LOW COST AIS RECEIVER FOR COASTAL ZONE MONITORING

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ABSTRACT

Article presents trends in Automatic Identification System (AIS) receiver and transponder construction and operation. Features of low cost AIS systems build by author's team are presented. Author copes with integrity and dependability of such non-professional solution. Example of monitoring Southern Baltic Sea costal zone is presented for comparison.

1 INTRODUCTION

AIS is an part in the SOLAS convention. It is a shipboard transponder system, operating in the VHF maritime band, that sends ship parameters and present status to other ships in vicinity and to shore stations. These information are:

- identification (MMSI, Call Sign, Name),
- position,
- heading,
- cargo information,
- other important issues.

At present many users of AIS systems are not professionsls and safety of navigation awarnenes in this group increases due to fact of using such system like AIS. This together with relatively low cost of AIS implementation leads to interest in small AIS receivers and AIS class B transponders.

1.1 Requirements of carrying AIS onboard ships

The requirements for AIS are outlined in Subparagraph 2.4 of Regulation 19 of Chapter V of SOLAS (the International Convention for the Safety of Life at Sea) [7]. The system has become mandatory on all new ships in international traffic since 1 July 2002, include all passenger ships, tankers and other ships of 300 tons during international voyages. System has been fully implemented in year 2008, the system will also cover all ships of 500 tons or more in national voyages. The legal requirements state that [5]: "AIS shall:

- provide automatically to appropriately equipped shore stations, other ships and aircraft information, Including the ship's identity, type, position, course, speed, navigational status and other safety-related information;
- receive automatically such information from similarly fitted ships;
- monitor and track ships;
- exchange data with shore-based facilities.

1.2 Some legal aspects of using AIS

Theoretically, the system is capable of handling over 2000 reports per minute, and updates as often as every two seconds. The VHF range is typically 20NM (abt. 40 km) for ship-to-ship communication and larger for ship-to-shore communication. The system uses self-organizing time division multiple access (SOTDMA) technology to fulfill the high broadcast rate and to ensure reliable ship to ship operation. AIS is required for the following ships [7,8]:

- Passenger vessels, of 150 gross tonnage or more, not later than July 1, 2003;
- Tankers, regardless of tonnage, not later than July 1, 2003;
- Vessels, other than passenger vessels or tankers, of 50,000 gross tonnage or more, not later than July 1, 2004;
- Vessels, other than passenger vessels or tankers, of 300 gross tonnage or more but less than 50,000 gross tonnage, not later than the first safety survey for safety equipment on, or after July 1, 2004, but no later than December 31, 2004.

IALA (International Association of Maritime Aids to Navigation and Lighthouse Authorities), stated purpose of AIS as: "to improve the maritime safety and efficiency of navigation, safety of life at sea and the protection of the marine environment". IALA presented the first proposal for AIS to IMO in the 1990s. The original couse of origin for the system was to identify vessels on the radar display; apart from that, the IALA Technical Clarifications [5] on ITU Recommendation ITU-R M. 1371-1 [9] states: "It was long been realized that an automatic reporting device fitted to a ship would have the potential to increase significantly the safety of navigation and would allow the improved control and monitoring of the maritime events. IMO together with the International Telecommunications Union (ITU) and the International Electrotechnical Commission (IEC) developed a new navigation system called the Automatic Identification System (AIS)".

1.3 Broadcasting in AIS

A Class A AIS unit broadcasts the following information every 2 to 10 seconds while underway, and every 3 minutes while at anchor. The information broadcasted includes[12]:

- MMSI number,
- Navigation status (as defined by the COLREGS "at anchor", "under way using engine", "not under command"),
- Rate of turn - right or left, 0 to 720 degrees per minute,
- Speed over ground - 1/10 knot resolution from 0 to 102 knots,
- Position accuracy - differential GPS or other and an indication if RAIM (Receiver Autonomous Integrity Monitoring) processing is used,
- Longitude - to 1/10000 minute and Latitude - to 1/10000 minute,
- Course over ground - relative to true north to 1/10 th degree,
- True Heading - 0 to 359 degrees derived from gyro input,
- Time stamp - The universal time to nearest second.

In addition, the Class A AIS unit broadcasts the following information every 6 minutes [4, 12]:

- MMSI number,
- IMO number - unique identification,

- Radio call sign - international call sign assigned to vessel,
- Name - Name of ship, 20 characters,
- Type of ship/cargo,
- Dimensions of ship,
- Reference point location (i.e. onboard antenna location),
- Type of position fixing device,
- Draught of ship - 1/10 meter to 25.5 meters,
- Destination - 20 characters,
- Estimated time of Arrival at destination - month, day, hour, and minute in UTC

Reporting intervals of ship in AIS are presented in table 1. AIS carrier link parameters are described in table 2.

