AIS Adding New Quality to VTS Systems

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In the foreseeable future, Automatic Identification Systems (AIS) will be installed aboard all sea-going ships larger than 300 g.r.t. These new devices broadcast data at regular and short intervals, by means of which the ship can be identified and tracked. Further data can be transmitted to provide additional information on the ship's motion, navigational status, intended voyage and cargo. The transmissions can be received by every interested party having an appropriate receiver both at sea and ashore. With these capabilities, AIS adds a new information quality to maritime traffic, which is relevant not only for ship/ship but also for VTS/ship interaction. This paper describes the genesis of the new systems and their operational and technical aspects. It continues with a discussion of their standard and extended applications and their – so far – unexploited potential. Where relevant, the results of R&D work and practical tests are mentioned.

KEY WORDS

1. AIS. 2. VTS. 3. Marine.

1. INTRODUCTION. 'Ship on my portside – ship on my portside – get out of my way!'; this is the beginning of a maritime joke. The sentence shows that until today, it has been very difficult to address an individual ship at sea. Of course, we do not know how the ship in question has been detected, whether by visual observation, or by radar. If the ship has not been seen visually, it might even have the right of way; for example, as a draft restricted vessel. This example shows that, with the electronic means installed aboard ships at present, it is neither possible to identify a target ship nor to determine with certainty who has the right of way. The same lack of information applies, of course, to VTS stations. Since radar became available on board and in coastal stations over fifty years ago, mariners and engineers have thought about solutions for automatically identifying the displayed targets. Now there is a solution in the form of the new Automatic Identification Systems (AIS).

However, AIS can provide further functionality. It will be shown that the system permits the tracking of vessels over longer distances, in archipelagos, and in narrow fairways. In all such cases, full coverage by radar would require the setting up of a large number of radar stations at high cost. This paper aims to answer the following questions: what are the pros and cons of using AIS or radar; do the two systems complement each other; what else can AIS be used for?

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2. THE DEVELOPMENT OF AUTOMATIC IDENTIFICATION AT SEA.

2.1. *RACONs, SARTs, and EPIRBs.* Many technical proposals have been made with respect to identifying objects electronically at sea. A solution applied to floating navigational aids, as well as to ships, is the radar transponder or RACON. It is a radar system fitted with an omni-directional antenna. Once the antenna is hit by an emission originating from a marine radar in the vicinity, it sends out its own identifier in the form of a Morse code modulated radar signal. The radar system that illuminated the transponder picks up the answer and displays it on the screen in Morse code form. In such a way the platform carrying the transponder identifies itself (Figure 1).

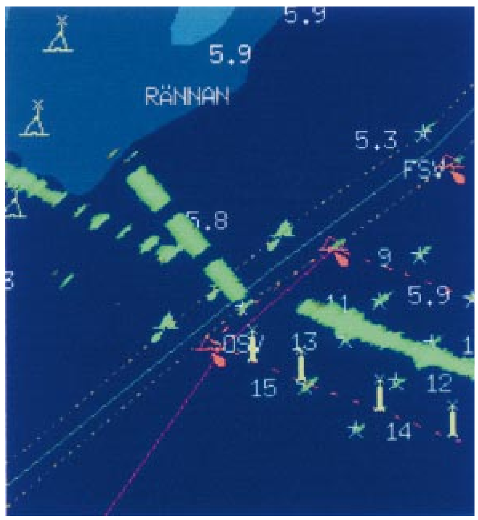

Figure 1. A RACON in the gap of the Oere Sound bridge.

While RACONs fitted on navigational aids are in continuous operation, the Search and Rescue Radar Transponder (SART) component of GMDSS[1] operates in emergency situations only. This transponder technique, which is also applied to aeroplanes, is not a suitable system to transmit much more information than a simple identifier. Otherwise, in dense maritime traffic situations, ships' radar displays would be cluttered. Other types of broadcast identification systems applied in the maritime domain are the Emergency Position Indicating Beacons (EPIRBs) and personal locators, which use radio frequency transmissions to transmit an identifier and a position in distress situations.

2.2. *The VHF DSC transponder.* In the mid 1970s, the International Maritime Organisation (IMO) proposed the development and integration of a 'Global Maritime Distress and Safety System' (GMDSS) to improve the alerting of rescue and stand-by forces in case of maritime distress. The system, which combines radio communication and satellite navigation technologies, became mandatory for all ships above 300 g.r.t. on 1 February 1999. It replaces verbal emergency communication by electronic alerting. The technique chosen for establishing the necessary communication, as well as for sending the digital messages, is known under the designation 'Digital Selective Calling' (DSC).[2] The system was adopted by IMO and incorporated into the 'Safety of Life at Sea' (SOLAS) Convention in 1988. In 1990, the 'International Association of Lighthouse Authorities' (IALA) which, among other issues, is taking care of the harmonisation of 'Vessel Traffic Services' (VTS), decided on DSC as the means for automatically identifying vessels within the VTS area. The DSC technique itself, and the messages to be transmitted, were specified on behalf of IMO and IALA by the 'International Telecommunication Union' (ITU) in the Recommendations R 493 and R 825.

