Standalone Maritime Aids-To-Navigation AIS Mobile Station

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Abstract - Automatic Identification System (AIS) is a VHF radio broadcasting system where transmits packets of data via VHF data link. It enables vessels and coastal-based station that equipped with AIS equipment to send and receive useful information. This information can be help in situational awareness and provide a means to assist in collision avoidance. In addition, AIS can be use as Aid-To-Navigation, by providing the location and additional information on buoys and lights. Besides, it can also contain details information in meteorological status of a particular ship location. This paper presents the standalone AIS system that able to receive and report own ship location, meteorological data collection and broadcast safety related information if necessary. With the unique ship's MMSI number, all the information of that particular ship can be monitor by using AIS program written in C++ programming language.

Index Terms— Automatic Identification System (AIS), Aids-To-Navigation (AToN)

I. INTRODUCTION

The use of radar technology in marine navigation has led to so called "radar assisted collisions". This was initially used to describe a problem frequent during the early days of radar technology at which time only a small portion of ships carried radar. Radar undoubtedly gave the mariners a whole new awareness of the traffic situation at night or in heavy fog. In addition, when only a very few merchant ship had radar technology, having radar gave a competitive advantage (at night or in heavy fog) since ships without radar had keep low speed and were unlikely to alter their course quickly. The radar however allowed the mariners to maintain full speed and maneuverability. "Radar assisted collisions" started to occur when more and more mariners got this new sight organ, and they were all following the logic outline above, assuming that others did not have radar technology.

In order to increase the safety of maritime and river traffic, improve traffic control and enhance aid for navigation service, AIS is introduced. It overcomes some weaknesses of previous navigation system such as radar technology. AIS will continuously transmit useful information nearby vessels. All other vessels will also receive data from other AIS equipped ship. The information including vessel identity, course and speed of vessel, classification, vessel registration number and others user configure information. With the present of AIS, the vessels able to locate any others neighbor vessels and send alert signal if necessary to avoid collision. There are two classes of AIS, Class A and Class B as described below:

- AIS class A ship-borne mobile equipment – intended for SOLAS vessels.
- AIS class B ship-borne mobile equipment – intended for non-SOLAS vessels.

AIS technology is widely use in several applications currently such as AIS Base Stations, Aids-to-navigation (AIS AToN), AIS on search and rescue aircraft and AIS search and rescue transmitters (AIS SART).

Without AIS, mariners must address each other by referring their position (i.e. "ship at position X Y") when trying to make radio contact. This way of addressing ship often does not yield an answer at all, or even worse, it does yield an answer, but from wrong ship. Apart from providing a solution to this problem, other objectives behind the introduction of AIS are to "assists in target tracking", "simplified informational exchange", and "provide additional information to assists situational awareness".

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Primary objective of this research is to design and construct a standalone AToN AIS mobile station for vessels where it acts as AIS client by implementing AIS technology to exchange meteorological and navigational information with AIS base station or with other AIS mobile station.

In this article, general hardware description is presented first, along with the brief overview of software design. Details AIS data packet encapsulation, binary data encoding and decoding technique is then introduced and described. Also, a detail of AIS binary message type is addressed. Finally, the final outcome of this project will be presented.

II. HARDWARE DESIGN

The hardware system block diagram shown in Fig1. The AIS AToN system mainly consist of the AIS transceiver, AIS controller, power supplies unit and followed by the peripherals such as GPS, sensors and navigation lantern. The power supply for this system is provided by two 12V sealed rechargeable lead acid batteries and two solar panels rated power 40W each is used to recharge the batteries. The power system of this system is designed to self-contained, power efficient and low maintenance required. Solar controller takes important part in this case which able to switching between the empty batteries to recharge by solar panel and the fully charged batteries to supply power to the system. The current sensor at the AIS controller power path is use to check the current batteries status, while the current sensor at the solar controller is to check the batteries charging status.

There are some weather sensors such as pressure sensor, wind speed/direction sensor. These sensors are connected to the Zeno data logger, while the Zeno data logger is connected to the AIS controller. It is specifically developed for environment monitoring purposes. Regarding its area of expertise, it is used to collect meteorological data from attached sensors as shown in Fig1 in this project. In spite of the current design, it also allows the system to reconfigure to attach with more and different type of sensors.

The AIS transceiver is working together with a Differential Global Positioning System (DGPS) module. Connection between the AIS controller and AIS receiver allow the communication in between both devices. The communication signals stands by its specific protocol and data format. Details of the communication will be deliberate intensely in next session. Besides there is another GPS module attach directly to the AIS controller. It is to provide an accurate one hertz pulse to AIS Controller for lantern control purpose and also for backup GPS besides DGPS.