Tab1. Reporting intervals in AIS

Ship's dynamic conditions	Reporting interval
Ship at anchor or moored and not moving faster than 3 knots	3 min
Ship at anchor or moored and moving faster than 3 knots	10 s
Ship 0–14 knots	10 s
Ship 0–14 knots and changing course 31	3 1/3 s
Ship 14–23 knots	6 s
Ship 14–23 knots and changing course	2 s
Ship >23 knots	2 s
Ship >23 knots and changing course	2 s

Tab. 2.AIS carrier link requirements

Parameter	Characteristics
Frequencies	161.975 and 162.025MHz (channels 87B and 88B)
Wavelength	1.85m
Transmitter power	2 and 12.5W
Bandwidth	12.5 and 25.0 kHz
Modulation	Gaussian minimum shift keying (GMSK)
Modulation index	0.25 for 12.5 kHz and 0.5 for 25 kHz
Receiver sensitivity	−107dBm for 25 kHz and −98dBm for 12.5 kHz bandwidth
Bit rate	9600 bit/s
Synchronization	UTC
Message length	26.7 ms (256 bits)
Frame length	1 min (2250 messages)
Capacity	4500 messages/min (for the two AIS channels)
Distance delay	12 bits, equivalent to 202 nm
Access schemes	SOTDMA, ITDMA, RATDMA, FATDMA

3. AIS TECHNICAL ASPECTS

AIS system consists of one VHF transmitter, two VHF TDMA receivers, VHF DSC receiver, and standard marine communications links complying IEC 61162/NMEA 0183 [6] to shipboard display and sensor systems. Position and timing information is obtained from global navigation satellite system (GNSS) receiver. Other information transmitted by the AIS, are digitally obtained from shipboard equipment via electronic interfaces (see fig.1).

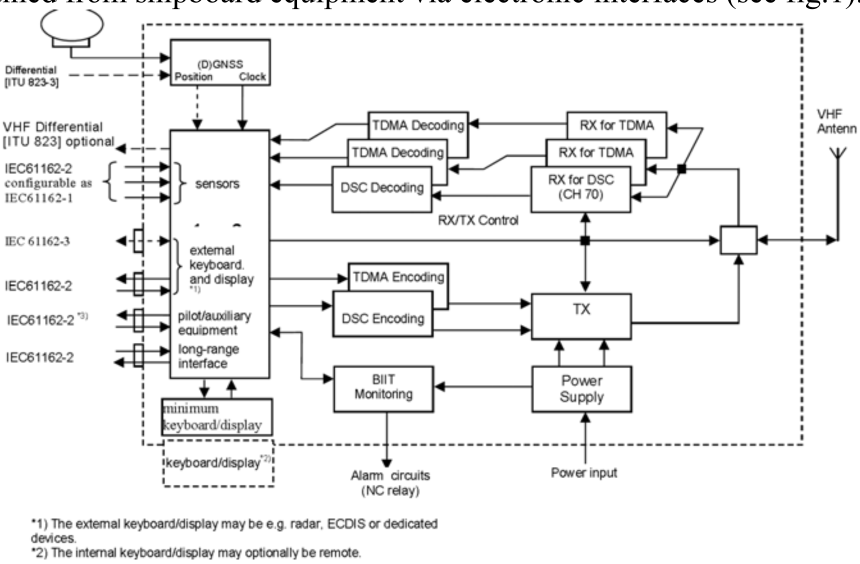

Fig.1 AIS system dependicies diagram [11, 10]

Transmissions is autonomous, continuous in 9.6 kb GMSK(Gaussian Minimum Shif Keying), FM (Frequency modulation) modulation over 25 or 12.5 kHz, channels using HDLC (High-Level Data Link Control) packet protocols. To avoid interference problems, as well as to allow channels to be changed without radio link loss, each station transmits and receives on two radio channels and it is: 161.975MHz - marine channel 87, and 162.025 MHz marine channel 88. Theoretically, automatic contention resolution between itself and other stations is provided in AIS as well as and communications integrity is maintained even in overload situations[6,11].

