Research, Design and Fabrication of a Data Transceiver Module for Vessel Monitoring Systems

Nguyen Dinh The Anh
Department of Space Systems Design
Vietnam National Satellite Center, VAST
Hanoi, Vietnam
E-mail: ndtanh@vnsc.org.vn

Le Xuan Huy
Department of Space Systems Design
Vietnam National Satellite Center, VAST
Hanoi, Vietnam
E-mail: lxhuy@vnsc.org.vn

Vu Tuan Anh
University of Engineering and Technology
Vietnam National University, Hanoi
Hanoi, Vietnam
E-mail: tuananhvu.uet@gmail.com

Bach Gia Duong
University of Engineering and Technology
Vietnam National University, Hanoi
Hanoi, Vietnam
E-mail: duongbachgia@gmail.com

***Abstract*—In this paper, we present a data transceiver module used in vessel monitoring systems. The realized transceiver is flexible, quick in response and low cost. The information about identification (ID), longitude, latitude and state of the vessel are packed into data frames and verified by a system prototype. The proposed system is capable of tracking targets and with information displayed on a computer's screen. The longitude and latitude data can be applied to Global Positioning System (GPS) using a Ublox Neo – M8N. The control board, data processing module and displaying module use STM32F407, 2.4 inch 320 x 240 TFTLCD, respectively. In addition, by using ADF7021 transceivers, the obtained data is FSK/MSK modulated with flexible changing of transmit/receive frequency in the band VHF-UHF, data rate from 0.05 kbps to 32.8 kbps, high receiving sensitivity. All experimental results are reported.**

Keywords—Vessel Monitoring System (VMS); VHF-UHF Transceivers;

I. INTRODUCTION

Maritime security has become major concerns of all coastal countries, and the fundamental requirement is "maritime domain awareness" via identification, tracking and monitoring of vessels within their waters [3]. In this paper, we will shortly introduce recent technologies and systems for different types of vessels. These systems have been designed and provided with regulatory framework for other reasons such as sustainable fishery, search and rescue, environmental protection, navigational safety, etc. Technologies such as automatic identification systems (AIS), Inmarsat-C, digital selective calling (DSC) and global system for mobile (GSM) are investigated with regard to the propagation/coverage, cost, reliability, etc. Finally, this paper proposes a data transceiver module used in vessel monitoring systems which is flexible, quick in response and low cost.

A. Recent technologies and systems for vessels

- Distant-Water Fishing Vessels: For sustainable fisheries, more and more fishing vessels are carrying automatic location communications (ALCs) as required by their flag State, the coastal State, or the regional fisheries management organizations (RFMO) to achieve greater control over fishing activities. The most widely accepted ALC is an Inmarsat-C transceiver with built-in GPS [3]. This satellite-based Vessel Monitoring System (VMS) has been implemented on most of the distant-water fishing fleet of developed countries as shown in fig. 1.

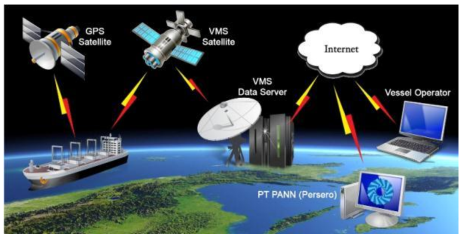


Fig. 1. Vessel Monitoring System

- International Convention for the Safety of Life at Sea vessels (SOLAS vessels): In order to improve the safety of life at sea, the safety and efficiency of navigation and protection of the marine environment, the International Maritime Organization (IMO) has introduced a series of measures including Ship Reporting System (SRS), Vessel Traffic Services (VTS), Global Maritime Distress and Safety System (GMDSS), Electronic Chart Display and Information System (ECDIS), and Automatic Identification System (AIS), through the 1974 International

Convention for the Safety of Life at Sea (SOLAS) [3].

- Other non-SOLAS vessels: Triggered by legislations such as E-911 of the United States, mobile positioning (positioning of the mobile phones) and location-based service (LBS) have become very popular topics of research and development. There are already many vessel tracking or fleet management applications available utilizing GSM, GPS, and/or other mobile positioning technologies. Cellular phones with built-in GPS have become one of the main trends. As GSM cellular phones are widely used instead of conventional marine radios for ship-shore communications in coastal waters, it is worth investigating the feasibility of its use in tracking small non-SOLAS vessels [3].