Furthermore, Navigational lantern is connected to the AIS controller through a specific lantern controller. The only task for the lantern controller is receiving instructions from the AIS controller and then drives the lantern accordingly. The AIS controller may need to send a serial data for example to control lantern blinking pattern.

There are five current sensors installed in the system. Current sensors that install at the lantern and Radar beacon power path are for device status monitoring purpose. If the device is turn on, the device will consume current and the current feedback path will return an analog signal to microcontroller. Hence, the ADC (analog to digital converter) of the microcontroller will decode the analog signal and follow by the internal firmware algorithm will monitor the signals and determine the status of the device.

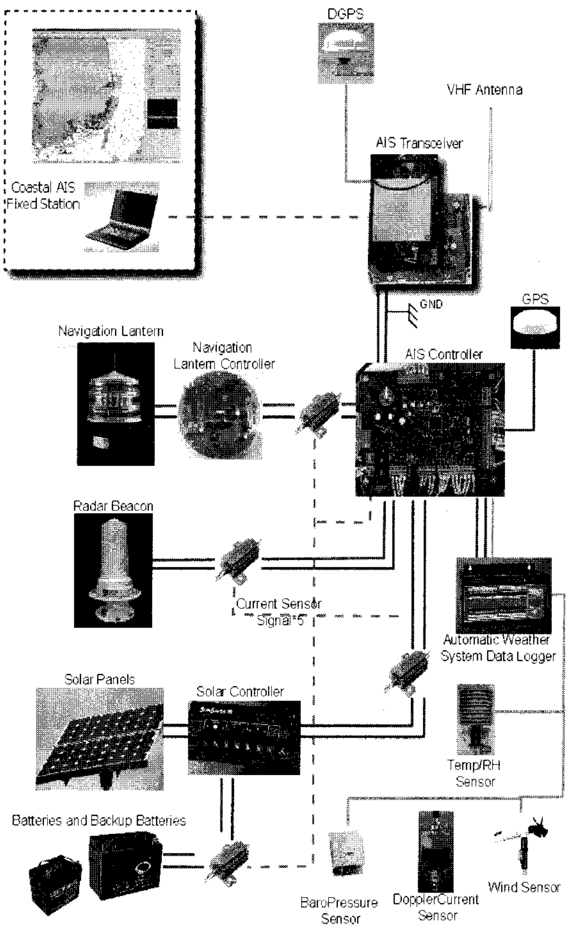

Fig1. Standalone AIS AToN Mobile Station Hardware Diagram

Difference purposes apply to difference current sensing path. For the case of the solar controller, it is use to check the available batteries supply power. When a week current detected, its mean current supply batteries needs to switch to charge by the solar panels, while the current sensor in the solar controller path is to check the batteries charging status.

In fact, the status of the navigation lantern needs to check to secure from the possible damages impact on the lantern. When the signal had conveyed to lantern controller and the lantern current sensor didn't sense current consumption by the lantern, AIS AToN system will aware the problem that occurred at lantern.

Racon is an acronym for radar beacons, which are the transponder devices use as a navigation aid, identifying landmarks or buoys on a shipboard marine radar display. The merge of Racon technology in this system entirely enhance the navigational aids that provide to vessel's crews. Racon technology is a standalone system towards AIS AToN system, it able to operate itself with its unique control system. In this system, the existing of Racon need to be acknowledges. Thus, a current sensor had attached at the Racon power supply path. The current sensor will sense the occurrence of the Racon and then feedback to the microcontroller. This information will embedded inside the AIS message ID and convey to the respective station. This fraction of operation is essence to the system to let the main station observe the Racon condition.

III. SOFTWARE DESIGN

A. Theory of Operation

In simple, this system contains some current and voltage sensors, weather sensors and a configurable lantern. The system block diagram is shown in Fig2 where shaded part is AIS controller. The main purpose of AIS controller is to collect data from all sensors, receive various types of AIS messages, pack them into appropriate AIS packet format and send it out via AIS transceiver.

There are two microcontroller units in AIS controller, PIC16F877A and ATMEGA128. PIC16F877A is connected to all the current and voltage sensors. At also, it connects to a GPS module and lantern controller. Its task is to collect all the current and voltage relevant information, positional and time/date information from GPS module, and send to the ATMEGA128 for further processing. At the same time, it receives command from ATMEGA128 to configure lantern controller.