DSC transponders, as they are required for GMDSS, mainly consist of a GPS receiver, a DSC controller and a ship's VHF set. Distress calls can be pre-selected and released by merely pushing a button. The distress call includes: a ship's identifier, the ship's current position and the cause of the distress. Such a message is a public broadcast. Most other DSC messages are addressed to another station, and a point-to-point call is established. It is also possible to poll information from a ship's station. Non-emergency message types have been defined such as those for VTS purposes.

The introduction of automatic identification systems was boosted tremendously by two dramatic oil tanker accidents causing heavy pollution: the grounding of the *Exxon Valdez* in March 1989 in the Prince William Sound in Alaska, and the stranding of the *Braer* in January 1993 in the Shetland Islands. After the *Exxon Valdez* accident, the US Coast Guard decided to implement an 'Automated Dependent Surveillance System' (ADSS) using DSC technology in Prince William Sound.[3] The *Braer* accident was followed by an investigation into measures to increase the safety of shipping in UK waters, led by Lord Donaldson.[4] One of the recommendations of his report was the implementation of maritime radio transponders based on the DSC technology on a worldwide basis. The report expressly deplores the slow progress in this field by the competent international regulating committees.

2.3. *The SOTDMA Broadcast Transponder*. At the time Lord Donaldson's report was published, a new system had been developed in Sweden. Although initially destined for aviation, its high potential in the maritime field soon became apparent. This new system is characterised by a transmission scheme that is completely different from the DSC transponder. Whereas the DSC system usually establishes a point-to-point communication or a group call, the SOTDMA ship stations *broadcast* identification and position reports at regular and short intervals. The broadcasts can be received by everybody using a suitable receiver. The transmission speed of the messages is 8 times higher than with DSC. As a result, not only can a larger number of ships participate, but also the transmission intervals for each ship can be shorter. The transmission time in the radio channel is divided into time-slots of a constant length synchronised by GPS time. Each participating station reserves a certain sequence of time-slots once it appears in the area. The spacing of the time-slots for a particular vessel depends on its speed and manoeuvring status. This segmentation of the transmission times is known as 'Time Division Multiple Access' (TDMA). In the Swedish system, there is no need for any central intelligence controlling the time-slot assignment. The process is fully *self-organising*, and meanwhile known under the acronyms STDMA or SOTDMA (Self-organising Time Division Multiple Access).

2.4. *The Regulation Process*. In 1995, the SOTDMA system was introduced to the IMO Sub-Committee on Safety of Navigation. Its greater potential was soon recognised by a number of nations, who preferred the concept to the earlier DSC technology. This led to a major debate between those nations who wanted a fast

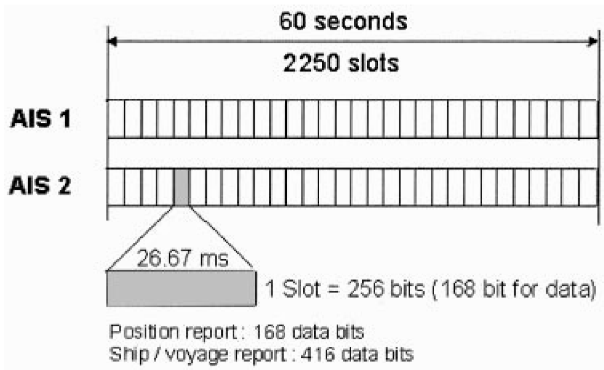

Figure 2. AIS TDMA slot arrangement.