B. Evaluation and discussions

- Inmarsat-C: Inmarsat-C ALCs can be remotely programmed to send out position reports at regular interval and instantly when polled. However, they must first be downloaded with a Data Network Identification (DNID) for the ocean region they are logged-in [3]. Vietnamese waters lie in the overlapping coverage area of the Indian Ocean Region (IOR) and Pacific Ocean Region (POR) satellites. Therefore, the communications server of the Inmarsat-C VMS subsystem has to keep track of ALCs' current ocean region, unless the ALC has been set to log in to POR in preference to IOR. According to the time stamp of responding position reports, it takes only about one minute for the polling command to reach the ALC. However, the delivery of reports, especially from the Land Earth Station (LES) to the monitoring center via internet as e-mails, can cause delay of about 5-10 minutes and even more [3].
- AIS: AIS devices operate on 161.975 and 162.025 MHz autonomously, using self-organized time-division-multiple-access (SOTDMA) to broadcast their identification, status, and intention to other AIS devices within the coverage of their own cell. Dynamic information such as GPS position, course, and speed are broadcast every 2-180 seconds, depending on the speed and the turning rate. Identifications such as Maritime Mobile Service Identity (MMSI), call sign, vessel name, and vessel type, as well as voyage related information such as dangerous cargo, destination and Estimated Time of Arrival (ETA) are broadcast every 6 minutes. These features make AIS an ideal device with great potential in maritime security, especially when used with radars and an integrated ship registration database. Unfortunately, the equipment cost is too high for most non-SOLAS vessels [3]. Fig. 2 illustrates an AIS system.

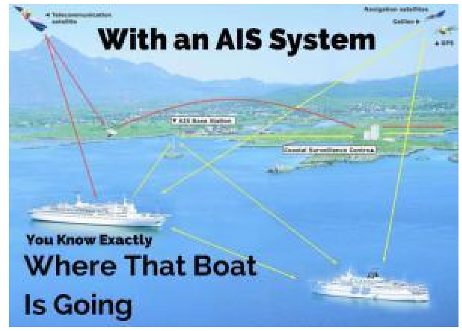


Fig. 2. AIS system

- VHF DSC: VHF DSC is a very important part of GMDSS, much cheaper than AIS, and has actually been used in identification and monitoring. However, as specified in ITU-R M.493, not all DSC equipment, which meet the minimum requirement of GMDSS, support polling and position reporting. Besides, without the optional expansion specified in ITU-R M.821-1, resolution of position coordinates is only about 1 nautical mile, which is inadequate for vessel tracking. Therefore, in order to utilize this technology for not only vessel monitoring but also search and rescue, equipment on both the ship-side and the shore-side have to be well specified and upgraded accordingly [3].
- GSM: GSM protocol limits the cell range to 37 km. Some base stations have been deployed to cover specific sea area. In these base stations, extended-cell technology has been adopted to double the cell range with halved capacity. However, it is observed that the use of GSM on coastal waters is not only limited by the rapid decay and fading in signal strength, but also by the frequent handover between coastal base stations. On the other hand, this also suggests that network-based mobile positioning using cell ID and TA (Time Advance) might be applicable to tracking specific targets. Some 15% - 40% of the position-reporting short messages failed to be delivered because of either a deep fading or a sudden handover [3].

In this paper, a data transceiver module used in the vessel monitoring systems is introduced. It can change frequency flexibly in VHF-UHF in order to directly communicate with the Continent besides the capability of connecting with satellites, quick response, easy to use, high customization and low cost. Moreover, the ID information, longitude, latitude and state of the device is obtained, packed into a data frame and tested with the proposed system which is capable of tracking targets.

II. PROPOSED TRANSCEIVER MODULE

The proposed transceiver module uses IC ADF7021 from Analog Device. ADF7021 is a high performance, low power, highly integrated 2FSK/2FSK/4FSK/MSK transceiver. It is designed to operate in the narrow-band, license-free ISM bands, and in the licensed bands with frequency ranges of 80 MHz to 650 MHz and 862 MHz to 950 Mhz. The device has both Gaussian and raised cosine transmit data filtering options to improve spectral efficiency for narrow-band applications [6].

The range of on-chip FSK modulation and data filtering options allow users greater flexibility in their choice of modulation schemes while meeting tight spectral efficiency requirements. The ADF7021 also supports protocols that dynamically switch between 2FSK/3FSK/4FSK to maximize communications range and data throughput. The transmit section contains dual voltage controlled oscillators (VCOs) and a low noise fractional –N PLL with an output resolution of < 1ppm. The ADF7021 has a VCO using an external inductor as part of its tank circuit. The dual VCO design allows dual-band operation where the user can transmit and/or receive at any frequency supported by the internal inductor VCO and can also transmit and/or receive at a particular frequency band supported by the external inductor VCO [6].

