Input paper: [[1]](#footnote-1) ENAV20-11.19

Input paper for the following Committee(s): check as appropriate Purpose of paper:

**□** ARM **□** ENG **□** PAP **□** Input

**x** ENAV  **□** VTS **x** Information

Agenda item [[2]](#footnote-2) 11

Technical Domain / Task Number 2 …………………………………

Author(s) / Submitter(s) Korean Register of Shipping

VDE Spectrum Mask Analysis

# Summary

We need to analyse the spectrum mask requirements for VDE shore station in terms of the frequency plan which is recommended in ITU-R M.2092 [Ref 1]. In this report, the Spectrum Mask Recommendation for the VDE shore to ship frequency channel is analysed and the IMD characteristics affecting the transmission spectrum are simulated in designing the actual VDE shore station transmitter

The transmitter output is designed to have a constant back-off characteristic in consideration of the PAPR characteristics. For example, the VDE 100kHz channel has 16QAM modulation characteristics, so it is necessary to select the FET of the final amplifier to have a maximum back-off of 7dB.

In this case, the IMD characteristic that can be obtained from the transmitter output is about max. -40dBc. But it does not satisfy the spectrum mask standard proposed in Recommendation ITU-R M.2092, therefore the linearizer must be applied to the transmitter in order to satisfy the specifications.

This report is not described about the type and technical structure of linearizer in detail.

## Purpose of the document

This report analyses the Spectrum Mask specification of Recommendation ITU-R M.2092 and identifies the spectrum mask characteristics in a general transmitter structure by simulation to propose the basic structure of VDE for shore to ship and ship to ship communication.

.

## Related documents

* [Ref 1] ITU-R M.2092
* Review ENAV19 20160922 v0 WD\_WG3\_Item110\_REC-M.

# Background

The frequency channel assignment of VDES is recommended in Recommendation ITU-R M.2092 as follows.



Figure 1. VDES Frequency Allocation plan

As shown in the frequency allocation plan in Figure 1, the VDE1-B channel of VDE shore to ship and ship to ship has four channels with a 25 kHz bandwidth, and the AIS and ASM channels have two channels each with a 25 kHz bandwidth. There are various methods for resolving the interference problem in system operation by allocating the frequency continuously without any separation between the channels.

The VDE1-B channel can be used in the 25kHz, 50kHz, and 100kHz bands, and the modulation methods are QPSK, 8PSK, and 16QAM. In the ITU-R M.2092, the spectral mask according to the bandwidth of each transmitter power of VDES is recommended as shown in the table 1, and an analysis report on spectrum mask according to the recommendation are still being proposed for discussion.

|  |  |  |
| --- | --- | --- |
| Transmitter parameters | Requirements | Condition |
| Frequency error | 3 ppm | normal |
| Maximum transmit power capability | For ship stations: Transmit average power should be at least 1 watt and not exceed 25 watts at the transmitter output.  For shore stations: Transmit average power should be at least 12.5 watt and not exceed 50 watts at the base of the antenna.  ±1.5 dB normal, +2/−6 dB extreme | Conducted |
| Maximum adjacent power levels for 25 kHz channel | 0 dBc  −25 dBc  −60 dBc | Δfc < ±12.5 kHz  ±12.5 kHz < Δfc < ±25 kHz  ±25 kHz < Δfc < ±75 kHz |
| Maximum adjacent power levels for 50 kHz channel | 0 dBc  −25 dBc  −60 dBc | Δfc < ±25 kHz  ±25 kHz < Δfc < ±50 kHz  ±50 kHz< Δfc < ±100 kHz |
| Maximum adjacent power levels for 100 kHz channel | 0 dBc  −25 dBc  −60 dBc | Δfc < ±50 kHz  ±50 kHz < Δfc < ±100 kHz  ±100 kHz < Δfc < ±150 kHz |
| Spurious emissions | −36 dBm  −30 dBm | 9 kHz to 1 GHz  1 GHz to 4 GHz |

Table 1. VDES Transmitter Specification



Figure 2. Maximum Adjacent Power level for VDE Channels 25KHz

# Intermodulation distortion

In order to satisfy the maximum adjacent power levels recommended in ITU-R M.2092, it is necessary to analyse the characteristics of intermodulation distortion (IMD) occurring in the transmitter. To analyse the inter-modulation characteristics, we use the output signal analysis method for a typical two-tone signal input.