implementation of the DSC system and the proponents of the new system. At the 41st session (1995) of the Sub-Committee, a draft on '*Provisional functional and operational requirements for an automatic identification system for ship-to-ship and ship-to-shore use*' was prepared, calling for an 'autonomous mode', but it was not adopted. In its 42nd session (1996), the Sub-Committee found itself in a dilemma. It produced '*Draft recommendations on performance standards for a shipborne Automatic Identification System* (*AIS*) *using broadcast techniques*' but also '*Draft recommendations on performance standards for a shipborne Automatic Identification System* (*AIS*) *installation using VHF Digital Selective Calling* (*DSC*) *Techniques*'. As a way out of this dilemma, a two-step approach was suggested: to start with, a DSC system (mainly for ship-to-VTS communication) and to implement, at a later time, a ship-to-ship system based on the broadcast (SOTDMA) principle. This approach was rejected, not least by intervention of shipowner representatives (INTERTANKO). It must be noted however, that the designation 'Automatic Identification System' (AIS) was coined, and that a draft time schedule for the implementation (2001–2004) was discussed. At the 43rd session (1997), the '*Draft performance standards for a universal shipborne Automatic Identification System* (*AIS*)' were finalised. These specifications called for a 'universal' system understood by some nations as a 'dual-fuel system' being capable of operating in both the DSC and the SOTDMA mode, but was meant by the vast majority as a unique system operating in the broadcast mode.

In October 1997, IALA summoned a working group of AIS manufacturers to agree on the technical solutions for AIS. The resulting draft recommendation was sent to the International Telecommunication Union (ITU), where a working party convened in March 1998 to develop the '*Technical characteristics for a universal shipborne Automatic Identification System using Time Division Multiple Access in the VHF Maritime Band*'. The recommendations of the working party were formally adopted in November 1998.[5] The Draft Performance Standards for U-AIS, as proposed by the Sub-Committee on Safety of Navigation, were adopted by IMO's Maritime Safety Committee (MSC) at its 69th session in May 1998. In September 1999, NAV 45 proposed the necessary amendments to Chapter V of the Safety of Life at Sea (SOLAS) Convention, and also a time schedule for the fitting of U-AIS to new and existing ships.

Two further international organisations/bodies are involved in U-AIS: in 1997, the ITU World Radio Conference (WRC) assigned two VHF radio channels for AIS

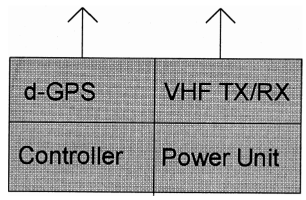

Figure 3. The Modules of an AIS.

purposes, and the International Electrotechnical Commission (IEC) is currently preparing the technical, performance and testing standards for AIS. The work should be completed by middle of 2000.[6]

2.5. *Definition and Main Characteristics.* What is a Universal AIS? A generally agreed definition does not seem to exist; the following is a suggestion:

> Automatic Identification Systems (AIS) are shipborne devices broadcasting the ship's identity, position and other data at regular intervals. By receiving the transmissions, shore or ship-based stations can automatically locate, identify and track ships carrying AIS. The systems are destined to enhance safety of navigation in ship-to-ship use and in maritime surveillance, ship reporting, VTS and Search And Rescue (SAR) applications.

3. TECHNICAL ASPECTS

3.1. *Components and Functions of an AIS*. An AIS transponder consists of the following modules (Figure 3):

a transceiver (transmitter/receiver),
a positioning receiver,
and a process controller module.

ITU specifies that the receiver must be dual frequency, receiving in both channels simultaneously, and that the regular transmissions alternate between the two channels. In this way, a redundancy is provided and the systems can cope with a certain level of interference in the radio channels. As regards the positioning system, neither IMO nor ITU are very specific. The only term given is 'GNSS'. In the absence of a more specific statement, it can be taken for granted that GPS is meant. It is also not yet clear if a separate positioning system is required, or if an existing ship-set can be used. ITU has specified a message for differential corrections transmitted from the AIS base station. More details can be expected from IEC in the AIS technical and testing specifications.

The controller module interrogates the positioning device, assembles the messages and controls the entire transponder process in its various modes of operation. The control of the system is relatively sophisticated. Three modes of operation are specified:

(a) the *autonomous* and continuous (broadcast) mode,

(b) an *assigned* mode (broadcast mode in which the shore-based authority can set the transmission parameters) and,

(c) a *polling* mode using DSC symbols (messages). Polling will normally originate from a particular shore station and can be used for local radio channel management.

Generally, the system operates in the autonomous mode. In all modes, operator intervention is kept to a minimum, if any is required at all. The process of gaining access to the TDMA regime, such as: to occupy time-slots, or to transmit messages that might be longer than the space in one time-slot, is much more complicated and is not discussed here. It is sufficiently described in the ITU Recommendation.

Table 1. Technical specifications of AIS.

Parameter name	Minimum	Maximum
AIS channel 1 (ch 87B) frequency, (MHz)	161·975	161·975
AIS channel 2 (ch 88B) frequency, (MHz)	162·025	162·025
Regional frequencies (MHz)	156·025	162·025
Channel spacing (kHz)	12.5	25
Channel bandwidth (kHz)	12.5	25
Bit rate (bit/s)	9600	9600
Transmit output power (low/high setting) (W)	2	12·5 (25)

3.2. *Basic Technical Specifications*. The basic technical specifications of AIS are listed in Table 1.