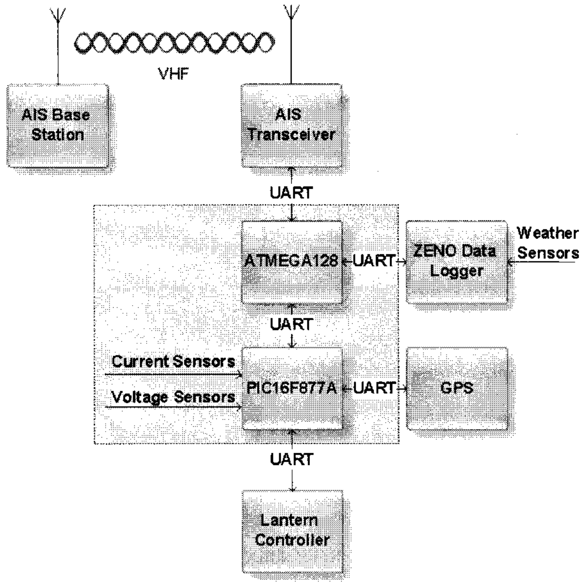

Fig2. System Block Diagram

Second microcontroller unit (ATMEGA128) is connected to ZENO data logger, AIS transceiver and also to PIC16F877A. The main task of ATMEGA128 is to receive all AIS packets from AIS transceiver and decide to drop or process the packets and also, it encapsulate necessary information with proper AIS packet format and send it out via AIS transceiver. Fig3 illustrates the firmware flow chart of AIS controller.

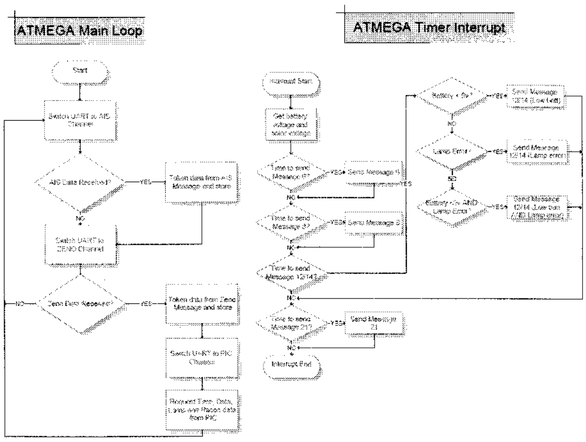

Fig3. Firmware Flow Chart

As shown in Fig3, the there are two process loop in the firmware. First is main loop and another is interrupt loop. Main loop will decode incoming AIS packets, reading meteorological information from data logger and request the rest sensors information from PIC16F877A. Interrupt loop will send AIS packets periodically and depend to situation; safety message might be broadcasted if necessary.

B. Packet Encapsulation, encoding and decoding Technique

Instead to process incoming packets or encapsulate outgoing packets, it is first necessary to understand the concept of packet encapsulation. The layer approach is implemented through the use of encapsulation. This concept can be best explained using the example shown in Fig4. This example shows how the sensors data is encapsulate before broadcast via AIS transceiver.

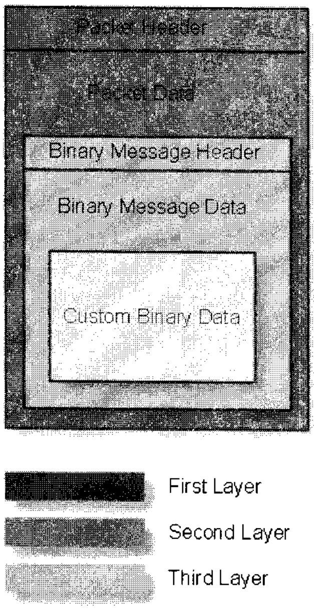

Fig4. Data Encapsulation Example

Starting at the third layer, when it is time to generate a packet which contains sensors information, it is need to pack into proper binary data format. This binary data would then be passed down to second layer, which would construct a binary message consisting of a header of binary message and binary data with proper data format as its datagram. Generally, the header contains the information such as message type, repeat indicator and source MMSI number. Not all messages will have same header field, some might include destination MMSI number. It depends to the message type.

At the first layer, a complete AIS packet is constructed to hold a binary message. Similar to binary message, the AIS packet consists of header and data where header contains information such as packet type, packet sequence identifier, source MMSI number, channel and message ID. Same with binary message, not all packets have same header. Incoming packets and outgoing packets have different header field. The data field of first layer contains the complete binary message to be transmitted. After this process, the complete packet will forward to AIS transceiver and send out via VHF radio band. An example data flow diagram for incoming packet is shown in Fig5.

