Low-cost AIS Transponder using an SDR device

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***Abstract*— With the advance of technology, several equipment that were expensive in the past are relatively cheap nowadays. One of this equipment is the Software Defined Radio (SDR). SDRs can transform expensive equipment available on the market into simple, cheap and easy to build computer applications. One of latter is the Automatic Information System (AIS). Because AIS is an equipment of great importance to the safety of navigation and it's not compulsory for small vessels, if there's a way of making it cheaper and accessible for everyone, it would have many advantages. On this paper we propose a creation of a Low-Cost AIS Transmitter using the SDR technology and open-source software.**

Keywords*— *SDR; AIS; Transmitter; Low-Cost

I. Introduction

Nowadays, the seas have an enormous importance in our life. Over 90% of the world's trade is carried by sea. By 2015, the world's commercial fleet consisted in 89464 vessels and in 2014, 9.84 billion tons of seaborn shipments were made [1]. From tourism to commerce, it's easily observed the dependency and the strategic importance of the seas to nations. Because of this, the density of ships navigating in coastal regions is quite high, raising problems regarding the safety of navigation. According to the European Maritime Safety Agency (EMSA), there were 3145 marine casualties and incidents in 2016 and 34% of these were due to contact or collisions [2]. Another problem inherent to the great number of ships traveling on the sea is their ecological impact and the accountability when there are ecological incidents. Chemical, Biological, Radiological and Nuclear (CBRN) incidents are examples of serious threats to the environment [3] where new types of agents create situations where detection and accountability becomes a hard task [4][5]. Automatic Identification System (AIS) is a widely deployed automatic ships' position reporting system that greatly contributes to reducing such incidents. AIS provides own ship data information, such as callsign, status, position, course or speed, to other ships and Vessel Traffic Service (VTS) stations [6]. The AIS also takes part in the Global Maritime Distress and Safety System (GMDSS) as an important Search And Rescue (SAR) [7] information system [8], and according to the International Convention for the Safety of Life at Sea (SOLAS), its use is compulsory for every ship with more than 300 tons engaged in international voyages or 500 tons if not in international voyages and all passenger ships.
Since the use of AIS is not mandatory for all vessel types, particularly small vessels, typically don't use it. One of the reasons for that, is the price of AIS equipment (transponder), which raises the question: is it possible to implement a low cost AIS transponder with the same capabilities of a commercial one?

With the evolution and large-scale production of technology, more of it starts to be available to the general public. One of these technologies is the Software Defined Radio (SDR). The SDR is a radio and software technique used in radio communications, where most or all of the signal processing, such as modulation, sampling and waveform synthesis, is done using software routines in general purpose processors (GPP) rather than application-specific hardware (like in hardware-based radios). Digital signal processing (DSP) made in software has several advantages over DSP made in hardware, including higher flexibility and adaptability (routines can be changed during execution) and a reduction of cost inherent to the hardware, since general purpose hardware is used. Other two important advantages of using SDRs is the existence of a big online community, offering lots of support and making it accessible and easy to work with, even for people with basic knowledge of signal processing, and the available open source DSP frameworks tailored for SDR applications. One of the most popular frameworks is the GNU Radio project, which includes a tool called GNU Radio Companion (GRC), offering an intuitive and quick tool, with a graphical interface, for rapid prototyping.

Like in other areas, SDRs can be used in a wide range of maritime applications. With just a laptop and an SDR, it is possible to build a device capable of receiving and transmitting AIS signals and, unlike a commercial AIS transponder, with the right software, can be used for other functionalities. The same device allows its user to use it in other useful maritime navigation applications, such as receiving the Global Positioning System (GPS), as a Very High Frequency (VHF) transceiver or as receiver for National Oceanic and Atmospheric Administration (NOAA) weather satellite images. This was done taking interoperability [9] with other systems

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into account [10], making this system open for new developments [11] in future works, increasing its potential [12].

This paper is focused on using the potentialities of SDRs and the open source software available on the Internet to build a low-cost interface, with the capabilities of receiving and transmitting an AIS signal like a commercial AIS transponder would do, in order to demonstrate the advantages and the potential of using SDRs in marine navigation. Regarding this, there are going to be presented some practical tests already done successfully that prove the concept, using an HackRF One as SDR and the GNU Radio project as DSP framework. The final purpose is to demonstrate and show how is it possible to implement this technology on a small vessel, using other SDRs and AIS transponders to receive the experimental AIS signal.

This paper is organized according to the following structure: section II provides some information about the AIS; section III describes how does the AIS Transponder works; section IV describes tests and experiments done; finally, a conclusions section.

