Paper xx – What is a Smart Buoy, fitted with AIS, and how will this technology make our navigable waterways safer for mariners and more profitable for its operators.

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ABSTRACT: Smart floating Aids to navigation fitted with AtoN AIS assist mariners in making landfalls when approaching from overseas, mark isolated dangers, make it possible for vessels to follow the natural and improved channels, and provide a continuous chain of charted marks for piloting. River environmental conditions, such as current, seasons, rain and sediments have an extreme impact on the safety of navigation. Smart buoys greatly improve the availability of real time data to Mariners, Authorities and Operators making our waterways safer, more efficient and ultimately more competitive

1- Importance of aids to marine navigation in safety of river navigation

Over 90% of all goods that are transported around the world are transported by water. Of this amount a growing percentage is transported by our inland waterways and rivers. In the United States, for example, more than one and a half billion tons of freight move an average of 450 miles each year by barge (University of Kentucky/Tennessee 2014). In comparison to other modes of transportation like rail and road, it is by far the most economical and environmentally friendly option. Visual aids to navigation [AtoN] such as buoys and lights play an important role in the safe movement of vessels on the water. Aids to navigation are placed at various points along coasts and navigable waterways to provide markers and guides to enable mariners to determine their position with relation to the land and to hidden dangers.

Aids to navigation assist mariners in making landfalls when approaching from overseas, mark isolated dangers, make it possible for vessels to follow the natural and improved channels, and provide a continuous chain of charted marks for piloting. Rivers’ environmental conditions, such as current, seasons, rain, sediments, etc. can have an extreme impact on the safety of navigation.

Recent technological advancements mean the aid to navigation can now be much more potent in providing important safety data.

2- Materials and design improvements

Largely outdated are steel buoys which relied on volume for the buoyancy required to support the weight of the buoy, and now obsolete gas lighting equipment.

Buoy manufacturers have experimented with different polymer to make buoys that are lighter, easier to handle and require less intensive maintenance. Trials and experiences with GRP proved it to be too brittle and vulnerable to damage. Elastomer skinned buoys and foam-filled buoys were introduced in the 1980's but have since been superseded to a great extent by rotationally molded polyethylene buoys that are robust, very resilient, require little maintenance and are less expensive.

Figure 1 - Rusting steel buoy

Polyethylene buoys have such reserve of buoyancy that it is possible to oversize the mooring chain to allow for wear, thereby extending maintenance intervals. The size of a polyethylene buoy and its daylight visibility depends to some extend on its focal plane height (FPH). A 2m focal plane height provides a geographical light range in excess of 5NM when the observer's eye is about 2m above sea level. Therefore FPH is revelant for its contribution to AtoN buoy size. A buoy diameter of about 1.5m can be sufficient for waterways applications.

In addition to new materials there have also been advances in geometric design. For example, this twin keel hull provides greater safety when handling buoys on a buoy laying vessel and also allows a greater number of buoys to be carried on the vessel.

In early years large buoys were also required to contain large acetylene gas cylinders for lighting and later, large solar panels and batteries to power incandescent lamps. With the advent of LED's and the improvement in efficiency a self-contained light is now able to provide ranges in excess of 5NM with considerably smaller solar power packs.

Buoys can now be made smaller, lighter and also take advantage of unique designs. Modern designs and technology have led to the advent of the "Smart" buoy.

What does SMART stands for? These buoys are not only capable of providing visual AtoN but can now provide a wealth of information to the mariner such as; monitoring and status, RACON signals, Automatic Identification System (AIS signals), plus metrological and hydrological data.

Figure 2 –

New Generation Polyethylene Buoy

The electronic **“SMART”** buoy is the future of aids to navigation.

3- AtoN Monitoring

As the sole purpose of having AtoN is to improve navigation and safety, obtaining information in real time from those AtoN’s is essential in providing safe navigation within waterways. Of the utmost importance is safety and compliance.

The benefits of having a monitoring system include;

- Confirmation that your AtoN is operating within its set parameters
- Confirmation of your AtoN geographical position
- Providing an immediate notification if the AtoN fails or is out of position
- Providing early warnings of negative trends in monitored parameters in order to schedule maintenance before failure
- Being able to plan maintenance visits more efficiently
- Maintaining historical records of AtoN operation

AtoN monitoring is not new and comes in many forms, from simple GSM to VHF radio or Satellite. In recent times AIS has started to play a more important role in not only monitoring but to also providing additional data such as metrological and hydrological information directly to the mariner.

Information sent to the administration can be stored, have trends analyzed and proof of compliance records maintained.

AIS also provides an electronic signal to approaching vessels providing its location, name and other data.

