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

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

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# Multiantenna and Interference Cancellation for Colocation of VDE-TER and AIS

# Introduction

The VHF Data Exchange System (VDES) is a new maritime communication system that was standardized in February 2022 by the ITU WP5B and published [1]. It will complement the existing AIS (automatic identification system) by providing ships with a data link either to the shore or between ships [2]. For this purpose, two frequency bands have been assigned to the VDE service. One for downlink (shore-to-ship) at 161*.*8 *−* 161*.*9 MHz, and one for uplink (ship-to-shore) at 157*.*2 *−* 157*.*3 MHz.

The project SCIPPPER aims to automate the procedure of a vessel to drive into a water lock. 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 regional correction data and concurrently receiving AIS messages from distant vessels.

The upper edge of the VDES downlink, however is located only 75 kHz away from the lower AIS channel at 161*.*975 MHz. As AIS is an important and mandatory tool for safety of navigation, it is important that the new services do not interfere with AIS. This provides a challenge for implementer 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 including additional infrastructure can be prohibitively expensive. Typical band pass filters for AIS radios do not filter out signals this close to the AIS frequency band. That AIS receivers are expected to have a sensitivity of 20 % PER @ *−*107 dBm [4], and VDES has a transmit power of 12*.*5 W or 41 dBm [3] poses a problem for the dynamic range of the AIS receiver.

# 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.
* Transmitter and receiver utilize the lower lag of the maritime band.

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.

The ITU regulations define also in ITU-R M.2092-1 the possibility to use the lower lag of the VDE band for transmission and reception. This would result in a separation of at least 4*.*5 MHz spectral separation. Therefore, a blockage is still reasonable, but counter measures by a filter are easier to realize. The impact on cutting the transmission capacity at least in half needs to be cautiously assessed compare to the counter measures to still receive AIS message of distant vessels.

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 600 kHz, already exhibit physical dimensions of 26 cm *×* 48 cm *×* 60 cm and a mass of about 14 kg [5]. Quartz filters for the VHF band are more promising as their frequency spacing is much less than 100 kHz with a strong attenuation of 60 dB of the interfering signal, but it accepts only a low input power of 0 dBm.

Interference cancellation techniques exploit the fact that the transmitted signal is known and thus can be subtracted from the received signal [6]. In theory, this results in the complete removal of the interfering signal from the received signal. However, it relies on precise knowledge of the signal parameters at the receiver. Factors such as relative antenna placement and (dynamic) surrounding reflectors affect the channel between the transmitter and the receiver, even though they are located very close together. Further non-linearities 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 principal of this approach is shown in Fig. 1.