II. AIS

The Automatic Identification System (AIS) is a Very High Frequency (VHF) transponder system with an automatic identification capacity, developed by the International Maritime Organization, in the sequence of the revision of Chapter V of the SOLAS Convention. It was designed as a navigation safety aid and as an environmental protection aid, through the exchange of information between ships and coast stations.

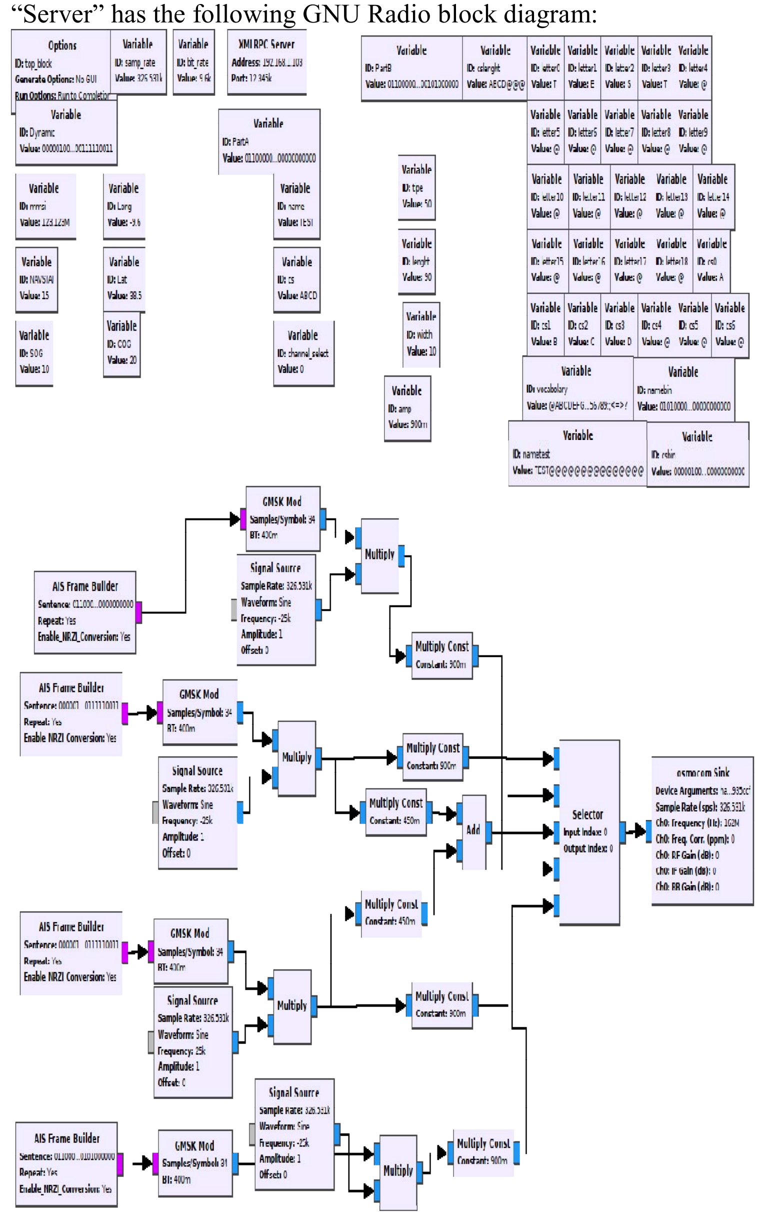
Because this system is compulsory for every ship with 300 or more gross tonnage and all passenger vessels and highly recommended for all ships, almost every vessel uses this system. Also, according to the MarineTraffic website, AIS information is used to serve several purposes such as tug operations, communication between vessel crews and their family's members, coast guard and border patrol operations, environmental protection agencies, among others.

The AIS transmits a great variety of information about the ship such as: GPS data (position, course and speed), data from the gyrocompass, International Maritime Organization (IMO) number, call sign, length and beam, location of the antenna, ship type and draft, hazardous cargo, destination, Estimated Time of Arrival (ETA) and route plan. Its data that can be programmed into the unit because it never changes is known as static data like the IMO number, the data introduced by the user is known as voyage related data, like the route plan and the data that's being constantly updated (automatically) is known as dynamic data, like the ships' position.

