3rd URSI Atlantic Radio Science Meeting

May 29 - June 3, 2022

URSI AT-AP-RASC 2022

ExpoMeloneras Convention Centre

Gran Canaria, Spain

We-B26-PM4-3 **Fully Passive Multi-rectenna Channel Estimation for Microwave Wireless Power Transfer**

Kentaro Murata (1), Shinnosuke Kondo (1), Naoki Honma (1)
(1) Iwate University (Japan)

Session B30: Antennas and sensors for wireless applications

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Monday, 30 May 2022 16:00 - 17:00 Room B3

Session Chairs: Filippo Costa (Univ. of Pisa, Italy), Andrea Michel (Univ. of Pisa, Italy)

Mo-B30-PM3-1 **Wireless Sensor for Precision Grasping of Objects and Tools by Robotic Hands**

Armin Gharibi (1), Simone Genovesi (1), Filippo Costa (1)
(1) University of pisa (Italy)

Mo-B30-PM3-2 **Design and implementation of a prototype with a low-cost SDR platform for the next generation of maritime communications**

Dayron Romero (1), Víctor Alexis Araña Pulido (1), Nicolás Molina Padrón (1), Francisco José Cabrera Almeida (1), Eugenio Jiménez Yguacel (1)
(1) Universidad de Las Palmas de Gran Canaria (Spain)

Mo-B30-PM3-3 **New Design Approach for Mutual Coupling Reduction in Two-Port Compact Antenna Array for W-LAN MIMO Applications**

Mohit Mishra (1), Rakhesh Singh Kshetrimayum (1), Sumantra Chaudhuri (2), Koushik Dutta (3)
(1) Indian Institute of Technology Guwahati (India); (2) Presidency University Banglore (India); (3) Netaji Subhash Engineering College Kolkata (India)

Session B31: Wideband RF links

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Tuesday, 31 May 2022 14:30 - 15:30 Room B3

Session Chairs: Reyhan Baktur, Andrea Michel (Univ. of Pisa, Italy)

Design and implementation of a prototype with a low-cost SDR platform for the next generation of maritime communications

D. Romero-Godoy(1), N. Molina-Padrón(1), F. Cabrera(1), V. Araña(1) and E. Jiménez(1)
(1) Instituto para el Desarrollo Tecnológico y la Innovación en Comunicaciones (IDeTIC), Universidad de Las Palmas de Gran Canaria, Las Palmas, Spain

Abstract

In the last years, the increasing amount of maritime traffic has compromised the security of the AIS (*Automatic Identification System*). The use of two 25 KHz channels is not enough for the global amount of ships at seas. With the purpose of reinforcing the AIS, the VDES (*VHF Data Exchange System*) has been proposed in 2013. This system adds the AIS and four additional services, with challenges in modulation schemes, channel bandwidths and bit rates. The adoption of this new system implies a hardware challenge, because the VDES equipment could be more expensive than current commercial AIS transceivers. The SDR (Software-Defined Radio) technology is a versatile technology which could reduce the cost of the next generation of maritime communications equipment. In this paper, a prototype for the AIS and VDES is implemented on a low-cost SDR platform. Additionally, an RF circuit for filtering and amplifier in transmission and reception has been designed to improve the SDR performance.

1 Introduction

Since the Titanic's accident in 1912, maritime safety measures have been reinforced through a multiple international standardisations. In 1914, the SOLAS (*Safety Of Life At Sea*) convention was a historic milestone where the first international rules for safety at sea were approved [1]. Nowadays, maritime communications tend to transmit more information, optimising the bandwidths. Because of the radio spectrum is a finite and demanded resource, there is a need to replace analog to digital systems to reduce the bandwidth requirements. In relation with this challenge, and to achieve a reduction of human error, a renewal of the GMDSS (*Global Maritime Distress Safety System*) has been proposed [2]. This renewal has meant a digitalisation of the maritime communication systems, where the AIS (*Automatic Identification System*) has been a good example of this transition.

