



AIS system description

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0 INTRODUCTION

This is a short description of the Class A and Class B AIS systems developed for Marine use and compares its operation to Radar. In particular, it considers the suitability of Class B systems for use in small craft.

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0.1 History

Version	Author	Changes	Date
A	DJL	1 st Version	1 st October 2003
B	DJL	Updated	Jan 2005
C	DJL	Updated	8 th September 2006
D	CNW	Formatting	7 th November 2007

0.2 References

- [1] ITU R M1371-1
- [2] IEC 61993-2
- [3] IEC 62287
- [4] SOLAS chapter V
- [5] Marine Transportation Security Act 2002

0.3 Contents

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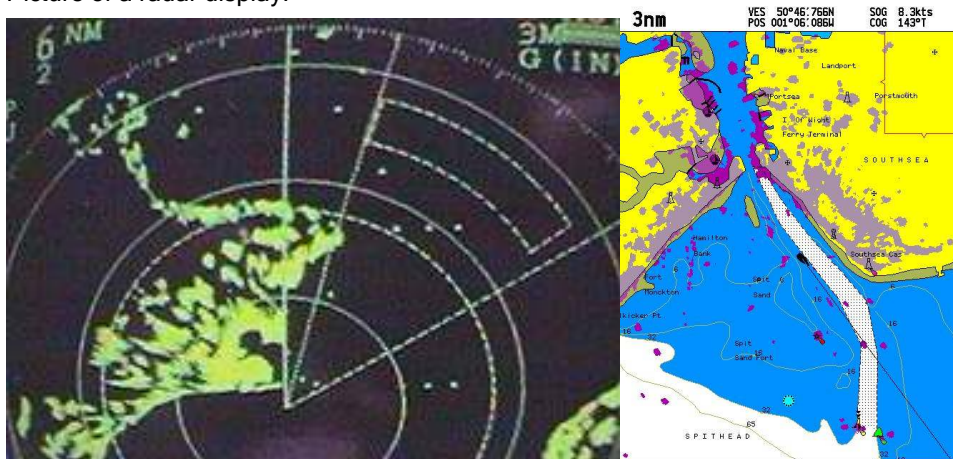
1 AIS – WHAT IS IT?

Since the early days of marine navigation the principle sensor that warns a navigator that he / she is heading into danger has been the mk1 eyeball. While this has been a tried and trusted system, it has long been realised that it does have serious limitations in conditions of poor or low visibility (in fog or at night for instance) and has a habit of shutting down completely after long periods of use.

The development of Radar was a major advance and enabled ships to travel with confidence at night or through the fog using a display that showed not only the coastline but also other vessels in the immediate vicinity so that they can be avoided (or in the case of the military, blown to pieces...). In recent years the price of small boat marine radar units has decreased to a level where many leisure boat owners can now afford to install such a unit in addition to the more established commercial users. However, radar is not without its problems. To start with it is still a large power hungry box that needs considerable space and adds significant weight high up - this is obviously not a good thing in a sailing vessel where there is a fundamental requirement to keep weight low down and windage to a minimum and where the only power supply is limited to a 12v battery. There are also problems with multiple returns and reflections which can “clutter” the display (especially in heavy rain). Similarly, not all vessels can be seen by radar, especially a fibreglass sailing boat with a very low metallic content. Even when fitted with approved radar reflectors, these are often limited in their effectiveness, especially when the boat is heeling significantly (as monohull sailing boats are wont to do) when travelling fast, which is just the time when the navigator needs as much warning of an impending collision as possible. There are other inherent problems with radar systems, which may not be immediately apparent:

- If a vessel passes behind another, one of the targets is lost.
- When a new target is first acquired by the radar system, it takes several sweeps of the radar to determine its speed and direction. It is not immediately apparent when the target first appears if it poses threat or not.
- A large target (such as a container ship entering harbour) can cause so many reflections as to effectively make the radar blind in some directions for several minutes.