The AIS works on VHF channel 87B and 88B at 161.975 MHz and 162.025 MHz respectively with a transmission bit rate of 9600 baud. It uses Self Organizing Time-Division Multiple Access in order to avoid collisions between the transmissions of the different stations, using the GPS time as a common time reference. AIS messages are standardized hence, it's relatively easy to create messages or to change their content directly on the raw code. This makes them rather vulnerable to jamming and spoofing, and thereby, a good and easy target to perform electronic attacks. There are tactical situations where it could be useful to create "ghost contacts" in order to baffle the enemy's perception of the surrounding environment. On the other hand, it might also be useful to deny them all AIS information by jamming the system.

III. AIS Transponder

The AIS Transponder is a program that has the capacity of creating AIS contacts. The AIS sentences on the program were built with the help of the "http://catb.org/gpsd/AIVDM.html" website and the AIS Frame Builder Block was created by Marco Balduzzi and it's available on "https://github.com/trendmicro/ais". The AIS Transponder is divided in two parts called "Server" and "Client". The "Server" has the following GNU Radio block diagram:



The used blocks were the: 1) Variables ID: "mmsi",

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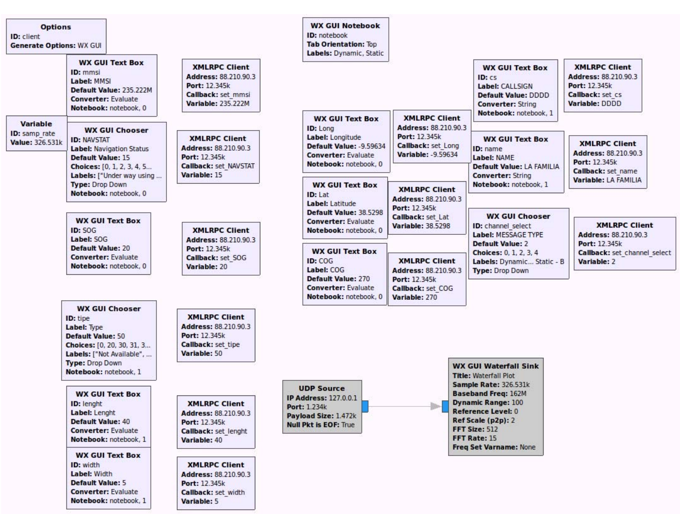
“NAVSTAT”, “SOG”, “Long”, “Lat”, “COG”, “name”, “cs”, “channel_select”, “tipe”, “length” and “width” that are variables that receive the values from the client through the XMLRPC Server block; 2) Variable ID “Dynamic” that builds the Dynamic AIS message (type 1), making it ready to introduce in the AIS Frame Builder; 3) Variable ID “Part A” and “Part B” that builds the Static AIS message (type 24), making it ready to introduce in the AIS Frame Builder. The type 24 AIS message is divided in two parts: A and B; 4) Variable ID “Vocabolary” which is a list of 6-bit ASCII characters used in AIS sentences; 5) Variable ID “nametest” which creates a 20-character sentence containing the name of the ship and, if the name isn’t 20 characters long, it replaces the empty spaces with the “@” character. The code used is: name+"@"*(19-len(name)) [The “@” is the first character in the 6-bit ASCII vocabulary (000000). That’s why it’s the character replacing empty spaces.]; 6) Variable ID: “letter(number)” that reads the character on the “nametest” variable. There is one “letter” variable for each character. The code used is: nametest[number]; 7) Variable ID: “namebin” which replaces each character in the “letter” variables for its 6-bit ASCII code equivalent. The code used is: '{0:b}'.format(vocabolary.find(letter0)).rjust(6, '0') + '{0:b}'.format(vocabolary.find(letter1)).rjust(6, '0') + … ; 8) Variable ID “cslenght” that has the same function as the “nametest” variable but applied to the callsign; 9) Variable ID “csbin” that has the same function as the “namebin” variable but applied to the callsign; 10) AIS Frame Builder that is the block that transforms the sentences from the Dynamic, Part A and Part B variables into an AIS Frame; 11) GMSK Mod which is the block that modulates the AIS Frame using Gaussian Minimum Shift Key modulation; 12) Selector that selects what signal to send to the “osmocom Sink” block; 13) osmocom Sink that sends the information for the SDR to transmit.

