Terrestrial VDE on the German Inland Waterways

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I. Introduction

The VHF Data Exchange System (VDES) is a new maritime communication system that is currently in standardization at the ITU. It will extend the existing AIS system by providing ships with a data link either to the shore or between ships [1]. For this purpose, two frequency bands have been assigned to the VDE service. One for downlink (shore-to-ship) at $161.8 - 161.9\,\mathrm{MHz}$, and one for uplink (ship-to-shore) at $157.2 - 157.3\,\mathrm{MHz}$.

Currently, the project SCIPPPER aims to automate the procedure of a vessel to drive into a waterlock. Therefore, high-precision positioning information is required. The support of additional correction data, such as RTK or PPP, would improve the positioning performance of GNSSs significantly. The VDE downlink is currently foreseen to transmit the correction data in a certain region.

The upper edge of the VDES downlink, however is located only $75\,\mathrm{kHz}$ away from the lower AIS channel at $161.975\,\mathrm{MHz}$. As AIS is an important tool for safety of navigation, it is important that the new services do not interfere with AIS. This provides a challenge for implementers which want to place VDES base stations in the same locations as their existing AIS base stations. Especially those that operate base stations in remote locations where setting up a new structure can be prohibitively expensive. Typical band pass filters for AIS radios do not filter out signals this close to the AIS frequency band. As AIS receivers are expected to have a sensitivity of $20\,\%$ PER @ $-107\,\mathrm{dBm}$ [3], and VDES has a transmit power of $12.5\,\mathrm{W}$ or $41\,\mathrm{dBm}$ [2], this poses a problem for the dynamic range of the AIS receiver.

II. Counter Methods

To address this issue, we investigate what strategies can be utilized to mitigate interference between the two systems. Possible approaches to this issue are:

- Accept interference from VDES on AIS.
- Limit the amount of time that VDES is allowed to transmit.
- Utilize steep filters that separate the two frequency bands.
- Employ analog and/or digital interference cancellation techniques.

To simply accept interference is a non-solution and can be assumed to usually not be viable, except for rare circumstances. However it may be tolerable or necessary to accept remaining interference after other measures have been employed to reduce it.

Limiting the transmit time of the VDE system does not reduce the strength of the interference during transmission, but reduces the probability that an AIS message is affected by local interference. When a certain probability of package loss is acceptable at the AIS system, this can be a viable method. The obvious downside to this approach however is that the downlink capacity of the VDE system will be severely reduced.

Utilising analog filters will be an element in any strategy to reduce interference. However, filters with such a steep transition between pass band and stop band as would be necessary for this use case would be expensive and have large physical dimensions. Commercially available duplex filters for the VHF band designed for a frequency spacing of of $600\,\mathrm{kHz}$, already exhibit physical dimensions of $26\,\mathrm{cm} \times 48\,\mathrm{cm} \times 60\,\mathrm{cm}$ and a mass of about $14\,\mathrm{kg}$ [4].

Interference cancellation techniques exploit the fact that the transmitted signal is known and thus can be subtracted from the received signal [5]. Theoretically resulting in complete removal of the interfering signal from the received signal. This however relies on precise knowledge of the signal parameters at the receiver. Factors such as relative antenna placement and surrounding reflectors affect the channel between the transmitter and the receiver, even though they are located very close together. Also nonlinearities in the RF hardware introduce signal distortions, leading to imperfect knowledge of the signal at the receiver. In the case of digital interference cancellation, the dynamic range of the Analog to Digital Converter (ADC), plays an important role. The operating princicpl of this approach is shown in Fig. 1

III. Laboratory Experiments

We focus mostly on the last approach of interference cancellation, it is however expected that a combination of all mentioned approaches will be necessary for a real world implementation.

As a testbed for interference cancellation, we utilize a Software Defined Radio (SDR) platform, based on an Ettus USRP B210, which provides two RX and TX channels each. One TX channel is used to provide the VDES signal. This signal is then Received on one of the RX channels for the purpose of estimating the channel parameters. The second TX channel is utilized to create an inversed signal with the channel parameters applied. This signal should closely match the received signal and can be subtracted from the received signal by analog means.