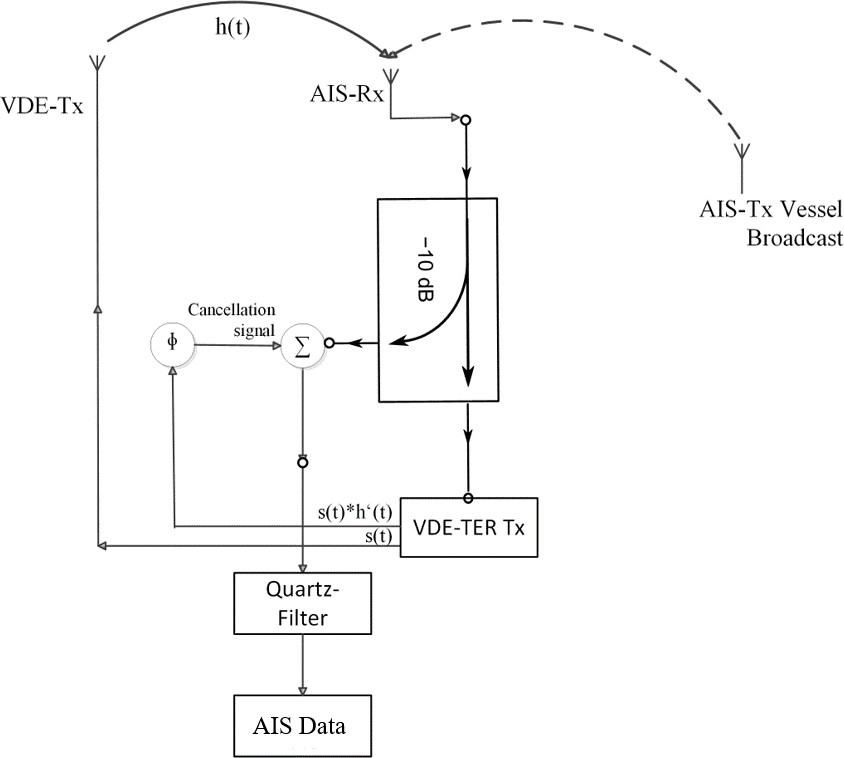


Fig. 1: Principal setup for interference cancellation

# 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. The structure of the interference cancellation structure is shown in Fig. 1. The following hardware is used to extract the interfering signal and subtract it from the interfered received AIS signal:

* The software defined radio is an USRP B210
* The transmit amplifier is a Kuhne KU PA 014018-50 HY
* The receiver low-noise amplifier is a Kuhne KU LNA BB 1018 A
* The quarz filter is a KVG XF-1620S04-LF, und KVG XF-1619S02-LF
* The combiner is a Mini-Circuits ZX10-2-12-S+
* The coupler is a Mini-Circuits ZX30-12-4-S+

As a test-bed 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.

In a simple laboratory setup, experiments with this technique have resulted in a 30 dB to 40 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 continuous wave portion is easy to see in the spectrum and allows you to compare signal levels, while the white noise allows you to see if frequency-dependent effects are present.

# Practical Experience

At a base station of the water and shipping administration (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. The backup AIS antenna was used for transmitting the VDES signal. We measured the path loss between both antennas. Fig. 4 shows the typical vertical separated setup of both antennas. The fine tuning of our SDR cancels the incoming VDES signal but we encountered the noise amplification by the transmitter at the receiver that required special attention. In the final paper we will further discuss the impact of a changing environment and different methods to resolve the impact in the cancellation chain.

Further, we used the AIS infrastructure from the WSV along the river Mosel and the WSV vessel to build up our test-bed. The test-bed intended to receive specific AIS base station messages (#4) from the AIS base station at the water lock in Lehmen. By activating the VDE transmitter on the vessel, the AIS reception on the vessel was nearly blocked. Only the AIS transmissions from the vessel itself, where received and decoded. The AIS transceiver antenna was about five meters horizontally apart. By activating the interference cancellation, the transmitted AIS message of the WSV base station was received along a distance of up to 2 km till the village of Brodenbach.

References

1. ITU-R M.2092-1, “Technical characteristics for a VHF data exchange system in the VHF maritime mobile band”, [https://www.itu.int/rec/R-](http://www.itu.int/rec/R-REC-M.2092)REC-[M.2092](http://www.itu.int/rec/R-REC-M.2092)
2. IALA Guideline G1117, “VHF Data Exchange System (VDES) Overview”, [https://www](http://www.iala-aism.org/product/).iala-[aism.org/product/](http://www.iala-aism.org/product/) vhd-data-exchange-system-vdes-overview-1117/
3. IALA Guideline G1139, “The Technical Specification of VDES”, [https://www](http://www.iala-aism.org/product/g1139-technical-specification-vdes/).iala-[aism.org/product/g1139-technical-specification-vdes/](http://www.iala-aism.org/product/g1139-technical-specification-vdes/)
4. ITU Recommendation M.1371, “Technical characteristics for an automatic identification system using time-division multiple access in the VHF maritime mobile band”
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6. 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.