## Two-Tone Analysis

As mentioned above, the VDE channel operates on 25kHz, 50kHz and 100kHz channels, where the frequency characteristics of the output IMD are analyzed through a two-tone signal analysis for the 100kHz channel.

For example, comparing the two-tone input signal with the output signal from amplifier for the VDE1-B channel, we can see the IMD components at the frequency separated by the left and right channel bandwidth of the input signal.

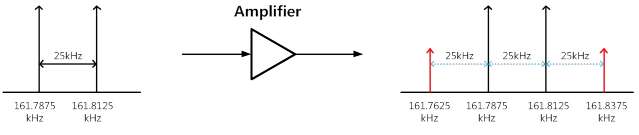


Figure 3. VDE 25kHz Channel Two-tone analysis

As a result of the above two-tone signal analysis, the IMD output characteristic by the amplifier has the following characteristics for the signal having a channel bandwidth of 25 kHz.

Figure 4. VDE 25kHz Channel Bandwidth IMD analysis

The output IMD characteristic of a signal with a channel bandwidth of 25 kHz appears as shown above. So we conclude that some of the output IMD components should be less than -60dBc by overlapping the maximum adjacent power levels per VDE channel in Figure 2 and the output IMD graph in Figure 4.



Figure 5. Spectrum Mask VS IMD analysis result

## Spectrum Analysis

Here we simulate the modulation scheme of the VDE signal defined in ITU-R M.2092 and the spectral waveform of the signal output from the modem according to the symbol rate.

And as this signal passes through the RF Transmitter, the output spectrum waveform from the RF Transmitter can derive the structure and performance specifications of the RF transmitter to meet the Spectrum Mask Specification defined in ITU-R 2092.

The modulation scheme of the VDE signal and the symbol rate are summarized in the table 2 as below.

|  |  |  |  |
| --- | --- | --- | --- |
| Channel Bandwidth | Modulation | Symbol Rate | Roll-off |
| 25kHz | PI/4QPSK | 19.2 ksps | 0.3 |
| 50kHz | 8PSK | 38.4 ksps |
| 100kHz | 16QAM | 76.8 ksps |

Table 2. VDE signal characteristic

Assuming that the IF frequency output from the modem is 70MHz, the below is the simulation result of each spectrum.