The AIS [3] is a broadcast radio communication system which operates at the VHF maritime band (156.025 MHz – 162.025 MHz). This system, which was developed in 1998 [4], allows the exchange of navigation data between ships and other infrastructures, such as shore stations or aids to navigation [5]. It operates on two 25 KHz channels, AIS-1 (161.975 MHz) and AIS-2 (162.025 MHz), applying a NRZI line code and a GMSK modulation scheme on the baseband signals. The transmissions are managed by the vessels themselves using a self-organised TDMA (*Time Division Multiple Access*) media access scheme, avoiding a centralised control as it is used in the traditional mobile networks [6]. With the AIS, a vessel can transmits its navigation parameters (position, speed, course, etc.) and receives the same parameters from neighbouring vessels. However, the system's capacity falls on two narrow band channels that share its usage through a TDMA scheme. In a high density of marine traffic scenarios, an increment of packet collisions can be produced, compromising the proper performance of the AIS. The AIS channel saturation has been studied in some areas of the world, such as Mexico or Japan [7].

In order to avoid the AIS channel saturation, the IALA (*International Association of Marine Aids to Navigation and Lighthouse Authorities*) and other authorities proposed a modernisation of the AIS in 2013, called VDES (*VHF Data Exchange System*) [8]. This new system integrates the AIS, and twelve new channels with higher rates and bandwidths are added, with changes on modulation and coding schemes. The VDES services may have fixed 25 KHz channels, as the LR-AIS (*Long Range AIS*) and the ASM (*Application Specific Message*), or variable with 25, 50 or 100 KHz, as the VDE-TER (*VHF Data Exchange - Terrestrial component*) and the VDE-SAT (*VHF Data Exchange - Satellite component*). In addition, the LR-AIS uses the same modulation scheme as the AIS (GMSK), the ASM uses a π/4-QPSK scheme, the VDE-TER can use π/4-QPSK, 8PSK or 16QAM schemes, and the VDE-SAT uses BPSK, QPSK or 8PSK modulation (in downlink) and QPSK, OQPSK and 16APSK (in uplinks) [9]. The VDE-TER service can achieve transmission rates 32 times higher than the AIS [10]. Despite the positive aspects offered by the VDES, there are still some technical issues to be resolved. Changes in the physical layer of the VDES involve changes in the hardware used for the AIS equipment [11]. In comparison with the current AIS commercial equipment prices, the implementation of the VDES hardware could experiment a prohibitive increment. For this reason, it is necessary to evaluate new alternatives for implementing the

VDES hardware, where the SDR (*Software-Defined Radio*) [12] could be a potential technology to achieve affordable cost for the next generation of maritime communications equipment.

In this paper, a prototype capable of transmitting and receiving signals conformed by the next generation of maritime communications, the AIS and the VDES, is proposed. This prototype is composed by a low-cost SDR platform, which executes a selectable code for the AIS and the VDES services in transmission and reception modes. Moreover, an additional platform for filtering and amplification in the AIS and VDES bands has been implemented to improve the performance of the SDR platform.

2 Prototype's architecture

The prototype's architecture proposed is shown in the block diagram of the figure 1, and it is formed by the following blocks:

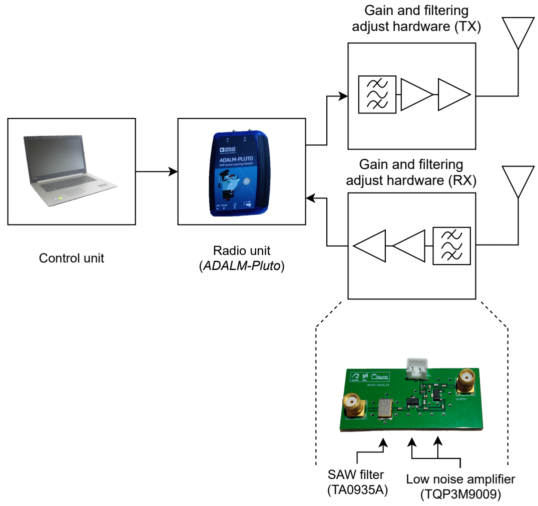

Figure 1. Block diagram of the prototype's architecture

- *Control unit*, based-on a personal computer (i7-8750H CPU, 16GB RAM, 1 TB) that is connected to the SDR platform for control tasks by a serial interface. Also, different algorithms for AIS and VDES services are executed from MATLAB.
- *Radio unit*, composed by an SDR platform (ADALM-Pluto by Analog Devices) that converts the digital instructions launched from the control unit in radio signals, received or transmitted in function of the selected mode.
- *RF front-end unit*, where an own designed PCB has been implemented to include a SAW filter (TA0935A) and two low-noise amplifiers (TQP3M9009) connected in cascade topology. This additional hardware is used to remove potential interferences and adjust the gain of both received and transmitted signals.

3 Methodology

As the proposed prototype is intended to transmit and receive messages on the different services like ASM, AIS and VDE-TER, several scripts were programmed. A global flow chart of each process is explained, differentiating the transmission and reception modes which has been implemented on the SDR platform.

3.1 Transmission mode

When a service is selected, the first step is to set up the transmission parameters, such as the symbol rate (9600 for the AIS, 19200 for the ASM), the number of samples per symbol (24 as the optimal value) and the sample rate, which is the product between the symbol rate and samples per symbol. Then, the SDR platform is configured as a transmitter, setting the desired channel frequency, samples per frame and sample rate. The binary packet is generated, adding the training sequence, payload and CRC. Lastly, an appropriate modulation scheme is applied on the binary packet, that will change in function of the selected service. When the packet is modulated, the SDR platform starts the transmission. The flowchart of the transmission mode is shown in figure 2.

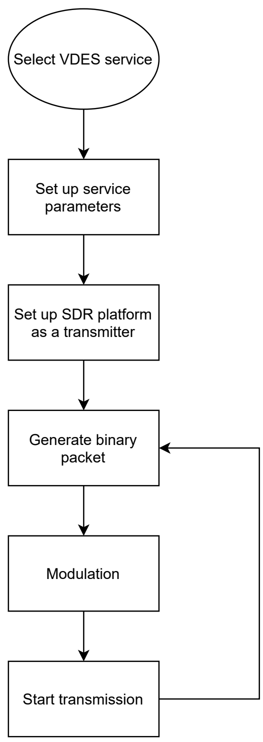

Figure 2. Proposed transmission flow chart

3.2 Reception flow chart

After a service is selected, several reception parameters are set, as the symbol rate (9600 for the AIS, 19200 for the ASM), samples per symbol (24 as the optimal value) and sample rate, conformed by the product between the symbol rate and samples per symbol. When the parameters and the SDR platform are set, the reception is started. Once a transmission is detected, the higher energy window within the received signal is considered as a packet. After storing the packet, DC offset is removed and I/Q imbalance compensation is performed. Later on, a demodulation is applied to retrieve the original signal, depending on the selected service. To retrieve the data within the frame, a synchronization process conformed by the detection and correlation of the training sequence is applied. The message's checksum is computed to check if the packet are valid or not. On the one hand, if the packet is invalid, it is discarded and the reception process will start again. On the other hand, if the packet is valid, payload is retrieved and decoded according to NMEA0183 protocol. The flowchart of the reception mode is shown in figure 3.