A position report from one AIS station (that previously derived one free slot) fits into one of 2250 time slots established every 60 seconds. AIS stations continuously synchronize themselves to each other, to avoid overlap of slot transmissions. Slot selection by an AIS station is randomized within a defined interval, and tagged with a random timeout of between 0 and 8 frames. When a station changes its slot assignment, it pre-announces both the new location and the timeout for that location. In this way new stations, including those stations which suddenly come within radio range close to other vessels, will always be received by vessels [10].

Type of transmission used in AIS guarantees almost unlimited capacity of targets - ships. When system works with high number of targets the throughput is mainly focused for vessels that are closer to own position (abt. 10 Nm). Thus the vessels that are in greater distance are not shown and not tracked all the time.

Other problem is to present huge amonut of AIS objects over Radar screem or chart device. From author's expeirience it is not unsignificnat problem. During shipping in Malacca strait AIS objects weri in hundreds (overe 300 different objects in range); nor radar neither chart system were able to present more than 200 AIS objects. Those displayed hadnt always had proper names, and parameters of its were unavialible for user. This situation might underline that AIS is not always the solution, at least the only solution.

4. SIMULATOR OF AIS RECEIVER

For comaprison of AIS system availibility, fast time simulator has been developed. Construction of simulator requires programming environment where modeling of radio channel with GMSK modulation is possible. GMSK is subtype of Minimum Shift Keying (MSK) modulation. MSK is a continuous phase frequency shift keying (FSK) binary modulation format. FSK is the digital equivalent to analog frequency modulation (FM). MSK is a form of FSK, with modulation index h = 0.5. MSK is popular in wireless communications because of its properties and desirable characteristics for digital modulation in land and sea mobile radio; and these are [2]:

1) compact output power spectrum;
2) high immunity to noise and interference;
3) ease of implementation.

Minimum Shift Keying (MSK) modulation fulfiles the above requirements except for the first one. To make the MSK output power spectrum more compact, the premodulation low pass filter is added and this filter should meet the following conditions[2]:

1) narrow bandwidth,
2) sharp cutoff to suppress high frequency components,
3) small overshoot impulse response to prevent excess deviation of the instantaneous frequency,
4) preservation of an integrated filter output pulse capable of accommodating a 90° phase shift to ensure coherent demodulation.

Often a premodulation low pass filter satisfying the above requirements is adopted for Gaussian Minimum Shift Keying (GMSK) modulation, where the data sequence is passed through a Gaussian filter, and the output of the filter is MSK modulated [1]. The width of the Gaussian filter is determined by the bandwidth-time product called BT (e.g, BT = 0.3 for GSM and BT = 0.5 for AIS).

MSK is unique due to the relationship between the frequency of a logical zero and one: the difference between the frequency of a logical zero and a logical one is always equal to half the data rate. The modulation index is 0.5 for MSK, thus:

$$m = \Delta f \times T$$

where:

$$\Delta f = \left| f_{logic1} - f_{logic0} \right|$$

$$T = 1/ bitrate$$

For example, a 1200 bit per second baseband MSK data signal could be composed of 1200 Hz and 1800 Hz frequencies for a logical one and zero respectively fig. 2,3.

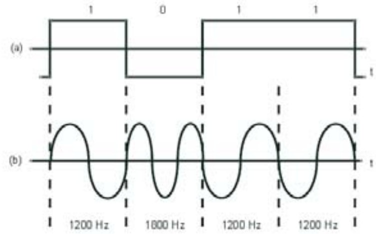

Fig. 2. 1200 baud MSK data. a)NRZ data, b)MSK signal [2]

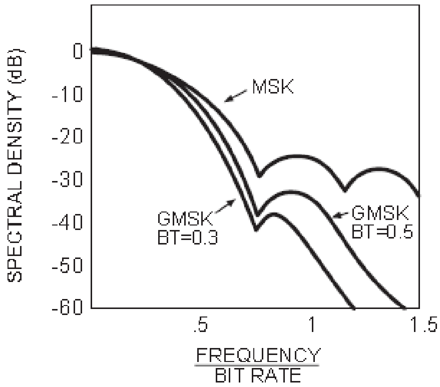

Fig. 3. Spectral density for MSK and GMSK (BT=0.3 and 0.5) [2]

AIS simulator has been developed in Matlab Simulink environment by the group of reaserchers with taking account following assumptions:

- additive white Gaussian noise channel with SNR ratio of -44 dB is used;
- AIS report is treated as random string with Bernoulli distribution;
- power of transmission in single AIS channel is at level of 12.5W;
- sampling period is 9600bps;
- speed and amount of transmitted data was obtained to simulate a group of 10 vessels;
- simulated vessels are in VHF range of abt. 12Nm;

For such formulated problem three parameters has been registered: rrror rate, total number of errors and total number of symbols used for comparison. Screen with simulator block schematic is presented at fig. 4.