The RF output frequency is calculated by the following:

$$f_{OUT} = PFD(Interger_N + \frac{Fractional_N}{2^{15}}) \qquad (1)$$

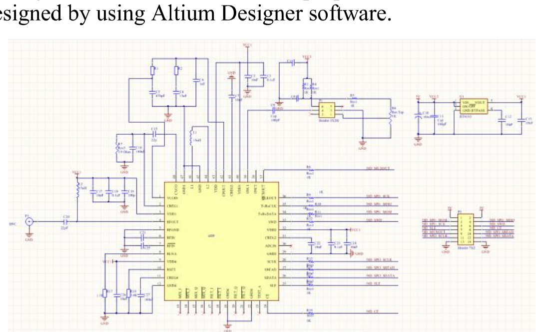
Where:

$$PFD = \frac{Xtal}{R\_Counter} \qquad (2)$$

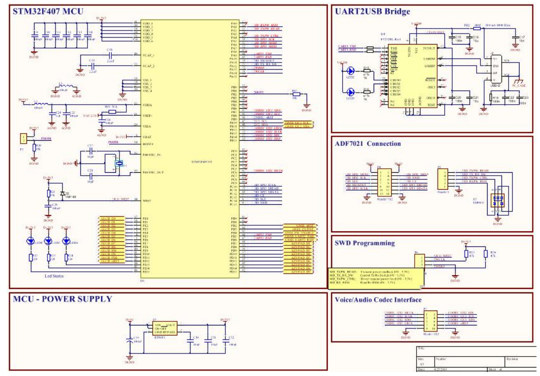
The control board uses IC STM32F407 to communicate with ADF7021, get the GPS information from IC Ublox Neo – M8N and pack into the data frame.

The STM32F407xx family is based on the high-performance ARM® Cortex®-M4 32-bit RISC core operating at a frequency of upto 168 MHz The Cortex-M4 core features a Floating point unit (FPU) single precision which supports all ARM single precision data-processing instructions and data types. It also implements a full set of DSP instructions and a memory protection unit (MPU) which enhances application security. The STM32F407xx family incorporates high-speed embedded memories (Flash memory up to 1 Mbyte, up to 192 Kbytes of SRAM), up to 4 Kbytes of backup SRAM [5].

Fig. 3 shows the schematic of proposed transceiver that is designed by using Altium Designer software.



(a)



(b)

Fig. 3. The schematic of proposed transceiver

(a) ADF7021 board, (b) Control and Display board

As discussed above, ADF7021 can operate in 80-650 MHz and 862-950 MHz. As a result, with the proposed transceiver, users can easily change the frequency by the touch screen on the control board with 10 kHz steps.

The ADIsimSRD Design Studio software is used to simulate Power-On Transient of ADF7021 and calculate its current consumption at an arbitrary frequency in 80-650 MHz and 862-950 MHz as plotted in fig. 4. Its current consumption is summarized in Table 1.

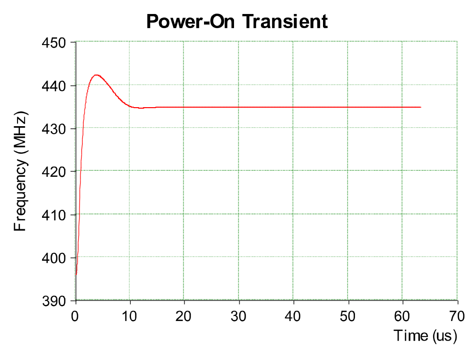


Fig. 4. Power-On Transient

Since the power-on transient is fast, the system delay is reduced significantly.

TABLE I. CURRENT CONSUMPTION

Period	Time	Current	Energy
Sleep	60.0s	100nA	0.2%
Idle/Rx	50.0ms	24.6mA	47.0%
Tx	71.7ms	19.3mA	52.8%
Average Current = 43.6uA Battery Life for 1.00 amp-hour capacity is 2.62 years			

III. MEASUREMENT RESULTS

Fig. 5 shows the fabricated transceiver module. Its core has a compact size of 90×55 mm which is suitable for portable devices. The proposed transceiver can be attached directly to a vessel or it can be integrated with a wireless system.