3.3. *Transmission Messages*. IMO has specified three message types:

3.3.1. *Static Messages*. These are the ship's:
IMO number,
call sign and name,
length and beam,
type,
location of the position fixing antenna on the ship.

3.3.2. *Dynamic Messages*:
ship's position with accuracy indication and integrity status,
time of the report in UTC,
course over ground,
speed over ground,
heading,
rate of turn,
navigational status,
and (optionally) angles of heel, pitch and roll.

3.3.3. *Voyage-related messages*:
ship's draught,
hazardous cargo type,
destination and estimated time of arrival (at master's discretion),
and (optionally) the route plan in form of way points.

The distinction of the message types does not only reflect a different *transmission interval* (dynamic data must be sent at a shorter sequence than voyage-related or static data), but also the *kind of data input* to the system. Static data can be permanently stored in the system. Dynamic data (with the exception of the navigational status) are collected from the respective ship's sensors, such as the positioning system, gyro compass or the rate-of-turn gyro. Voyage-related data should be put in manually whenever one of the values change.

It should be noted that not all of the data items in the messages are explicitly specified in the ITU recommendation, particularly those that are characterised as 'optional' or 'master's discretion' in the above list. For those concerning the ship's motion data, which could be highly dynamic, such as course over ground or rate of turn, it would be good to know the 'age' of the data or the characteristics of any possible pre-filtering processes, particularly if the data are used for target tracking in a VTS ashore or in the ARPA aboard another vessel. It is hoped that IEC deals with these issues in the process of specifying interfaces to the ships' sensors.

Other open subjects to be mentioned here are: the manual data input for the static/voyage-related reports aboard, and the display of the AIS data received and their graphical visualisation aboard ships, as well as ashore. The German Institute of Navigation (DGON) set up a working group that prepared and submitted a proposal through the German Government to the competent committees.[7] The proposal has been put into practice in the BAFEGIS project,[8] and has proven to provide excellent usability (Figure 4).