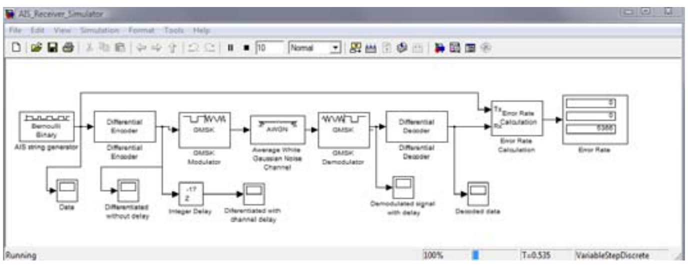

Fig. 4. AIS receiver simulator schematics

One of proposed simulator possible application is assessment of readout errors in low cost AIS system build on basis of CMX 7042 type microcircuits. And assessment made for BT=0.3 and BT=0.5 presents error rate as follows:

BT product	Error rate	number of errors	total symbols compared
0.3	0,000750	72	9,60E+04
0.5	0,000771	74	9,60E+04

5. COASTAL ZONE AIS MONITORING WITH LOW COST RECEIVERS

5.1 Software Side

As a cost of receiver drops the new trend has appeared in tracking of vessels. This together with availability of satellite based images software (like Google Earth) has lead to increase of such tools on commercial market and between enthusiast of ship tracking. Typical tool is VesselTracker presented on fig 5. From hardware side it uses low cost AIS receiver (like those SR 162, or Comar) and Ethernet adaptor to serial port. It transmits data over internet to decoding server, that apart from this, sends data to clients based on Google Earth.

Fig.5. Typical commercially available AIS visualization over Goggle Earth .kmz link (courtesy of Vesseltracker.com)

Other type of software is comercial and special purpose software based on charts (vector and raster) on desired area. Typical example of such software is Maritime Safety Information Exchange System implememted in Polish Maritime Authorities, and other countries as well. It basis on Helcom (Helsinki Commision) AIS exchange data, that provides high speed AIS link over Baltic Sea. System uses redundant high speed connections with specialy designed replications servers and main switch engine server. At the client side, computer utilizes raw data and transltes it to operator demands. Such system is presented on fig 6. Both, at figures 5,6 same situation is presented.

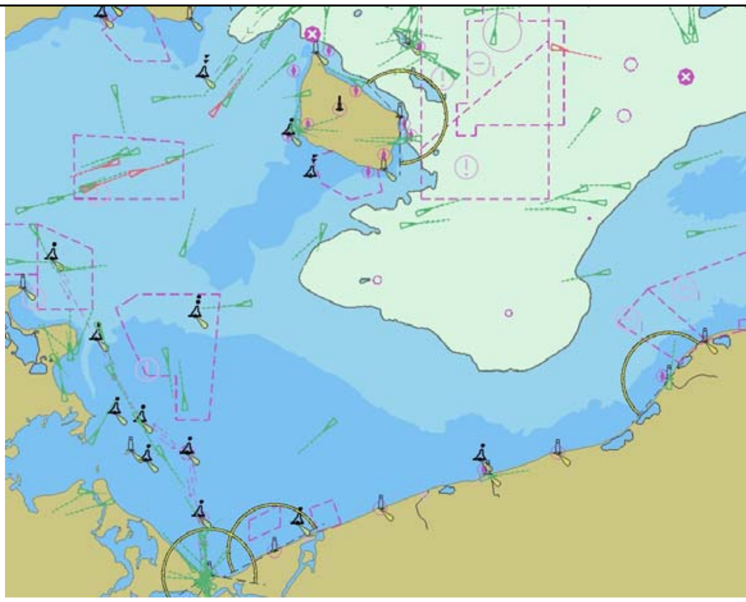

Fig.6. Visualization in special purpose system (courtesy Gdynia Maritime Administration VTS Center)

5.2 Construction Of Low Cost AIS System

As described previous AIS system seems to be very complex and constructional demanding structure; its true when transponder class A is taken into consideration; whilst receiver and class B transponder is rather simple and quite inexpensive device. Building AIS receiver developer needs following subsystems:

1) radio RF circuit and FM detectors for proper frequency,
2) analog audio recovered from RF interface,
3) GMSK demodulator,
4) HDLC/NRZI(Non Return to Zero Inverted) buffer,
5) common digital interface.