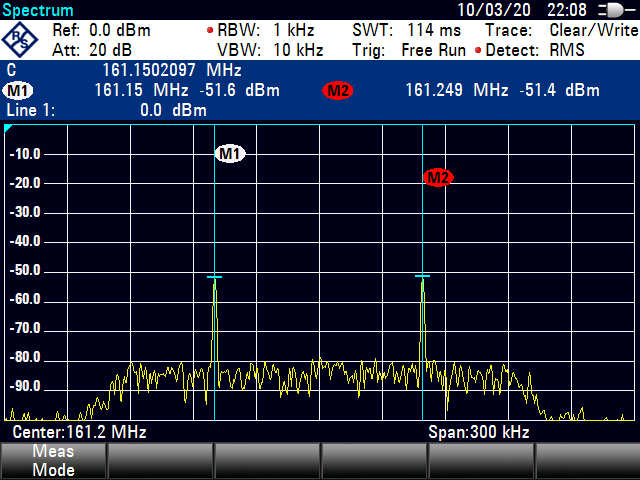


Fig. 2: Test signal without cancellation as reference.

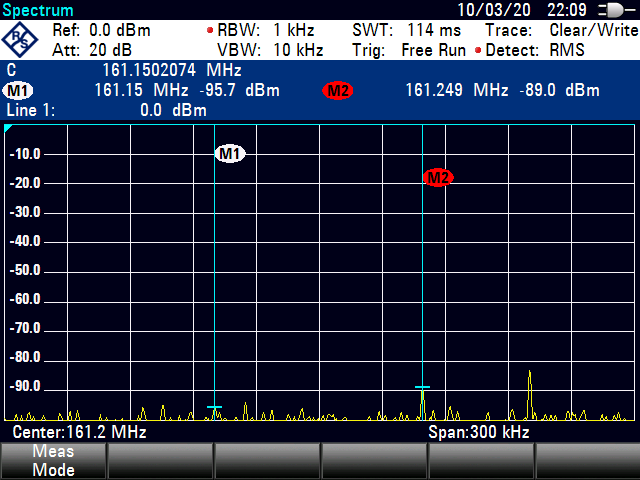


Fig. 3: Test signal after cancellation of the interference.

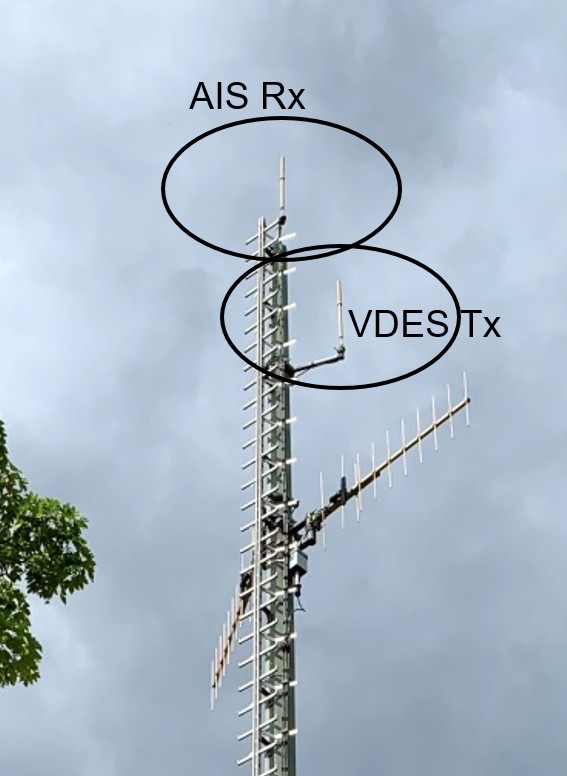


Fig. 4: WSV antenna setup with AIS receiver antenna and VDES transmitting antenna.

# Action requested of the Committee

The Committee is requested to:

1. Take note of the attached procedure for a concurrent usage of transmitting VDE-TER and receiving AIS.

1. Input document number, to be assigned by the Committee Secretary [↑](#footnote-ref-1)
2. Leave open if uncertain [↑](#footnote-ref-2)