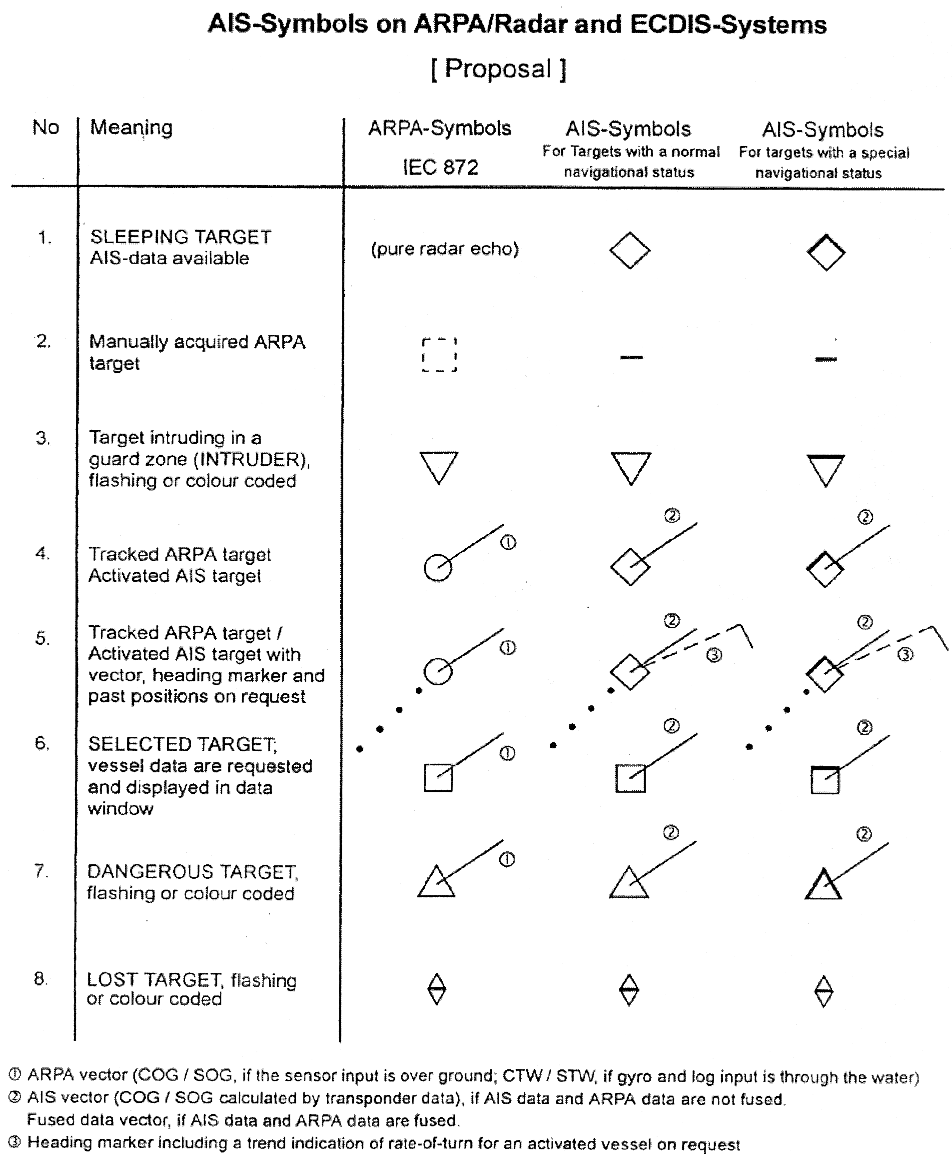

Figure 4. The AIS symbol set, as proposed by DGON.

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3.4. *Transmission Scheme*. How often does a ship have to send reports to satisfy the requirements of the users of such reports? As mentioned above, the update rate depends on the type of message. ITU specifies the following (Tables 2 and 3):

Table 2. AIS message update intervals.

Type of message	Reporting interval
Static information:	Every 6 minutes and on request
Dynamic information:	Dependent on speed and course alteration according to Table 3
Voyage-related information:	Every 6 minutes, when data has been amended, and on request
Safety related message:	As required

Table 3. AIS dynamic information update intervals.

Ship dynamics	Reporting interval
Ship at anchor	3 minutes
Ship 0–14 knots	12 seconds
Ship 0–14 knots and changing course	4 seconds
Ship 14–23 knots	6 seconds
Ship 14–23 knots and changing course	2 seconds
Ship > 23 knots	3 seconds
Ship > 23 knots and changing course	2 seconds

It is not clear how the intervals of these tables have been derived. An analysis based on the requirements assumed for tracking systems (either a VTS system or a ship's ARPA) suggests that the data in the tables are adequate for course change conditions and the envisaged sizes of ships. On the other hand, it was found that for larger ships the interval could be considerably longer in order to save channel capacity.[9]

4. AIS FUNCTIONALITY

4.1. *Identification*. As the designation 'AIS' suggests, automatic identification of ships is one of the main tasks of such a system. In AIS, two levels of ship identification could be distinguished. Every message, such as a position report, contains the Maritime Mobile Service Identity (MMSI)[10] as the user ID. In order to know the ship's name, the call sign or the IMO number, one has to enter the static information report carrying the same MMSI and look it up. It has yet to be defined how this data correlation should be automated in the onboard Radar, ARPA or ECDIS systems, or the onshore VTS systems. Solutions, however, exist and have been implemented in the BAFEGIS test bed, the EU-POSEIDON[11] project, and some commercial VTS projects. In the latter systems, when a target is marked on the screen, a data window opens that contains the full ship's identification. Similar solutions will most likely be specified for the onboard ECDIS systems. It has yet to be decided whether such a solution will be required for future ARPA systems.

4.2. *Tracking and Radar/AIS Target Fusion*. Using frequently received AIS position reports, ships could be tracked by means of a suitable system, be it an ARPA system aboard or a VTS system ashore. In a number of AIS test beds (R&D projects), and even commercial projects, it has been proven that tracking is possible with great accuracy, providing the data rate is sufficient particularly when a ship is manoeuvring. Data rates of 2 to 4 seconds for manoeuvring ships, as specified by ITU (see Table 3), are similar to the update rate of a ship's or VTS radar (3 seconds). As the data rate must be increased to such values once a ship starts to change course, safe and fast criteria to detect the start of a manoeuvre will have to be defined.

In the general case, an AIS will not be the sole sensor to detect and position ships, but will be combined with one (or more) radar(s). As a result, the tracking and presentation system will have to cope with several target tracks that might in reality be originating from the same ship. This problem could be solved in a simple way by selecting the target with the highest predicted position accuracy. In more sophisticated systems, a filter process evaluates the complete set of motion data for each target to determine if it is the same, and estimates using statistical methods the best fitting combined position in the positive case. This process is called 'target fusion'. While such processes are already implemented in VTS systems (Figure 5), a decision is