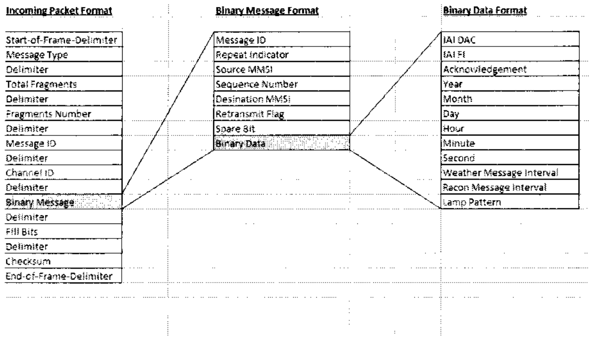

Fig5. Incoming Packet data format with Binary Message ID 6

As explained above, a full AIS packet will come with header, binary message and checksum. All fields are in standard ACSII format except binary message is encoded with six bit binary format. This will be explaining later in the same session. Consider the following incoming packet:

!AIVDM,1,1,,A,14eG;o@034o8sd<L9i:a;WF>062 D,0*7D

The headers and checksum of this packet can be easily get using standard C string library but there is a need to have custom algorithm to decode the data from binary message which encoded with six bit binary format. Each ACSII character corresponds to six binary bits, so it is needed to convert them into six binary bits and strung back together. There are two ways to do this decoding. First method is by calculation, as shown in formula (1):

$$A = B\text{-}48$$
$$A = A\text{-}8,\ if\ A>40 \qquad (1)$$

The second method is by using lookup table. All the six bit binary values that correspond to its standard ASCII characters key in to a lookup table as a conversion table, hence there is no formulas needed to do the conversion. Fig6 shows the example lookup table for ASCII character to six bit binary conversion.

```
__flash char EIGHTBIT_ASCII_TO_SIXBIT_BIN[128] = {
  // 0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
    0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF,
  // 0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,    0,
    0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF,
  //  ,    !,    ",    #,    $,    %,    &,    ',    (,    ),    *,    +,    ,,    -,    .,    /,
    0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF,
  // 0,    1,    2,    3,    4,    5,    6,    7,    8,    9,    :,    ;,    <,    =,    >,    ?,
    0x00, 0x01, 0x02, 0x03, 0x04, 0x05, 0x06, 0x07, 0x08, 0x09, 0x0A, 0x0B, 0x0C, 0x0D, 0x0E, 0x0F,
  // @,    A,    B,    C,    D,    E,    F,    G,    H,    I,    J,    K,    L,    M,    N,    O,
    0x10, 0x11, 0x12, 0x13, 0x14, 0x15, 0x16, 0x17, 0x18, 0x19, 0x1A, 0x1B, 0x1C, 0x1D, 0x1E, 0x1F,
  // P,    Q,    R,    S,    T,    U,    V,    W,    X,    Y,    Z,    [,    \,    ],    ^,    _,
    0x20, 0x21, 0x22, 0x23, 0x24, 0x25, 0x26, 0x27, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF,
  // `,    a,    b,    c,    d,    e,    f,    g,    h,    i,    j,    k,    l,    m,    n,    o,
    0x28, 0x29, 0x2A, 0x2B, 0x2C, 0x2D, 0x2E, 0x2F, 0x30, 0x31, 0x32, 0x33, 0x34, 0x35, 0x36, 0x37,
  // p,    q,    r,    s,    t,    u,    v,    w,    x,    y,    z,    {,    |,    },    ~,    0,
    0x38, 0x39, 0x3A, 0x3B, 0x3C, 0x3D, 0x3E, 0x3F, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF
};
```

Fig6. Lookup Table for Standard ASCII to Sixbit Binary Conversion

After decoded, the example binary string should hold the six bit binary data as follow:

14eG.....
1 = 000001
4 = 000100
e = 101101
G = 010111
......

The complete data string decoded shown as below when strung back together.

000001 000100 101101 010111 011100 001010 010000 000000 000000 000000 110111 001000 110111 100001 101000 011100 011101 110010 011111 101011 110000 110101 010111 010000 000000 001000 011000 011011

Where
MMSI Number - starting from bit 8 for 30 bits
010010110101011101110000101001 = 316005417

HDG - bit 128 for 9 bits
COG - bit 116 for 12 bits (and divide by 10)
SOG - bit 50 for 10 bits (and divide by 10)

And so on.