Radio RF and detectors could be easily build using existing VHF marine band radio or so called radio scanner with receiving marine frequencies function. Cost of such scanner is around 100 USD. Other possibility is to build dedicated radio circuit – although fine tuning will be problem than it is in existing radio. Any RF circuit needs to have analog output of unfiltered audio channel. Huge Internet based directory of rebuilding RF's possibilities is described in [3]. At this point analog signal is converted to digital signal (ADC) – and of possible soutions could be implemented in computers audio card. Although its not to complicated it gives satosfactory results. After that, all processing is done in specialized software like Shipplotter (software license) or better AISMon (freeware license). Such implemntantion made by author with Kenwood TH 28 VHF handheld scanner is presented at fig. 7.

Fig.7 Kenwood TH28 handheld scanner with application for AIS decoding during tests

Other option is to use dedicated chip, like those produced by CML microcircuits of CMX type. CMX7032 that combines in its structure subsystems: analog audio recovered from RF interface, GMSK demodulator, HDLC/NRZI (Non Return to Zero Inverted) buffer, common digital interface. Additionally CMX7032 meets the requirements for SOLAS class B transponder [1]. Schematic of this microchip system is presented at fig.8.

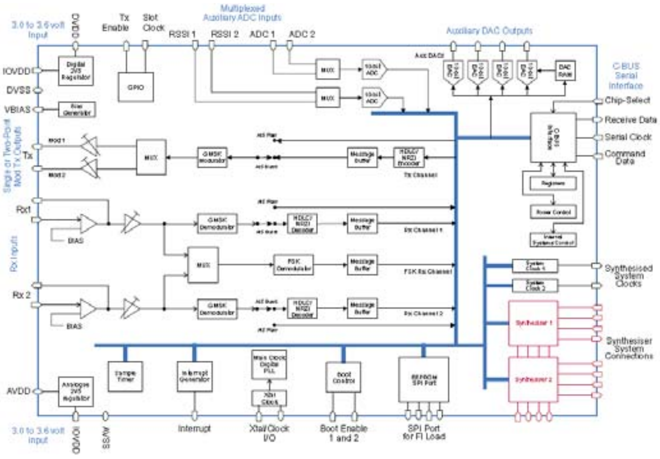

Fig. 8 CMX 7042 microchip schematics [1]

Adding to CMX chip microprocessor and RF part let's build standalone (without computer based software) low cost receiver with class B transponder possibilities. This seems to be a perfect solution for particularly any small vessel. Preliminary tests of this chip are quite optimistic and ranges obtained during field surveys are similar to those established by professional receivers. Although full effectiveness of range in real conditions, and comparison to other types of AIS is not yet done. Fig. 5 presents proposed application schematics. Costs of single CMX AIS microcircuit is at level of 50 USD.

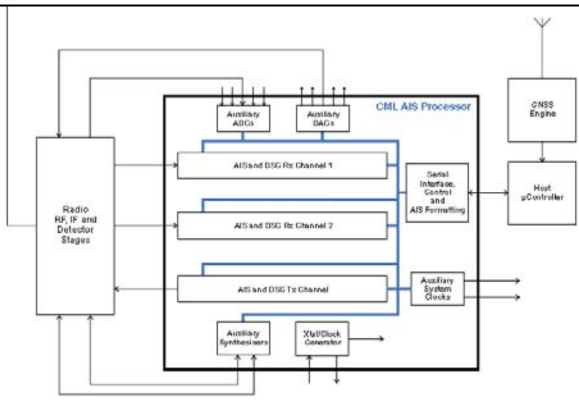

Fig. 9 Application of CML microcircuit.[1]

2 CONCLUSIONS

AIS is open navigation standard now, and if it is used properly, it is ultimate tool for navigation safety enhancement. However it is oftenly confused with substitute of radar and such situation for less experinced useres seems to be dangerous. It can be projected that new technologies will arise over AIS (like it is in aircraft navigation).

Nowadays it is possible to build AIS receiver using commonly available components i.e.: standard VHF radio and PC computer. This option is often devloped by shippotters (peoples that's are passionate about ships – ship-lovers seems more appropriate name). Detailed technical solutions used for AIS are presented in article. Also following conclusions can be stated:

- low cost AIS receiver or class B transponder can obtain high integrity level – compared to commercially available ones;
- low cost receiver together with appropriate interface can be used as remote traffic monitoring station,
- created simple simulating environment can easily model this low cost receiver.

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