Picture of a radar display:

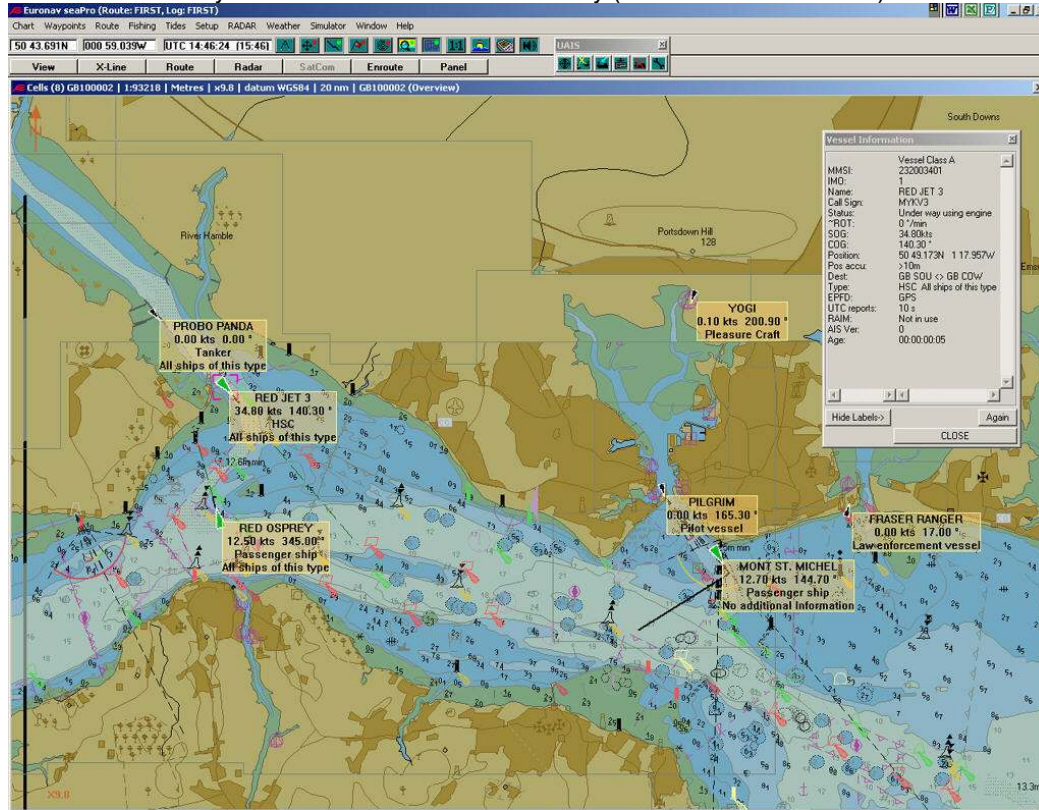


The advent of low cost GPS / GLONASS devices has now made it possible to derive a different type of navigation system based not so much on signal detection, but on an “all informed network” of radio transceivers. If all vessels in a particular area are equipped with a GNS system, then each vessel knows where it is (up to the accuracy of the GNS system in use). Therefore if this information can be communicated to all the other vessels in the area, the positions can be overlaid on an Electronic Chart (or existing radar display) and clearly

shown to the user. In addition, course and speed could also be displayed and a decision taken as to whether any particular target posed a threat or not. So now, with the aid of the electronic chart or display, the mariner can now tell where he is and where all the vessels close to him are as well (all the ones fitted with an AIS unit that is...).

To make this system feasible two radio channels have been assigned specifically for this purpose, known as AIS1 and AIS2 (original, eh?) within the existing marine band. A radio protocol to control each transmitter has also been developed to ensure that all the transmitters come on in an orderly manner and the messages do not collide. This is a development of the aviation VDL4 specification and in marine parlance is known as SOTDMA (self organising time division multiple access), which has the major advantage over other systems of not requiring a master controller in the system, each unit operates autonomously, taking account of other units it has heard in the system, and at the same time, informs all the other units of the next time it intends to transmit.

Picture of an AIS system with Electronic Chart overlay (with thanks to EuroNav):



2 HOW AIS WORKS

In an AIS network, each vessel has its own on board GNS system, which provides the position, course and speed of the vessel. This is linked (or in many cases, integral with) a radio transceiver. This has three receive channels (AIS1, AIS2 and DSC channel 70) but only one transmitter (which can transmit on any of the channels). The two radio channels are split up into time slots of 26ms each, so that there are 2550 slots in every minute. When an AIS unit first switches on, the first thing it does is listen to the AIS channels for any existing vessels that may be transmitting. From the radio traffic on these channels it builds up a “map” of the activity on each channel so that it can then chose a time to transmit when the channel is likely to be quiet. Once it has chosen a time slot in which to transmit its message, it also sends a message to reserve a slot in the next frame so that other ships will not transmit at the same time as it. Each vessel will report its position, speed and course at a defined rate depending on its size and speed:

Reporting rate table:

Ship's dynamic conditions	Nominal 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	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

The data transmitted in a standard position report consists of:

- User ID MMSI number
- Navigational status: (see below)
- Rate of turn
- SOG
- Position accuracy
- Longitude
- Latitude
- COG
- True heading
- Time stamp
- RAIM-flag

Navigational Status indicators:

- under way using engine
- at anchor
- not under command
- restricted maneuverability
- constrained by her draught,
- moored
- aground
- engaged in fishing
- under way sailing
- ships carrying DG, HS, or MP, or IMO hazard or pollutant

In addition, each vessel will report more detailed ships static and voyage related data at a much lower rate (every 6 minutes). Should it wish to, a shore based VTS can also interrogate any vessel for this data. Safety and distress messages may also be sent and received.