4- What is AIS?

All vessels on an international voyage must be fitted with an AIS transmitter and receiver. This is mandated under SOLAS, Chapter 5, Regulation 19. The technical standard is ITU RM 1371-4.

AIS provides vital data to vessels within VHF range and its prime purpose is to assist in collision avoidance. It is now common practice to mandate the use of AIS for vessels operating within coastal waters and also on canals and rivers.

Data is broadcast on VHF between vessels and between vessels and any land based receiver. It includes;

Static Data

- MMSI;
- IMO number;
- Call sign and name;
- Length and beam;
- Type of ship; and
- Location of position-fixing antenna on the ship (aft of bow and

Dynamic Data

- Ship's position;
- Position time stamp in UTC;
- Course over ground (COG);
- Speed over ground (SOG);
- Heading;
- Rate of turn;
- Optional - angle of heel and pitch and roll;
- Navigational status

Voyage Data

- Ship's draught;
- Hazardous cargo (type; as required by a competent authority);
- Destination and estimated time of arrival (ETA) (at masters discretion); and waypoints

port or starboard of centerline).

- Provision must be made for inputs from external sensors giving additional information.
- Optional - route plan (field not provided in basic message).

4.1 AtoN AIS

Not only can vessel data be transmitted but also important safety information from an administration with a transmit and receive base station, as well as from an AIS AtoN. Vital data can be transmitted to vessels and the administration. These transmissions are called "messages" and the main ones for an AtoN are messages 21, 6 and 8. These are outlined in ITU RM 1371-4 and also in the IALA Guideline A-126.

Message 21 is received by all vessels on their standard display and is normally broadcast every 3 minutes. The most important feature is location and others include;

- Type of AtoN;
- Name of the AtoN;
- Position of the AtoN;
- Position accuracy indicator;
- RAIM indicator;
- Type of position fixing device;
- Time stamp;
- Off position indicator;
- Dimension of the AtoN and reference positions;
- 8 bits reserved for use by the regional/local authority (can include the technical status of the aid to navigation);
- Virtual AtoN target flag

Figure 3- AIS fitted within a self-contained lantern

IMO Circular 289 FI 31 Meteorological Message 8 is received by all vessels with a compatible display. Information transmitted will depend upon the sensors fitted and includes;

- Average wind speed
- Wind gust
- Wind direction
- Wind gust direction
- Air temperature
- Dew point
- Air pressure
- Air pressure tendency
- Horizontal visibility
- Water level
- Surface Current Speed (incl. tide)
- Surface Current Direction
- Current Speed, #3
- Current Direction, #3
- Current Measuring level, #3
- Significant Wave Height
- Wave Period
- Wave Direction
- Swell Height
- Swell Period
- Swell Direction
- Sea State
- Water Temperature
- Precipitation (type)

- Current Speed, #2
- Current Direction, #2
- Current Measuring level, #2
- Salinity
- Ice

IALA A-126 GLA Message Message 6 is not received by vessels and is designed to only be received by the local administration. It is commonly used for remote monitoring data and includes;

- Health of lantern (healthy or fail)
- Battery voltage
- Position
- Auxiliary

Incorporating AIS AtoN units on the buoys will improve the availability of real time information.

5- AIS Monitoring, Metrological and Hydrological

Above is an outline of AIS capabilities. A new generation **SMART** buoy is typically used to transmit remote monitoring data, metrological and hydrological data.

Apart from receiving the buoy position electronically, the mariner can also receive vital data such as wind speed and direction, water level and current.

Numerous sensors can be fitted to a buoy. Figure 4 shows a buoy fitted with wind and temperature sensors together with a current sensor. It is used to provide real time data on the internet.

Figure 4 - SMART buoy in action

When entering narrow channels, navigating through bridge channels, accessing channel crossovers and even locks, this data is vital to ensure safe passage and today's generation of **SMART** buoys can provide that.

Often water depths change and many channels have a limited draught. SMART buoys are able to provide accurate tide heights to enable the mariner to ensure safe passage.

Wind speed and currents are a danger to navigation as they both effect the safe handling of the vessel and sudden changes in current or wind provide additional hazards. Accurate, real time data can assist the mariner in calculating safe passage.

By monitoring a **SMART** buoy you can immediately be notified of failures of the lantern, or if the buoy is off position, for example and allowing you to issue a notice to mariners and reduce your liability.