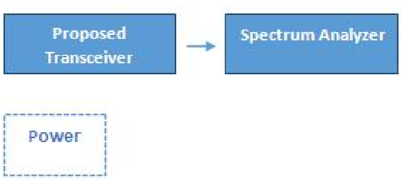
(a)

(b)

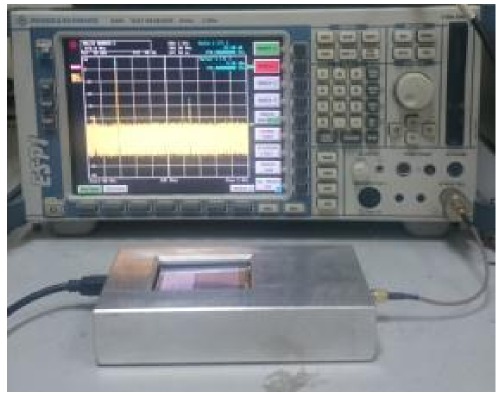
Fig. 5. The proposed transceiver (a) inside view, (b) outside view

A. Measurement results of the proposed transceiver

The ESPI Spectrum Analyzer 9 kHz - 3 GHz is used to verify the proposed transceiver as in fig. 6 and the measurement results are shown in fig. 7-9.



(a)



(b)

Fig. 6. Testing the proposed transceiver

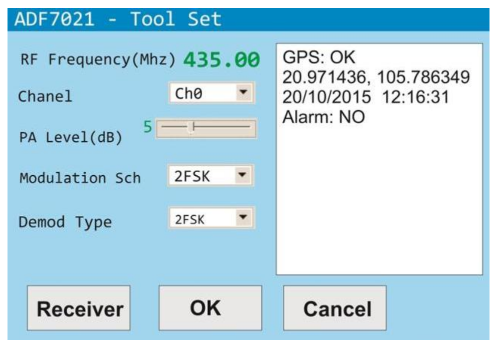


Fig. 7. Setting parameters

Transmit/receive mode, frequency, power level can be set using the touch screen of the control board. The ADF7021 transceiver's touch screen is shown in fig. 7.

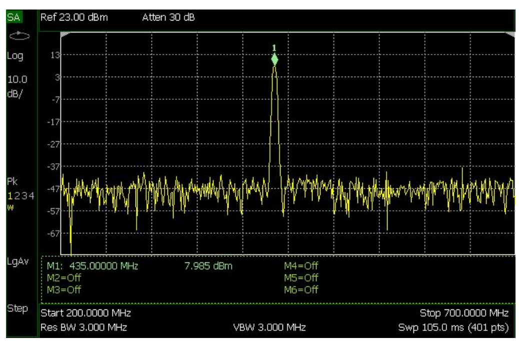


Fig. 8. Transmitted power spectrum

As seen on fig. 8, the transmitted power level and frequency equal to those once set on the touch screen of the control board. The transmitted power is approximately 8 dBm at 435 MHz.

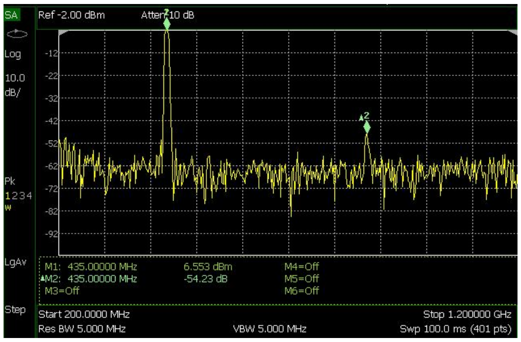


Fig. 9. Measurement of harmonics

The suppression of harmonics is an important parameter. Normally, a good RF component requires at least 30 dB for the suppression of harmonics. In the proposed transceiver, we integrated a LC bandpass filter to get about 50 dB for the suppression of harmonics in whole operating band. The measurement result of harmonics is demonstrated in fig. 9.

B. Using the proposed transceiver on vessels

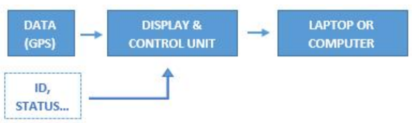


Fig. 10. On vessels

The proposed transceiver can directly connect to a computer as illustrated in fig. 10. The information is packed into data frames including ID, longitude, latitude, state of vessel (<GPS>, <ID>, <LAT>, <LONG>, <SOS>). They are then displayed on the computer's screen by using our software. This will help the vessel owners monitor the information and the state of vessel as well as increase the safety on the sea.

We tested the proposed transceiver in a small area with a radius of 2 km. The results are showed in fig. 11 – 12.