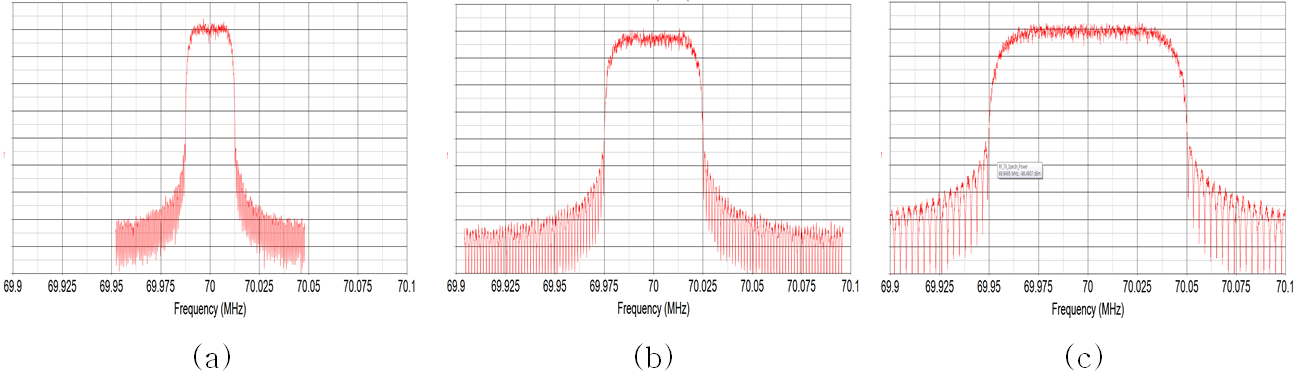
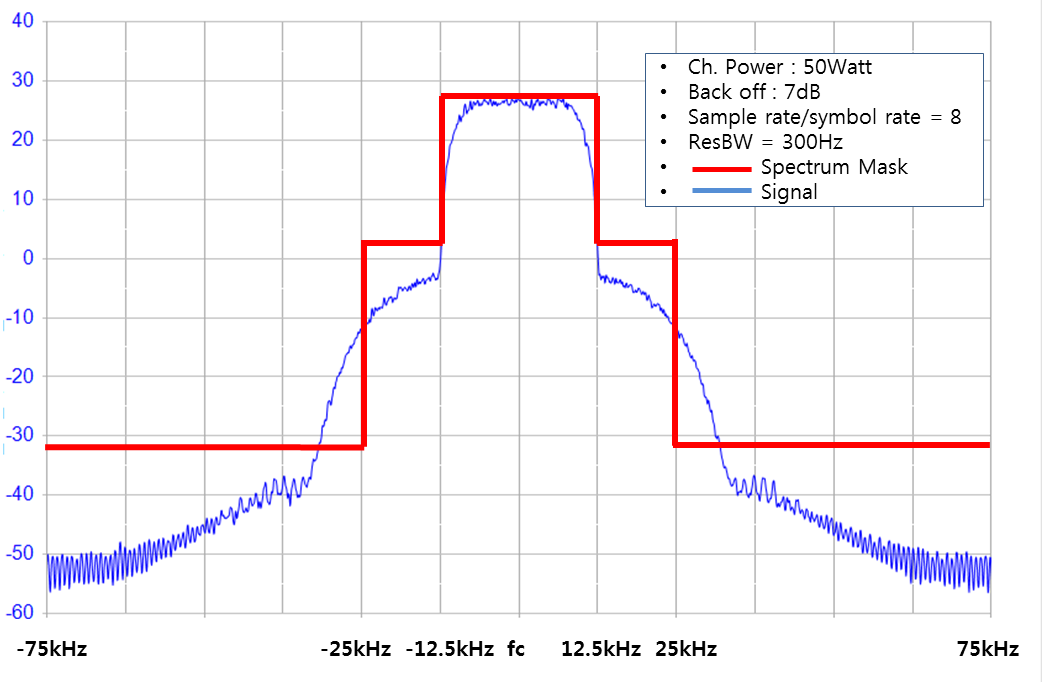
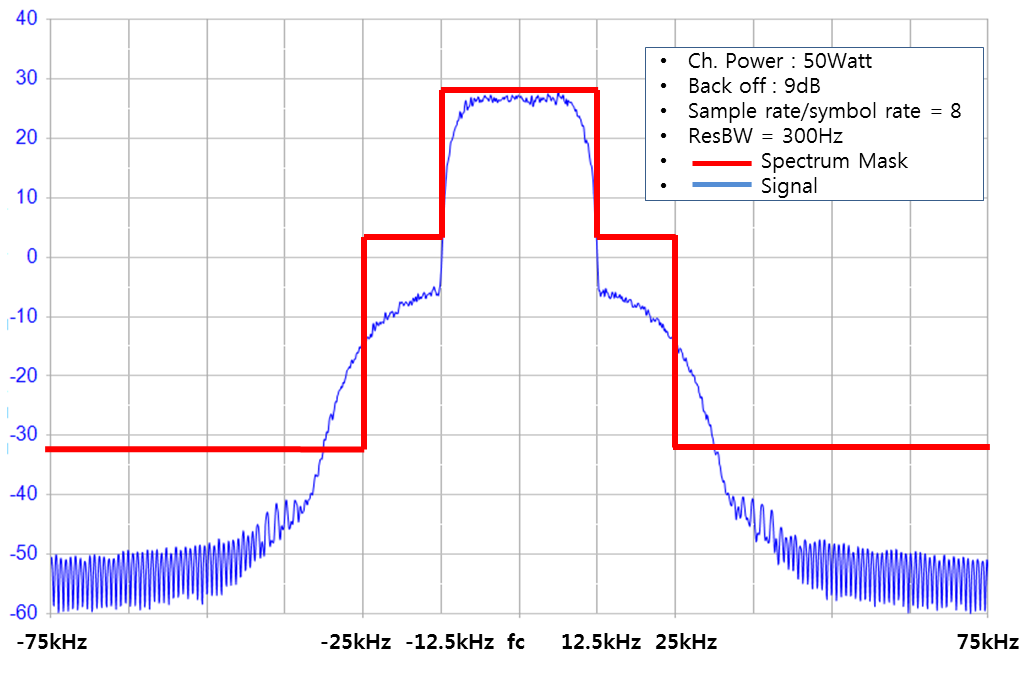