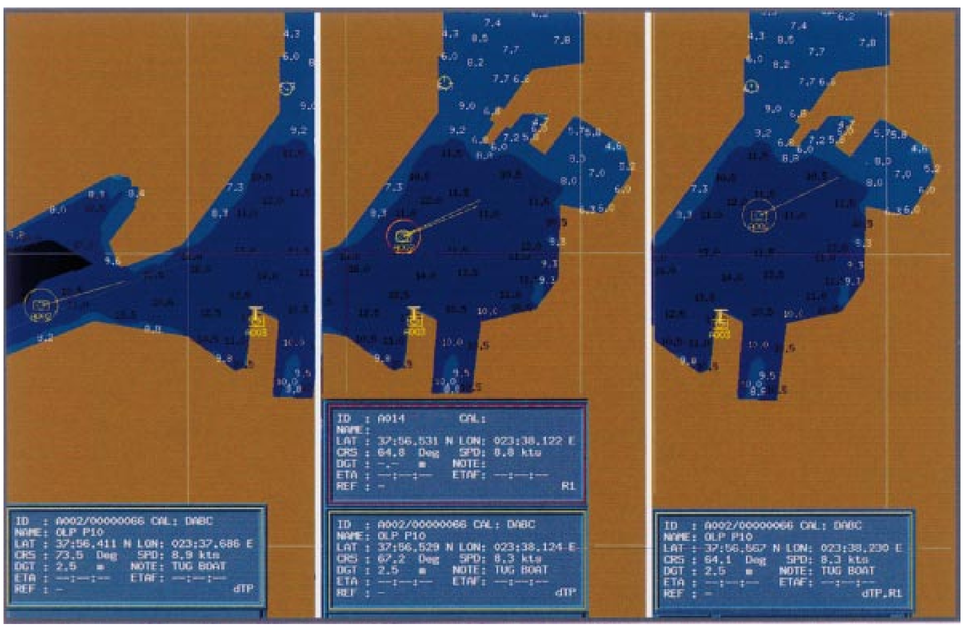


Figure 5. Track fusion: left – AIS track; middle – separate radar and AIS tracks; right – track fusion of radar and AIS.

necessary if and to what extent AIS position reports can be used in ARPA systems for tracking purposes.

4.2.1. *AIS versus Radar*. A question that often arises in discussion on the use of AIS is whether AIS could replace the radar sensor. Table 4 elucidates the pros and cons of the two systems.

AIS has its strength as a means for surveillance and tracking of those ships that are equipped. Obviously, ships not equipped, or with a switched-off system, remain invisible. Because of their different characteristics, Radar and AIS complement each other, such that the implementation of AIS provides considerable 'added value' to

Table 4. Comparison of Radar and AIS characteristics

Radar (Non co-operative tracking)	AIS (Co-operative tracking)
(+) practically all targets visible.	(−) only AIS vessels visible.
(+) coastlines and other fixed or floating targets visible.	(−) coastlines not visible, fixed or floating navaids visible only if equipped with AIS.
(−) not always complete coverage of area (radar shadow).	(+) full area coverage.
(−) bad weather limitations.	(+) practically, few weather limitations.
(+) unrestricted number of targets.	(−) number of targets is limited.
(+) high update rate for all targets.	(−) update rate dependent on target speed.
(−) high equipment costs.	(+) low equipment costs.

the existing state-of-the-art. The table also makes it obvious that AIS cannot replace Radar.

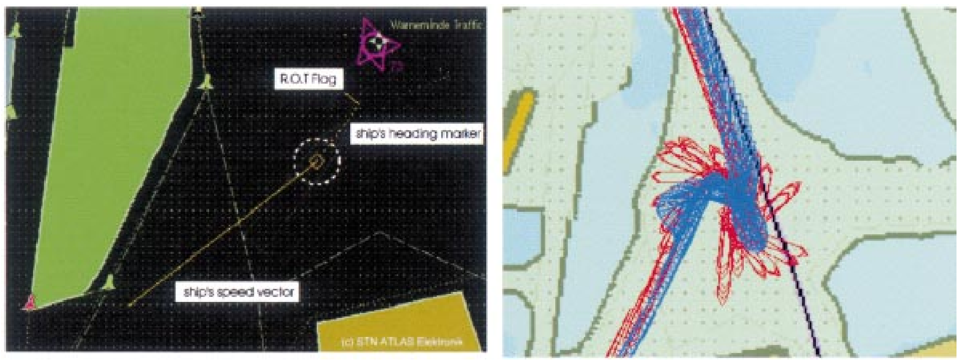
4.2.2. *Long-range tracking*. 'Long-range' can be defined as making reference to the average radar or AIS-VHF range of, say, 20 to 30 nautical miles. A requirement for long-range tracking exists in certain VTS areas, such as archipelagos or navigable rivers. It may also arise in the future within the Exclusive Economic Zone (EEZ) for ship reporting purposes, or in epi-continental seas, such as the Baltic, for ro/ro and ferry safety enhancements. The latter purpose was the prime objective in the BAFEGIS project, where ferries were tracked on their entire voyage from Germany to Sweden. In this project, it was proven that long-range tracking could be achieved using AIS aboard and in a number of (repeater) stations ashore. An AIS repeater shore station receives a message from a ship and re-transmits it. If the destination station could not pick up the original message it will then receive the re-broadcast message through the repeater station(s). By means of two repeater stations, it became possible to bridge the distance from Warnemünde/Germany to Trelleborg/Sweden.