Ships Static / Voyage Data:

- AIS version indicator
- IMO number
- Call sign
- Name
- Type of ship and cargo type
- Dimension/reference for position (Also indicates the dimension of ship (m))
- Type of electronic position fixing device
- ETA
- Maximum present static draught
- Destination

The system is designed to handle approx. 4000 vessels in any particular area with a statistically average distribution of reporting rates. This should be sufficient for most areas of the globe, however the system will de-grade gracefully if more vessels than this enter the area and will result in the coverage area “shrinking” so that the most distant targets will be lost first, the strongest (and hence closest) being preserved.

The requirement for the two AIS channels not only enhances the data handling capability of the system, but also applies some level of redundancy or fall back (should one channel become blocked) however all AIS transmitters have a time out circuit built in, so they should never transmit for longer than 1 second in any case, but interference may come from a multitude of sources, some of them marine, some land based. In extreme cases, the shore based VTS controller can send a message out on the DSC channel to instruct all vessels to use a different frequency for AIS use. This can also be used in some areas to facilitate frequency management.

Sadly, recent experience has shown that many vessels do not keep their voyage data up to date and the interfaces to some sensors (especially gyro compass's) seem to have a habit of failing regularly, so the data must always be tempered with common sense. There is no excuse for static data being wrong, however, there are still vessels out there reporting a greater beam than length! Both the UK and US Coastguards now have schemes in place to report erroneous AIS data transmissions, so it is to be hoped that these occurrences will decrease as time goes by. Despite this, the significant data (position, course, speed) is derived automatically (from the GPS unit) and so the anti-collision aspects of the system are not impaired.

One significant area of failure of the system would be if the GNS system failed (possibly due to sun-spot activity?), in which case the marine world would have to revert to the tried and tested systems of the pre-GPS era, but this would also cause considerable disruption to many other systems, both marine, land and air based. To cope with this (hopefully, unlikely) calamity, some authorities are looking at Loran as a terrestrial back-up to GPS / GLONASS / Galileo satellite systems.

3 AIS EQUIPMENT TYPES AND SOLAS

The Safety Of Life At Sea (SOLAS) regulations have mandated the installation of AIS systems in all vessels over 300tons by July 2007. In the UK, the MCA have advanced the timing so that this should be the case by the end of 2004. In the USA the requirement for fitting Class A units has been extended down to vessels greater than 65ft in length.

Essentially, after July 2007, every vessel over 300t will need to have an AIS system installed. However, SOLAS regulations do not apply to smaller commercial or leisure craft however, so the initial specification for AIS recognised two classes of equipment, Class A for the SOLAS requirements and Class B for the non-SOLAS requirements.

3.1 Class A AIS

Class A AIS is the full specification equipment. This requires the full ITU 1371-1 specification to be implemented, which is targeted at commercial vessels, and so results in a large heavy, power hungry box with many connections for external sensors (compass, rate of turn indicator, rudder position indicator, ARPA display outputs etc). As a result, the cost of these units is generally several thousand dollars. On the other hand, they are solidly built and are likely to survive the severe punishment and extreme conditions that can be expected from an installation aboard an ocean going vessel.

The latest revision of the Class A standard (expected at the end of 2007) is expected to remove some of the more esoteric requirements of the existing standard (12.5kHz operation, DSC Tx for example) which may make future designs cheaper and smaller.