Figure 6. IF signal Spectrum, (a) 25kHz (b) 50kHz (c) 100kHz

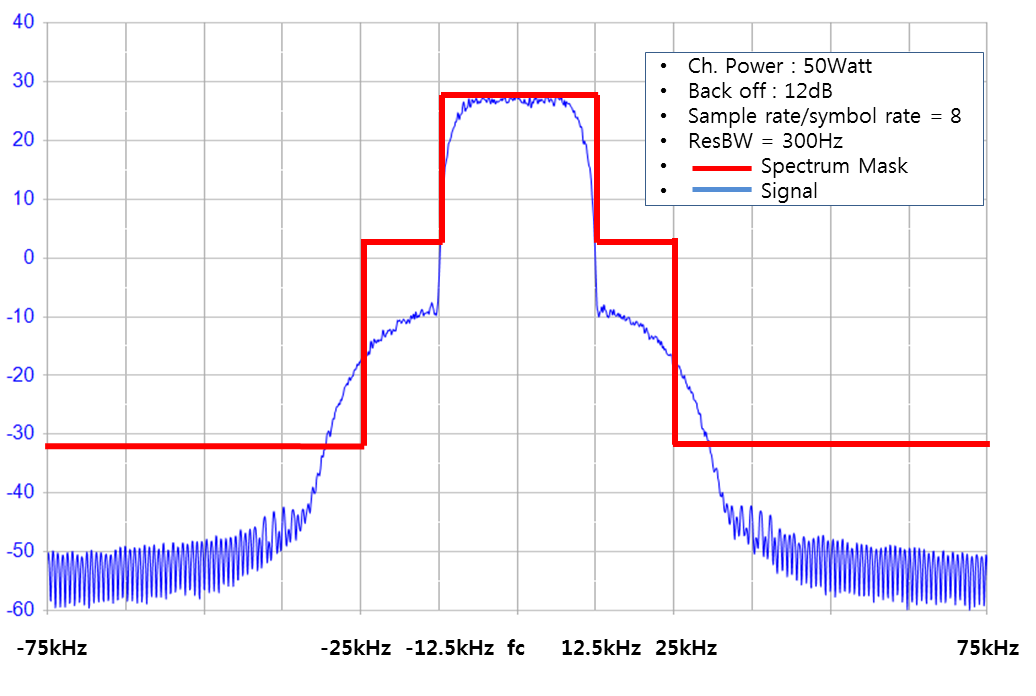
The 70 MHz IF signal output from the modem is up-converted to the RF carrier frequency by a general RF transmitter and applied to the antenna as shown in figure 7. As described above, the spurious emissions including IMD components are generated due to nonlinear elements of RF Transmitter. The IMD components affecting spectrum mask specifications can be obtained through simulation.



1. Back off = 7dB



1. Back off = 9dB



1. Back off = 12dB

Figure 7. The output spectrum for VDE 25kHz channel

The waveform (a), (b) and (c) in Fig.7 show the output spectral when the transmission output amplifier back-off for the VDE 25kHz channel is composed of 7dB, 9dB, and 12dB, respectively.

As shown in Fig. 7, it cannot satisfy the specification of -60dBc in the range of ± 25 kHz <Δfc <± 75kHz due to the IMD components from the center frequency.

VDE 50kHz, 100kHz also exhibits similar IMD output characteristics.

One way to solve this problem is as follows. First, a narrow band pass filter is applied to the transmitter output stage. Second, a linearization technique is applied. In the first case, it is impossible to implement a filter satisfying both the rejection characteristic and the insertion loss satisfying the spectral mask with the filter of 25 kHz bandwidth in the VHF band.

The second case can be implemented by applying analogue pre-distortion (APD) and or digital pre-distortion (DPD) techniques. The circuit implementation using the linearization techniques in the amplifier are somewhat complex and have high level of difficulty, but these linearization techniques have been already used in communication applications so this method has high feasibility.

Therefore, the Spectrum Mask specification of VDE recommended in ITU-R 2092 should be proposed and discussed in the optimized design structure through analysis of channel interference.

# Action requested of the Committee

The Committee is requested to review the information and take appropriate action.

1. [↑](#footnote-ref-1)
2. [↑](#footnote-ref-2)