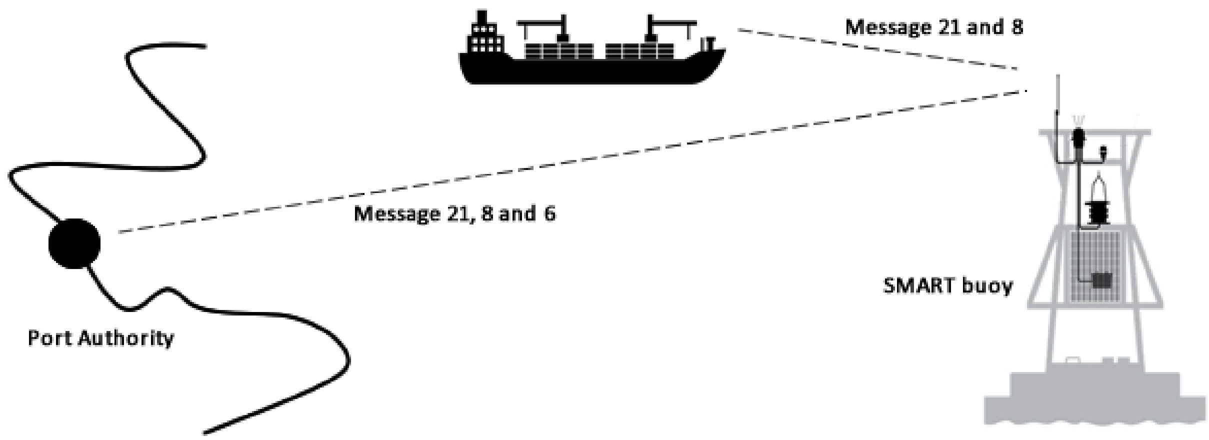

Figure 5- Typical application

6- Virtual AIS

Virtual AIS is starting to be considered by many authorities. The United States Coastguard are conducting trials in several locations with excellent results.

Virtual AIS is when an AIS AtoN position is broadcast by a competent authority, or even an AIS AtoN itself, to identify targets when AIS is not actually installed.

For example, an AIS AtoN can be fitted to show the centerline of passage under a bridge and can also broadcast the location of the bridge piers (abutments). Not only does the mariner have regular AtoN lights for reference. but an electronic signature as well.

Virtual AIS is normally only used to mark fixed structures or to provide AIS targets where no buoy exists. It is not normally used to mark actual buoy locations.

Virtual AIS is an excellent tool for marking a new hazard before physical AtoN can be installed.

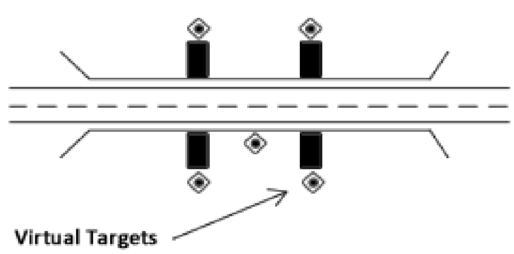

Figure 6- Bridge marked by real and virtual AIS

Another example is when AIS is used to mark an underwater pipeline where there may be only one or two physical buoys -or even no buoys.

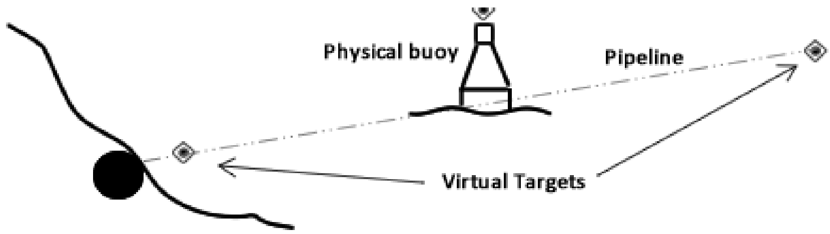

Figure 7- Pipeline marker with virtual AIS

7- Conclusion

The evolution and growth of "brown water" transportation is picking up pace. Driven by the desire to lower transport costs from hinterlands to coasts, as well as the clear benefits to the environment, countries are investing in their inland waterways at an unprecedented pace.

As these essential arteries are developed to accommodate higher volumes of waterborne traffic, as well as larger vessels, technology in the form of "SMART" aids to navigation (AtoN) can provide another layer of safety for the mariner and Authorities. Ensuring consistently safe passage of goods is paramount in the continued growth of this form of transportation.

While added safety is one benefit of "SMART" AtoN, certainly its benefit to the operator in terms of improved efficiency is also crucial. If brown water transportation is to be fully embraced by countries around the world, both safety and efficiency are "must haves", and "smarter" AtoN are certainly a proven method by which this can be accomplished.

SMART buoys are making our waterways safer, more efficient and ultimately, more competitive.

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