description and selection of frequencies for VDES.

VHF data exchange system (VDES) considers both WRC-15 Agenda item 1.16 and WRC-12 revisions to RR Appendix 18, including both terrestrial and satellite components, which address the need to protect the integrity of the AIS VDL by moving AIS applications and ASM to other channels and the designation of some of the duplex channels previously designated for VHF public correspondence (VPC) for digitally modulated emissions in accordance with Recommendation ITU‑R M.1842 (which describes VDE). The VDES integrates the functions of AIS, ASM and VDE and includes the channels used for these functions. A possible arrangement of the globally available channels and functional designated usage is shown in Table 1.

**Table 1**

Example channel designations

Appendix 18 channels and frequencies for the VHF data exchange system (AIS, ASM and VDE)

|  |  |  |
| --- | --- | --- |
| Channel number in RR Appendix 18 | Transmitting frequencies (MHz) for ship and coast stations | |
| Ship stations (ship-to-shore)  (long range AIS)  Ship stations (ship-to-satellite) | Coast stations  Ship stations (ship-to-ship)  Satellite-to-ship |
| AIS 1 | 161.975 | 161.975 |
| AIS 2 | 162.025 | 162.025 |
| 75 (long range AIS) | 156.775 (ships are Tx only) | N/A |
| 76 (long range AIS) | 156.825 (ships are Tx only) | N/A |
| 2027 (ASM 1) | 161.950 (2027) | 161.950 (2027) |
| 2028 (ASM 2) | 162.000 (2028) | 162.000 (2028) |
| 24/84/25/85 (VDE 1)  24  84  25  85 | 25/100 kHz channel  (24/84/25/85, lower legs, merged)  Ship to shore  Ship to satellite | 25/100 kHz channel  (24/84/25/85, upper legs, merged)  Ship to ship, Shore to ship  Satellite to ship under certain conditions |
| 157.200 (1024) | 161.800 (2024) |
| 157.225 (1084) | 161.825 (2084) |
| 157.250 (1025) | 161.850 (2025) |
| 157.275 (1085) | 161.875 (2085) |
| 26/86 (SAT 1/VDE 2)  26  86 | 25/50 kHz channel  (26/86, lower legs, merged)  Ship to satellite/shore | 25/50 kHz channel  (26/86, upper legs, merged)  Satellite/shore to ship |
| 157.300 (1026) | 161.900 (2026) |
| 157.325 (1086) | 161.925 (2086) |

Additionally it is noted that more channels are available in some Regions, see RR Appendix **18** footnotes w, x, y. An example of the possible utilization of these channels is given in Table 2.

**Table 2**

**VHF data exchange – table of regional frequencies (MHz)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Regional VDE (Regions 1 and 3)** | | | | | | |
| Ship transmit | 1080  157.025 | 1021  157.050 | 1081  157.075 | 1022  157.100 | 1082  157.125 | 1023  157.150 | 1083  157.175 |
| Ship received | 2080  161.625 | 2021  161.650 | 2081  161.675 | 2022  161.700 | 2082  161.725 | 2023  161.750 | 2083  161.775 |
|  | Can be used separately and/or as 50 kHz channel(s) or as one 100 kHz channel | | | |  | Can be used separately or as one 50 kHz channel | |
| NOTE – The VHF channels shown above are a contiguous set in RR Appendix **18**. They comprise a contiguous frequency block, and thus are amenable to protection by a single selective filter in the receiver. | | | | | | |

The various functionalities of VDES and their uses by ships, shore stations and satellites are illustrated pictorially in Figure 1. Note the channel usages have some suggested alternative examples, beyond those designated in Table 1, which have been considered.

**FIGURE 1**

**VDES Functions and Frequency Usage (with channel use options beyond Table 1)**

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Note from Figure 1 that the AIS-VDE ship receiving range is 161.800-162.025 MHz, which includes channels 2024 to AIS2. This arrangement makes it possible to prevent VDES receiver blocking from the VHF voice radio transmitter by means of a bandpass filter at the input of the VDES receiver (Figure 2).

**IMPORTANT FOR ADMINISTRATIONS TO CONSIDER:** The plan to protect the VDES receiver with a bandpass filter is potentially conflicted (in the future) by the WRC-12 revision of Appendix 18 in which the four simplex channels 2078, 2019, 2079 and 2020 were added (covering the range of 161.525-161.600 MHz), which would permit ship borne VHF voice radios to transmit on the upper side of the 4.6 MHz separation shown in Figure 1. Historically, marine VHF ship borne voice radios were not permitted to transmit above 157.425 MHz. Voice communications on these channels will block AIS because of their long duration, while properly interleaved data will have a minimal impact. Administrations who are concerned about this potential impact on the AIS should consider proposals for appropriate revision of Appendix 18 by the WRC-15.