3.2 Class B AIS

Class B now has two flavours to suit two markets:

- Class B-CSTDMA
- Class B-SoTDMA

Class B-CSTDMA is designed to enable the development of a smaller, cheaper more power efficient variant specifically for the leisure and small commercial market. It only requires two receive channels, the DSC capability being performed by time-sharing with the AIS channels at the appropriate times. The reporting rates are reduced to every 30s, and the standard position message that it sends (msg 18) has been carefully designed so that it fits into a single transmission slot. The power rating of the transmitter has been reduced to 2W, both to reduce the overall power consumption, and to reduce the potential impact that a large number of Class B-CS vessels could have on the overall AIS system (the 2W rating reduces the coverage area compared with the 12.5W of the Class A). This does mean that only the closer Class B-CS targets will be received, but as these are the ones that are likely to pose the most immediate threat, this seems to be a sensible decision. In all cases the Class B-CS specification has been carefully constructed so that it does not harm or degrade the functionality of the Class A units in the system. The principle mechanism for this is the "carrier sense" protocol which checks the intended transmission slot for the presence of a Class A signal before transmitting its own data. If a Class A signal is detected, the Class B-CS unit will randomly select another slot until it finds a free one. In this manner, the important Class A transmissions are protected from interference by the Class B-CS's.

Class B-CS units are being developed by several manufacturers at the moment, and more will inevitably appear as the technology matures. Trials of the Class B-CS systems have been carried out aboard the German research vessel, Gauss, in the North Sea, and with the assistance of the Northern Lighthouse Authority, in and around Oban, Scotland. These were

successful in proving that the units will work in a mixed Class A and Class B-CS environment and can exchange data accurately and reliably in a multitude of operational scenarios.

The current Class B-CS units are small (one mounts in a 2inch plastic tube about 3 feet long, and includes the antenna) and consume minimal power and so are ideal for installation aboard sailing craft.

The Class B-SoTDMA standard is essentially a cut-down version of the Class A standard, removing many of the costly requirements for interfacing to external sensors and keeping the same environmental requirements as the Class B-CS. This is principally intended for use by commercial vessels that are not covered by the SOLAS regulations (tugs, pilot vessels, fishing boats etc.). The same protocol is used by both Class A and Class B-So so they are inherently compatible, but the lower size and costs of the Class B-So allow them to be deployed on smaller vessels.

3.3 RX-only

There are now several RX-only devices on the market. These monitor the AIS network and receive position reports from both Class A and Class B devices and can display their positions on a screen. These unit are primarily for use by Harbour Authorities who wish to monitor and control the activity in their area, and, if necessary, advise vessels to take action to avoid accidents by VHF voice.

Their use on board a small boat is also useful, especially, in times of poor visibility, and can lessen the occurrence of small craft hindering the passage of commercial traffic since the smaller boats will be able to see the positions of the larger ones and take avoiding action in good time. The limitation in this scenario, is that the commercial traffic in question would have no knowledge of the small craft until it's too late, however that is the same position that they are in at the moment. It should, at least, lessen the risk of an RX-only equipped boat getting in the way of the numerous high speed ferries that now pepper the UK coastline, and it is generally a lot easier for a 24 foot yacht to get out of the way of a 4000 ton cargo vessel than the other way around in any case. In this case, an RX-only device does put the onus on the smaller craft to keep a good watch and take avoiding action as required, which may not be a bad thing, bearing in mind the recent stories of commercial shipping seen steaming along with no-one (apparently) on watch to respond to an alarm in any case¹.

Certainly, reading some of the skippers logs of cross-channel racing yachts, having an Rx-only device on board does seem to significantly reduce the stress involved in crossing the (very busy) traffic separation zones.

Some users of these devices have set up small networks of receivers on land to monitor shipping in particular areas and share the data over the internet, see:

- o www.ais-live.co.uk
- o www.aisliverpool.org.uk

amongst many others.

3.4 Aids to Navigation

There are currently 3 styles of transponder under development for mounting on navigation buoys and other Aids to Navigation. These are particularly useful to the navigator an accurate

¹ There is a perceived danger that, on a commercial vessel equipped with Autopilot, GPS, ECDIS, radar and AIS, the watch keeper may spend so much time looking at the video displays he may actually forget to look out the window.....

This concern may be extended to small craft as well, in that keeping a close eye on the RX only display to avoid the commercial shipping, doesn't stop him running into another RX-only equipped small boat doing exactly the same!

position of the buoy at all times (important in the case of bars and spits that may move from one storm to the next) and to keep the local authority informed of the status of their units and provide hydrological data (wave height, interval, tidal streams etc). The three different styles range from essentially a Class A design with reduced power consumption, a Tx/Rx design with an Rx channel for management and control and a Tx only design which will transmit on fixed slots which would have been previously reserved for it by the local base station.

Base Stations may also broadcast pseudo-AtoN messages which can highlight a potential danger to mariners (such as a wreck) before the authorities have been able to put a physical marker in place.

3.5 Base Stations

The base station standard is similar to the Class A in respect of its RF performance, however it has a more versatile command and control interface so that it can be operated either locally or remotely.