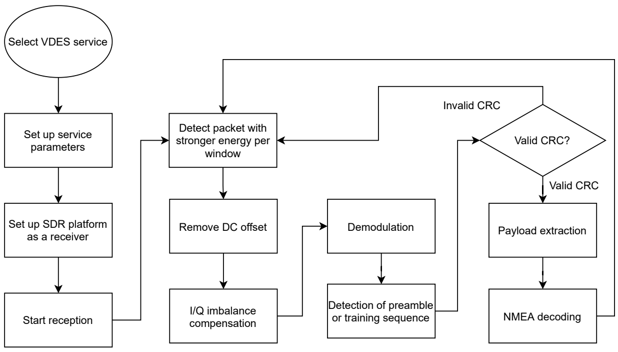

Figure 3. Proposed reception flow chart

4 Results and discussion

To verify the prototype's design, firstly the RF front-end has been tested. For reception mode, the filtering and amplification capacity of our design have been tested connecting the PCB input to a VHF antenna (located at a rooftop) and the output to an spectrum analyser (Advantest R3131A). In figure 4(a), the spectrum of the FM commercial band is attenuated from -21.4 dBm to -31.3 dBm, providing an attenuation of 9.9 dB. An AIS signal received is amplified from -61.3 dBm to -20.5 dBm, obtaining a gain of 40.8 dB. These results show an improvement in the reception capacity of the SDR platform, which also allows to avoid possible close out-band interferences. For transmission mode, an AIS signal at 162.025 MHz is generated by the SDR platform, obtaining a power output of 32.8 dBm, very close to 33 dBm that the AIS class B transceivers achieve. The transmitted signal obtained is shown in figure 4(b).

In figure 5 is shown a time domain representation of the AIS signal received by the SDR platform. It can be identified

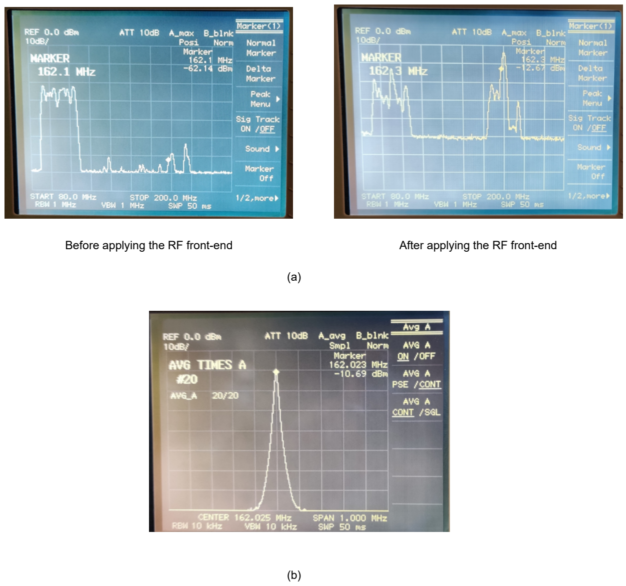

Figure 4. Spectrum without (left) and with (b) filtering and amplification hardware

the ramp-up period and the start and stop bytes, besides the payload.

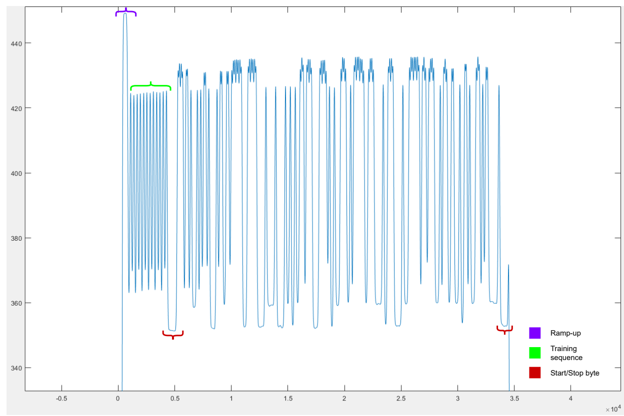

Figure 5. Analysis of an AIS signal received in time domain

5 Conclusions

In this paper, a prototype to transmit and receive AIS and VDES signal with a low-cost SDR platform has been implemented. The algorithms for transmission and reception modes are described. Aditionally, a filtering and amplification hardware unit has been implemented to improve the prototype performance, showing the attenuation of the out-band interferences and also, the amplification of the AIS and VDES signals generated and received by the SDR platform. Finally, the AIS and VDES services implementation in a low-cost SDR platform has been verified, showing a potential alternative for the next generation of maritime communications deployment.

6 Acknowledgements

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