IV. BINARY MESSAGE TYPE

AIS transceiver will forward all received AIS packets to AIS controller and AIS controller will decide to drop or process the packets. For current stage, only two types of binary messages will be processed by AIS controller regardless to its packet type which is:

- Message 6: Addressed binary message
  Based on the amount of binary data, the message length is variable. Minimum length is 1 slot and should not more than 5 slots.
- Message 21: Aids-to-Navigation report
  This message should be used by an AtoN AIS station and transmit autonomously of once every three min

Table 1 Structure of Binary Message 6

Parameter		***Number of bits***	***Description***
Message ID		6	Identifier for Message 6; always 6
Repeat indicator		2	Used by the repeater to indicate how many times a message has been repeated.
Source ID		30	MMSI number of source station
Sequence Number		2	0-3
Destination Number		30	MMSI number of destination station
Retransmit flag		1	Should be set during retransmission
Spare		1	Not used. Zero by default
Binary data	DAC	10	Always 440
	FI	6	Always 52
	Ack	1	Always 0
	Year	14	1900-2999
	Month	4	1-12
	Day	5	1-31
	Hour	5	0-23
	Minute	6	0-59
	Second	6	0-59
	Interval	6	Weather Interval (1-60 mins)
	Interval	6	Racon Interval (1-60 mins)
	Interval	5	Lamp Pattern (0-15)

Table 2 Structure of Binary Message 21

Parameter	***Number of bits***	***Description***
Message ID	6	Identifier for Message 21; always 21
Repeat indicator	2	Used by the repeater to indicate how many times a message has been repeated.
Source ID	30	MMSI number of source station
Type Aids-to-Navigation	5	0 = Not available
Name Aids-to-Navigation	120	Name of AtoN in 6-bit ASCII
Position Accuracy	1	1 = high (>10m), 0 = low (<10m)

Longitude	28	Longitude in 1/10000 min of AtoN position
Latitude	27	Latitude in 1/10000 min of AtoN position
Reference for position	30	Reference point for reported position
Type of position fixing device	4	0-7. Defining the type of AtoN device used
Time Stamp	6	UTC secibd when report is generated
Off Position Indicator	1	0 = off position, 1 = on position
Other field that not in used	-	

The AIS controller also able to forward five types of packets which are:

- Packet Type of ANABM with message number of 6
  - Contain information of data, time, positioning data and meteorological data.
- Packet Type of ANBBM with message number of 8
  - Contain information of date, time, positioning data and all current/voltage sensors' data.
- Packet Type of ANABM with message number of 12
  - Addressed safety related message. Forward to a fixed station if there is lamp error or power failure occurs.
- Packet Type of ANBBM with message number of 14
  - Same with message 12 but with different packet type and message number.
- Packet Type of AIACE with message number of 21
  - Ship status message. Broadcasted every three minutes. Contain information of lamp status, power failure status and name of AtoN.

V. RESULT

The system has been installed to a small ship and tested by using computer based AIS monitoring software at coastal AIS station. Fig7 shows the data receive from AIS mobile station. All data received successfully and information also can be decoded and display in human readable format.

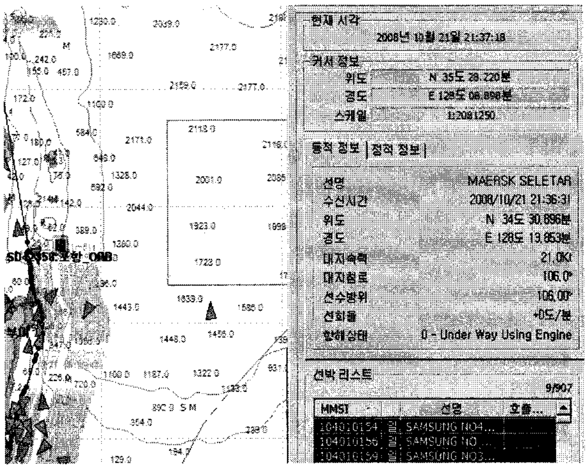

Fig7. Result of Computer based AIS monitoring software

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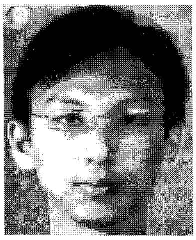

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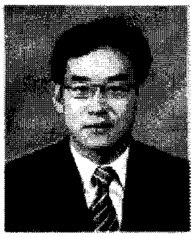

Soohong Park (M'2006) received the B.S degree in 1986, M.S degree in 1989 and Ph.D. degree in 1993 from Busan National University. During 1995-1996, he was visit professor at the Beijing Aero & Astrometry University, China. In year 2002-2003, he also was visit professor at the Oregon Sate University , U. S.A.. Currently, he is a professor at the Mechatronics Department, Dongseo University. His main research topics are control and unmanned vehicles and robot.