4 RADAR V AIS? WHICH IS BETTER?

Strictly, neither. Both systems have their merits and in an ideal world the inputs from both systems would be combined and presented to the navigator on a single integrated display (this has been demonstrated in land based trials with a remarkably good correlation between the two systems). In the commercial market in the near future it is likely that both systems would be required, however in the leisure market, different rules apply. If the AIS units can be made cheap enough, then they are likely to find a ready market, much more so than a more expensive radar unit especially as the installation of the AIS on a small vessel is considerably easier than a radar.

The AIS system works best when the majority of vessels are fitted with it. However a significant advantage to the small boat sailor can still be attained with using a Class B unit just to monitor the activities of any Class A equipped (ie big stuff) in the locality and hence, keep out of their way. As a secondary issue, the Class B transmitter will also make the smaller vessel visible to the Class A vessels, however the Class A vessels still need to keep an adequate look out for those vessels not equipped with any transponder at all.

Radar on the other hand is a stand-alone unit that does not rely on any other vessel to be equipped with anything other than a decent reflector and so can operate in isolation to any other system. AIS demands that other vessels also be equipped to be visible.

However, in the leisure market, the final issue is likely to come down to price. Small boat radar are probably nearing the end of their design cycles and due to the mechanical components required are not likely to drop significantly in the near future. Class B AIS on the other hand has been designed specifically to be low cost, and, especially with the recent introduction of integrated circuits that perform many of the coding and formatting functions required, potentially could reach a similar cost to existing VHF / GMDSS transceivers with sufficient production volumes. This factor on its own may be the deciding factor in the success or failure of the AIS market.

As for me, I'll be fitting an Rx-only device in my 7m sailing Catamaran for this season, and a Class B-CS as soon as I can get hold of one. Radar? No thanks, its too expensive, heavy and power hungry - but I may just get a bigger radar reflector, just in case....

APPENDIX 1: AIS TIME SCHEDULE – USA

Automatic identification systems (new sec. 70114 of title 46) - This section directs the Secretary to issue regulations for requiring certain vessels to be equipped with an automatic identification system (“AIS”) while operating on U.S. navigable waters. The AIS includes a position-indicating transponder on the vessel and an electronic charting or situation display to enable the vessel operator and shore-based Coast Guard facilities to access the information made available by the transponder.

- Covered vessels; waivers. Section 70114 specifies that the AIS requirement will apply to all self-propelled commercial vessels of at least 65 feet in length overall, vessels carrying more than a certain number of 5 passengers for hire specified by the Secretary, towing vessels of more than 26 feet in length overall and 600 horsepower, and all other vessels specified by the Secretary. However, the Secretary is authorized to waive the AIS requirement for vessels and waters that the Secretary considers do not require the AIS for safe navigation.
- AIS Phase-in schedule. Section 102(e) of the Act provides the following schedule for phasing in the AIS requirements: (1) on and after January 1, 2003, for vessels built after that date; (2) on and after July 1, 2003, for vessels built before January 1, 2003, that are passenger vessels required to carry a certificate under the International Convention for the Safety of Life at Sea, 1974 (SOLAS), tankers, or towing vessels engaged in moving a tank vessel; and (3) on and after December 31, 2004, for all other vessels built before January 1, 2003.

APPENDIX 2: AIS TIME SCHEDULE - SOLAS

All ships of 300 gross tonnage and upwards, engaged on international voyages and cargo ships of 500 gross tonnage and upwards, not engaged on international voyages and passenger ships irrespective of size shall be fitted with AIS, as follows:

- ships constructed on or after 1 July 2002;
- ships engaged on international voyages constructed before 1 July 2002;
- in the case of passenger ships, not later than 1 July 2003;
- in the case of tankers, not later than the first "safety equipment survey" after 1 July 2003;
- in the case of ships, other than passenger ships and tankers, of 50,000 gross tonnage and upwards, not later than 1 July 2004;
- in the case of ships, other than passenger ships and tankers, of 10,000 gross tonnage and upwards but less than 50,000 gross tonnage, not later than 1 July 2005;
- in the case of ships, other than passenger ships and tankers, of 3,000 gross tonnage and upwards but less than 10,000 gross tonnage, not later than 1 July 2006;
- in the case of ships, other than passenger ships and tankers, of 300 gross tonnage and upwards but less than 3,000 gross tonnage, not later than 1 July 2007; and
- in the case of ships not engaged on international voyages constructed before July 2002.