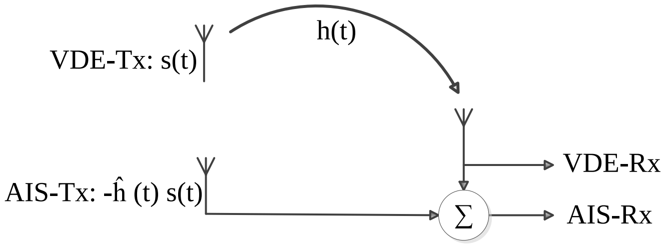

Fig. 1: Principal setup for interference cancellation

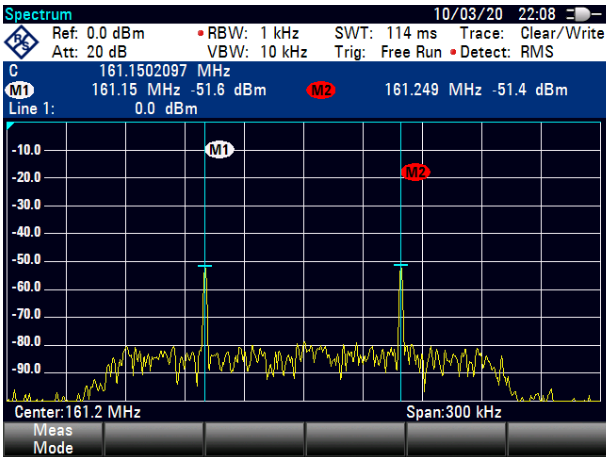

Fig. 2: Test signal without cancellation as reference.

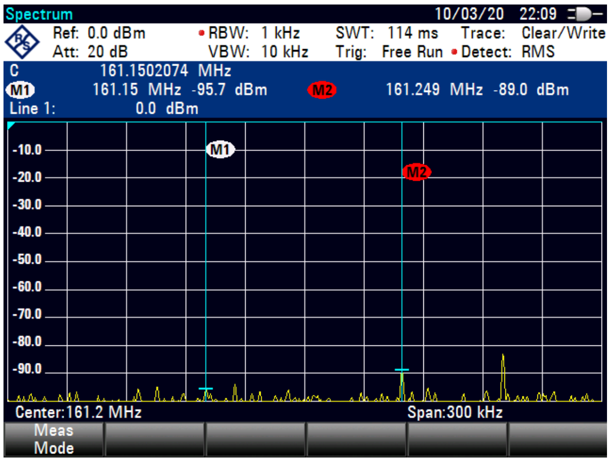

Fig. 3: Test signal after cancellation of the interference.

In a simple laboratory setup, experiments with this technique have resulted in a $30\,\mathrm{dB}$ to $40\,\mathrm{dB}$ reduction in received signal power for the interfering signal. This is shown in Fig. 2 and Fig. 3. For the laboratory experiment a combination of white noise and a Continuous Wave (CW) was used instead of a VDE signal. The CW part is easily discernible in the spectrum and allows for comparison of signal levels, while the white noise allows to see whether frequency dependent effects are present.

IV. Practical Experience

At a base station of the WSV at the Spree-Oder-Wasserstraße we could investigate our proposed techniques with the current antenna setup. The setup utilized the current AIS antenna and the backup AIS antenna at the base station. Fig. 4 shows the typical vertical separated setup of both antennas. In the final paper we will summarize our findings.

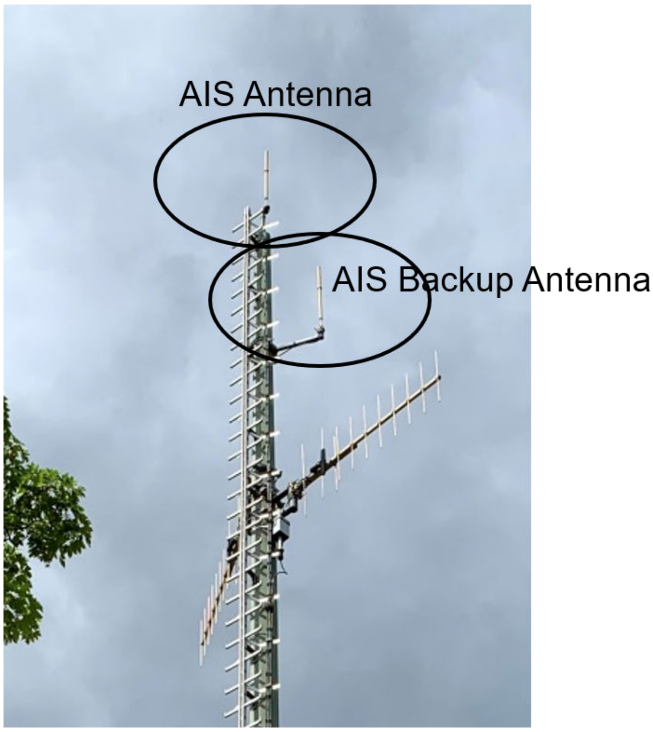

Fig. 4: WSV antenna setup with AIS and backup AIS antenna.

References

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[2] IALA Guideline G1139, “The Technical Specification of VDES”, https://www.iala-aism.org/product/g1139-technical-specification-vdes/

[3] ITU Recommendation M.1371, “Technical characteristics for an automatic identification system using time-division multiple access in the VHF maritime mobile band”

[4] https://amphenolprocom.com/products/filters/770-dpf-2-125

[5] C. D. Nwankwo, L. Zhang, A. Quddus, M. A. Imran and R. Tafazolli, ”A Survey of Self-Interference Management Techniques for Single Frequency Full Duplex Systems,” in IEEE Access, vol. 6, pp. 30242-30268, 2018.