Another type of long-range tracking applied in VTS stations was developed in the EU POSEIDON project, where INMARSAT-C position reports have been used to track ferries on their way from Bilbao/Spain to Southampton/U.K. ITU states that AIS should 'provide an interface for equipment that provides for long-range communications'. At the moment, the details are not clear.

4.3. *Further vessel information*. AIS includes several functions not yet mentioned, which partly provide long-desired and very useful information to the receiver of the AIS messages.

4.3.1. *Additional motion data* (*heading*, *rate of turn*). The standard AIS position report includes a data field for the ship's heading. With this information, the receiver of the message can calculate the ship's aspect angle, information which so far could only be derived roughly by visual observation and somewhat better using the ship's lights at night. The aspect angle is essential for determining if an obligation to give way exists in a close quarters situation, and for whom. This transmission of heading requires the connection of the ship's gyro compass to the AIS system. Because of the variety of mostly analogue gyro interfaces, this will not be easy to achieve and might not be possible for older ships.

In the BAFEGIS project, heading information from the target ships was transmitted and processed in the VTS station in Warnemünde probably for the first time in VTS history. It is very interesting to observe a turning manoeuvre of the ferry 'Mecklenburg-Vorpommern' in the inner port. Using the symbols suggested by DGON, it was obvious whether a displayed target was moving forward or backwards (Figure 6).



(a) (b)

Figure 6 (a). The ferry MECKLENBURG-VORPOMMERN turning in the port of Warnemünde showing the symbols proposed for use in ECDIS by DGON. (b). Ship's outlines during the turn. Both diagrams visualise – for the first time in a VTS – a ship's movement astern.

4.3.2. *Navigational* (*COLREG*) *Status.* Another important information item that can be included in the AIS position report is the ship's navigational status. Knowledge of status is another essential requirement for the determination of the obligation to give way. ITU specifies the following navigational states as:

Number	Status
0	Under way
1	At anchor
2	Not under command
3	Restricted manoeuvrability

In the DGON symbol proposal, a slightly modified symbol was suggested for ships having a status other than zero. The status itself can then be retrieved from an information window. As the number of states is smaller than the number of ship daytime visual signals, signs or lights specified in the COLREGS care should be taken that all relevant cases are covered. If this is the case, for the first time, it will be possible to assess collision situations by using electronic means alone.

4.4. *Provision of additional data.* Finally, the AIS radio channel offers the possibility to transmit messages that do not belong to the groups specified by IMO/ITU (3.3 above). These messages are called 'Binary and safety related messages' and may cover a wide variety of issues.

4.4.1. *Traffic Related Message*. In the MOVIT[12] project, STN ATLAS Elektronik developed together with CELSIUSTECH a VTS system for rivers and narrow fairways based solely on AIS. The system was tested under VTMIS-NET in the Kiel Canal. In the system, the VTS acquires and displays the positions of the ships in the canal by means of portable AIS sets to be installed aboard the ships while they are in the locks. Another important functionality is the exchange of traffic-related messages by means of the AIS. In the VTS centre, the messages can be entered into the VTS workstation; aboard they will be displayed on a dedicated pilot's lap-top. Messages containing the state of the traffic lights installed along the canal were demonstrated (in graphical form) as well as text messages informing the pilot aboard on the approaching traffic. All this was possible without disturbing the regular AIS function.

4.4.2. *Dissemination of Radar Echoes*. In the VTMIS-NET[13] project, a large-scale AIS test was performed in the Oere Sound. It was an ideal site for this test, as most of the ships observed were related to the bridge construction work and, in addition, four ferries from the BAFEGIS test bed were all fitted with AIS. At the time of the test, the area probably had the highest density of AIS-equipped ships in the world. The test had two objectives; firstly, the connection of two VTS in the same area, but in different member states of the EU (Denmark and Sweden) by means of a Wide Area Network (WAN), and secondly, the dissemination of VTS information by means of the AIS radio channel. For the latter purpose, radar track information from both VTS stations was converted into the format of AIS position reports and transmitted from the respective AIS base stations. Together with the regular AIS position reports emitted by more than ten ships in the vicinity, the entire traffic image, that is all AIS and radar-tracked targets, were 'on the air' and could be received by the onboard AIS stations. On a test vessel, a standard VTS station was installed and connected to the ship's AIS so it could receive and display the same traffic image as the shore VTS stations. Such a solution is of interest for a number of services, such as Coast Guard vessels, SAR vessels and pilot services.