1. **An Example VDES Internal Architecture**

It may not be necessary to have a single box solution, however an example of a single box architecture (to support Table 1) is shown below in Figure 2. Note that the VDES is protected from receiver blocking by the 161.800-162.025 MHz bandpass filter.

**FIGURE 2**

**Example VDES Functional Diagram**



It should be noted that the AIS-VDE transmitter will need to be designed to support the complex waveforms used in Recommendation ITU-R M.1842-1, e.g., QAM waveforms have peak-to-average power ratios of over 10 dB. To minimize the receiver desensitization effects on the VHF voice radio from the VDES transmitter broadband noise floor, the power level in the resonant circuit of the VDES transmitter frequency source, e.g., the Tx VCO, should be as high as practical, e.g., a power level of +10 dBm or higher is recommended.

1. **Analysis of Signal Levels Between VDES and VHF Voice Radios**

Figure 3 is a graphical representation of the transmission spectrum of a typical VHF marine voice radio transmitter, referred to the antenna connector of the radio, based on measurements taken from several manufacturers of these radios. Note that the power level at the VDES antenna connector will have to account for transmission losses in the antenna cables, isolation between the VDES antenna and the VHF radio antenna, and must also consider the different frequencies of interest between the VDES and the VHF radio transmitter. Table 3 shows the power levels delivered to the VDES (Figure 2) from the VHF marine voice radio transmitter (Figure 3). This table illustrates the need for the protection of the VDES receiver with the bandpass filter (which is absent in the current AIS) and for the installation of the two VHF antennas to achieve the highest practical isolation. Note that protection of the VDES is considered here and is achieved in this manner because voice communications by the VHF voice radio require it to be keyed for much longer duration than the VDES, whereas protection of the VHF voice radio from the VDES is achieved by controlling the timing and maximum durations of the VDES transmissions. The duty cycle of each transmitter should be low to support a large population sharing the same data link and minimizing the interference on voice communications.

**FIGURE 3**

**Typical VHF Marine Voice Radio Transmitter**

**Power, Spurious and Noise Levels**



Note: The noise floor levels are typical for radios currently in production. Some installed radios may be 10-20 dB better.

**TABLE 3**

**Power Levels Delivered to the VDES (ref. FIGURE 2)**

**From the VHF Radio Transmitter (ref. FIGURE 3)**

|  |  |  |  |
| --- | --- | --- | --- |
| **VHF Tx Output** | **Antenna**  **Isolation** | **VDES Input**  **(2 cable losses = 3db)** | **VDES Rx Input**  **(Rx Filter = 40dB/2dB)** |
| **+44 dBm**  **@157.4 MHz** | **20 dB** | **+21 dBm** | **-19 dBm** |
| **+44 dBm**  **@157.4 MHz** | **41 dB** | **0 dBm** | **-40 dBm** |
| **-66 dBm**  **@162.0 MHz** | **20 dB** | **-89 dBm** | **-91 dBm** |
| **-66 dBm**  **@162.0 MHz** | **41 dB** | **-110 dBm** | **-112 dBm** |
| **-71 dBm**  **@162.0 MHz** | **20 dB** | **-94 dBm** | **-96 dBm** |
| **-71 dBm**  **@162.0 MHz** | **41 dB** | **-115 dBm** | **-117 dBm** |

1. **Conclusion**

ITU has recognized the efficiency and the necessity for digital communications, has produced technical standards and has revised the VHF marine band (RR Appendix 18) to designate channels for data transmission. It is recognized that both analog voice communications and digital communications will share the band. This document illustrates how the design and installation of the new VDES (Figure 1) should address the compatibility and interoperability of both systems. The VDES, as envisioned by IALA and presented to ITU, addresses the identified need to protect AIS along with essential digital communications contributions for e-Navigation and GMDSS Modernization.

1. Report ITU-R M.2169 refers to a study of the effects of data burst transmissions on voice radio communications which concludes that the consequential loss of intelligibility of human speech is tolerable if the frequency of occurrence and the length of the data bursts are appropriately limited, e.g., as in AIS. Considering the successful implementation of AIS in the VHF marine radio environment, similar timing limits to AIS are proposed for VDES. [↑](#footnote-ref-1)
2. DSC calls are repeated if they are not acknowledged, since it is understood that a single call may be blocked. [↑](#footnote-ref-2)
3. DSC distress alerts are repeated until acknowledged. Each transmission is 1500ms long and contains five repetitions of the DSC distress call. [↑](#footnote-ref-3)