The “Client”, which is the part responsible for providing the user with a graphical interface to change parameters has the following block diagram:

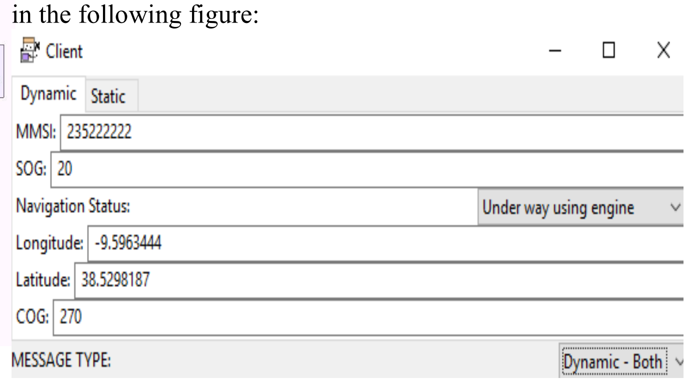


The used blocks were: 1) WX GUI Text Box ID “mmsi” that allows the user to input the MMSI; 2) WX GUI Chooser ID “NAVSTAT” that receives the navigational status and converts it into a number for the construction of the final message; 3) WX GUI Text Box ID “SOG” that receives the speed over ground value in knots; 4) WX GUI Chooser ID “tipe” that receives the type of ship and converts it into a number; 5) WX GUI Text Box ID: “length” that receives the length of the ship value in meters; 6) WX GUI Text Box ID “width” which receives the width of the ship value in meters; 7) WX GUI Notebook ID “notebook” which creates an interface to accommodate all the text boxes and choosers; 8) WX GUI Text Box ID “Long” that receives the longitude value for the position of the ship; 9) WX GUI Text Box ID: “Lat” which receives the latitude value for the position of the ship; 10) WX GUI Text Box ID “COG” that receives the course over ground value in degrees; 11) WX GUI Text Box ID “cs” which receives the callsign of the ship; 12) WX GUI Text Box ID “name” that receives the name of the ship; 13) WX GUI Chooser ID “channel_select” which allows the user to choose the AIS channel and which message does he wants to send. The available options are: Dynamic - CHA, Dynamic - CHB, Dynamic - Both, Static – A and Static – B.

IV. TESTS AND EXPERIENTS

In order to test the AIS Transponder, several tests were done in two different platforms. One of the platforms used was to connect another SDR to another computer and, with the “AISMON” and “OPEN CPN” software, which allows its user to receive AIS messages through the SDR and see them on a chart, it was possible to receive the generated messages by the SDR AIS Transmitter and see its position and other details on the chart.

The other used platform was a Portuguese Navy Ship at the Lisbon Naval Base. The purpose of the tests on this platform was to check out if a real AIS receiver would receive the messages transmitted by the SDR AIS Transmitter successfully. The tests were made with the following settings: The tested modes were the “Dynamic – Both”, “Static – A” and “Static – B”. For the “Dynamic – Both” mode the configuration was the following: MMSI: 235222222; SOG: 20 KTS; Navigation Status: Under way using engine; Longitude: -9.5963444; Latitude: 38.5298187; COG: 270. These parameters were set to the AIS Transponder as shown in the following figure:



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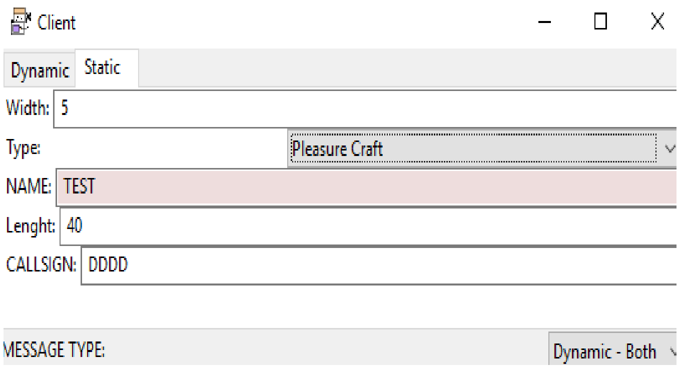
For the “Static – A” and “Static – B” mode tests, the configuration was the following: Width: 5 m; Type: Pleasure Craft; Name: TEST; Length: 40 m; Callsign: DDDD.
These parameters were set to the AIS Transponder as shown in the following figure:



The results of this test were also positive since the generated ship by the SDR AIS Transmitter was detected just like any other ship in the proximities.

V. Conclusions

The tests previously mentioned proved that the SDR AIS Transmitter can be works and it is able to send AIS messages that are received by commercial AIS equipment. The total cost of the AIS Transmitter is around 150€, which is only the cost of the SDR (HackRF One), because all the programs that are used are open source and free. The same SDR can also be used for receiving AIS data, without needing further equipment for the reception of AIS messages, making the SDR to work as a transceiver. Although this concept proves the potential of SDRs, it’s also important to point out the easiness of creating fake AIS contacts which might be a threat to navigation, especially if it’s done in a malicious way.

Even so, it has been shown how easy and cheap it is to create and replicate existing transmitters available on the market (which transmit messages that are open source) with the SDR technology.

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