4.4.3. *Dissemination of DGPS Corrections*. For maximum position accuracy, the AIS GPS set should operate in the differential mode; that is, it should be fed with the position corrections determined ashore at a reference station. This can be achieved in a number of different ways:

(a) the ship's DGPS set connected to the AIS to supply DGPS positions,
(b) the AIS can use an internal DGPS set fed with the differential corrections received aboard from the IALA MF beacons,
(c) the AIS can use an internal DGPS receiver fed with differential corrections received through the AIS radio channel from an IALA MF beacon receiver installed in the AIS base station ashore,
(d) same as (c), but the differential corrections are determined by means of a DGPS reference station in the AIS base station.

In the BAFEGIS project, the second solution was applied, as the German authorities were keen to use the IALA beacons installed for shipping. In the EU-Poseidon project, a fully self-contained solution using the principle at (d) was tested. A mobile VTS station was set up in areas where no DGPS corrections were available, and in an unknown position. After a couple of hours, own position was determined with an accuracy of a few metres and the AIS carrying ships could be tracked with similar accuracy, just using the AIS internal transmission of the differential corrections. In the meantime, several VTS systems have been put into operation using one or the other of the solutions mentioned above.

5. CONCLUSIONS. The electronic *detection* of ships at sea and the display of their positions has been state-of-the-art for more than 50 years using radar, but the automatic *identification* of the radar echo has remained an unresolved issue. By means of radar alone, it has never been possible to determine heading, nor whether a vessel is sailing ahead, astern or transversely, nor could the navigational status of a vessel (important for collision avoidance) be determined. With the new AIS, which will shortly become a mandatory requirement, all such ship data can be acquired automatically by other traffic participants or by coastal stations. If processed, the data can provide the information needed for assessing not only whether a collision threat exists, but also enable the operator to determine who has the obligation to give way. These two issues alone seem to justify the introduction of AIS, but there is more. The AIS radio channel can be used to disseminate further ship's data, messages and warnings, and also differential corrections for GPS receivers.

It has been shown that AIS cannot replace radar, but will complement it to provide more complete information on the maritime traffic situation. AIS has proven its applicability and information value in a number of test beds, R&D and most recently in commercial projects. The paper has also shown that the full potential of AIS has yet to be fully developed and exploited, particularly for ship/ship collision avoidance, but also for VTS operations, ship reporting, and SAR. An interesting period of evolution of the AIS system and its data use can be expected.

REFERENCES

[1] Further information on GMDSS: http://www.navcen.uscg.mil/marcomms/gmdss/

[2] Further information on DSC: http://www.navcen.uscg.mil/marcomms/gmdss/dsc.htm

[3] Jagodnik, Cairns, Ross and Winterhalter. (1993). Digital Selective Calling in the Prince William Sound Vessel Traffic Service System.

[4] Donaldson, Lord. (1994). *Safer Ships, Cleaner Seas*. HMSO, London.

[5] *Technical Characteristics for a Universal Shipborne Automatic Identification System Using Time Division Multiple Access in the VHF Maritime Band*. International Telecommunication Union, Recommendation ITU-R M.1371, appeared in January 1999.

[6] Further information on AIS: http://www.navcen.uscg.mil/marcomms/ais.htm

[7] Galaske, T. (1997/8). *Diploma thesis*. ISSUS, University of Applied Science, Hamburg.

[8] Benedict, K., Müller, R. and Harre, I. (1998). BAFEGIS – an approach for increased ro/ro ferry safety. *Proceedings of ISIS* 98, *International Symposium on Ships*. M/F Kronprins Harald, 22–24, November 1998.

[9] Harre, I. (1997). An improved transmission scheme for Automatic Identification Systems (AIS) using the broadcast principle – the Loa concept. *Ortung und Navigation*, No 2, 1997.

[10] Further information on the MMSI: http://www.navcen.uscg.mil/marcomms/gmdss/mmsi.htm

[11] Details on the project can be found under: http://hermes.civil.auth.gr/poseidon/poseidon.html

[12] Details on the project can be found under: www.e-motive.com/movit/

[13] Details on the project can be found under: http://issus.susan.fh-hamburg.de/iss_web/home_eng.htm