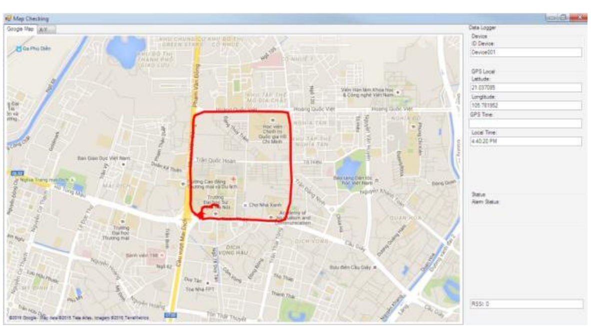


Fig. 11. Displaying the location in Google map

Our software is applied with the offline Google map, which helps users determine the direction of movement as depicted in fig. 11. The red line is the route of one device.

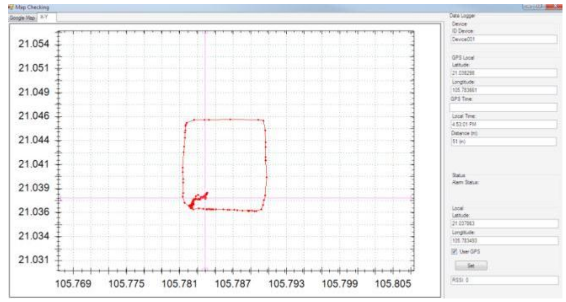


Fig. 12. Displaying the position in XY axis coordinates

Beside the digital map, our software is capable of tracking by using XY axis coordinates, displaying the position of the vessels and calculating the distance from the vessels to the Continent as demonstrated in fig. 12.

C. Using the proposed transceiver in wireless systems

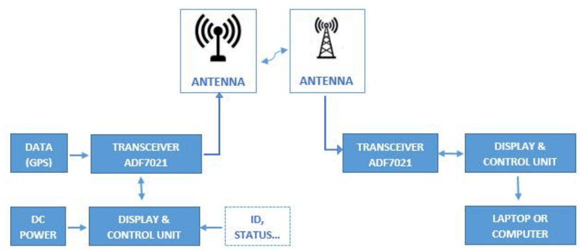


Fig. 13. Wireless system prototype

Fig. 14. A wireless system using proposed transceiver

The wireless data transceiver system is emulated and tested at short distance as demonstrated in fig. 13-14. In addition to the information of the coordinate of the vessels, this system is also capable of monitoring the state of the vessels whether they are safe or not (SOS) as shown in fig. 15-16.

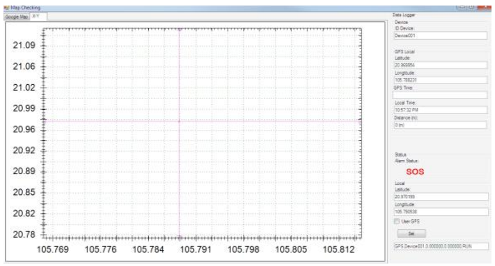


Fig. 15. Displaying in XY axis coordinates

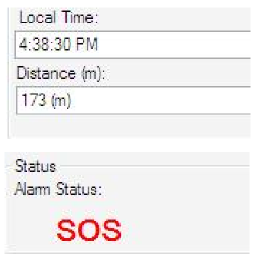


Fig. 16. State of vessels

When in danger, the control station in the Continent will receive the urgent message (SOS) and determine exactly the coordinate of the vessels at that time. After that, they will cooperate with other systems to rescue quickly and sensibly.

IV. CONCLUSIONS

In this paper, we have proposed a solution which increases the flexibility and customizes the vessel monitoring system. We have successfully built and tested a system prototype which is capable of tracking targets and monitoring on the computers' screen at short distance.

ACKNOWLEDGMENT

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REFERENCES

[1] Jacques Verborg, " The European VMS", International conference on Fisheries Monitoring, Control and Surveillance, Brussels, Belgium, October 2000.

[2] James C. Reynolds, Robert P. Denaro and Rudolph M. Kalafus, " GPS-Based Vessel Position Monitoring and Display System", IEEE AES Magazine, July 1990.

[3] Shwu-Jing Chang, "Vessel Identification and Monitoring Systems for Maritime Security", IEEE 37th Annual International Carnahan Conference on Security Technology, pp. 66-70, 14-16 Oct. 2003,.

[4] Marza Ihasan MARZUKI, Rene GARELLO, Ronan FABLET, Vincent KERBAOL, Philippe GASPAR, "Fishing Gear Recognition from VMS data to Identify Illegal Fishing Activities in Indonesia" IEEE, 2015.

[5] STMicroelectronics, "STM32F407XX Datasheet".

[6] Analog Devices, " High Performance Narrow-Band Transceiver IC ADF7021 Datasheet".