Identification of Ships and Transfer of Information through Transponders

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In this paper, we shall outline the reasons why the installation of shipborne equipment, which enables vessels to be positively identified from the shore and from other vessels, is so important and necessary. We shall also describe the latest innovations in this field and propose minimum standards for a transponder system.

1. INTRODUCTION. Coastal countries take different actions to achieve safe navigation of vessels in the vicinity of their shores, and to minimise the potential risks to the environment involved in the great amount of dangerous and polluting goods carried by some of them. Among these actions, *passive* measures such as *Traffic Separation Schemes* and *Areas to be avoided* have been established in different geographical areas, as well as *active* measures such as radar surveillance and voluntary reporting systems.

The need for automatic identification, both ship-to-shore and ship-to-ship, has long been present in the maritime scene. Identification would be of great help for all kinds of vessels, especially under adverse meteorological conditions, such as poor visibility, allowing them to know the name of other ships in their vicinity. Radar transponders have been used by Air Traffic Control (ATC) centres to identify and control aircraft in their area of responsibility for many years, and appropriate lessons and experience gathered from that area should be applied to the maritime industry, in order to adapt such systems to marine vessels.[1]

2. IDENTIFICATION SHIP–SHIP/SHIP–SHORE. Undoubtedly, there is a need for a ship-to-shore and ship-to-ship identification system to permit global, active, maritime traffic control; however, the difficulties involved in the implementation of such a system are not technical, but mainly of a political, social and legal character.[2] VTS centres have solved the problem of identification of vessels entering their area of responsibility by means of oral questioning to obtain the position of each ship and her particulars; through this process, the ship is subsequently located on the radar screen. The risk of errors through misunderstandings in the VHF communications between ships and VTS centres implies the need for a better and more reliable system of identification. This need, among others,[3,4] for a reliable means of identification has also been strongly expressed by the mariner because the officer of the watch is the only one able to manoeuvre a vessel in case of emergency. A vessel can plot the course and

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speed of another ship within its radar range by means of the ARPA functions, but the ship cannot be positively identified. Most mariners are used to receiving VHF messages like 'ship on my starboard bow, please give way', heard in the middle of the night or in poor visibility conditions. But, who is calling? and where is the calling ship? Ships approaching each other by night or in poor visibility conditions should know the identity of those vessels sailing in their vicinity to enable immediate communication should a need arise.

This problem could be solved with an automatic ship-to-ship and ship-to-shore *transponder* capable of continuously transmitting specified information to the VTS operator or to other vessels in the vicinity, such as name or call sign, course made good, heading, position and status of the ship. When required, other data could be provided: type of vessel, maximum draught, cargo onboard, etc.

There are a number of different possibilities to meet the need for identification of marine vessels. The main options are: Automatic Dependent Surveillance (ADS), radar transponders, DSC transponders and 4S GNSS transponders.

2.1. *Automatic dependent surveillance (ADS).* To those not involved in marine navigation, it may appear that the radar equipment installed on board most ships is enough for solving all relative navigational problems, avoiding obstacles and harmonising the movement of the vessel with the movements of other craft; however, the facts show the contrary. The COST301[5] study carried out in 1987 by the European Community indicated that, irrespective of the equipment carried on board, 500 vessels are involved in accidents every year within European waters alone (40 percent collisions, 40 percent grounding) and this excludes port waters. The problem seems to be related to intrinsic limitations of primary radar. A vessel equipped with radar is able to receive information on the area around her (position in respect to other ships, other obstacles big enough to be detected by the radar: such as buoys, the coast, etc.); however, the officer of the watch has little, or no information, about the nature of the detected objects (type of vessel) or possible manoeuvring intentions. Every agreement on a given manoeuvre can only be transmitted by radiotelephony in channels that usually are rather saturated. Ignorance of the identity of the vessels to which the message is addressed seriously impairs the efficiency of the transmission. The absence of safe communications is observed by some experts as a primary cause of collisions, and sometimes the only possible explanation for certain collisions between well-equipped vessels.

The availability of accurate navigation data from global positioning systems has many uses but some, perhaps less obvious, applications to collision avoidance can be foreseen in the near future. In the ADS concept, each user transmits either on demand or periodically on a common channel, and listens to similar messages broadcast by others with a format containing position information and other data. Consequently, everyone can locate on a chart, or electronic display, the position of all the other users in the area. In civil aviation, this 'pseudo-radar' is being developed by a number of authorities to meet the requirements of the Future Air Navigation System (FANS) defined by the International Civil Aviation Organisation (ICAO). For example, tests have been successfully carried out in a Boeing 747 from British Airways in cooperation with British Telecom, Racal and Honeywell using ADS and the on-board Inertial Navigation Systems.[6] Tests have also been successfully completed in the area of the Northern Caribbean combining ADS and Loran-C.[7]

Maritime navigation faces similar problems to air navigation, but with different equipment and in a different environment. Maritime traffic is less complicated than air traffic; every marine captain may navigate freely, except for specific areas with heavy traffic and navigation lanes or Traffic Separation Schemes (TSS) covered by a harbour or coastal Vessel Traffic Services (VTS) centre.

ADS has the following attributes:

(i) a 'pseudo-radar' facility for the presentation on an electronic display of all suitably equipped targets in a given area; the presentation is enriched with other pieces of information such as identity, speed, type of cargo, etc.

(ii) a data interchange allowing two (or more) stations to agree on the manoeuvres to be carried out without using VHF R/T, eliminating in this way the problems of misunderstanding when dealing with a foreign language, since most marine officers are not native English-speakers.

Clearly, this system can be adapted to the needs of a harbour or coastal VTS. Thomson-CSF adopted the ADS concept for maritime use as part of an anti-collision system that can be employed to meet the needs of Maritime Traffic Management from a Vessel Traffic Management Services (VTMS) centre.[8] ADS has already been installed in Valdez, Alaska, to control landfalls and navigation of suitably-equipped tankers in Prince William Sound. The Valdez system works with a shore-based control that detects any deviation of a vessel from the correct track and allows for subsequent information and advice.[9]

The current process of maritime traffic control can be carried out only in limited areas, due to the limitations in range that are inherent to VHF and radar equipment. Those areas are normally harbours and harbour roads, waterways, channels and coastal waters with Traffic Separation Schemes. ADS, therefore, has both the added potential for regional, or even global, coverage and the possibility of an immediate and positive identification of ships with suitable equipment on board. The system is much more economical than radar surveillance stations located ashore and could be considered safer, as it is effective in any weather conditions, whereas radar is much more likely to be affected by rain or sea disturbances.

In theory, such modern communications could provide global control of maritime regions, apart from VTS areas, although this possibility is not yet politically correct or acceptable. A global surveillance system will face legal, social and political opposition and such a system might not be implemented in the short term. The possibility of a progressive and slow implementation seems to be more realistic, and some years will pass before an international agreement on the subject is achieved. European governments will, in any case delay the implementation of ADS by IMO until the EURET programme (European Research in the field of Transport) is completed. Meanwhile, the USA is pressing on and establishing ADS in Prince William Sound unilaterally.

3. RADAR TRANSPONDERS. Secondary Surveillance Radar (SSR) transponders are used in air traffic control (ATC). In this system, a ground-based transmitter sends a pair of pulses, coded by the interval between them, from a directional antenna. The aircraft transponder answers at a slightly different frequency using a number of possible codes and, in the latest version of the system Mode S, the reply can include a high-speed datalink. This reply is received and decoded in the ground station.

Use of a similar system in marine navigation would have the following advantages:[10]

(i) A large number of vessels could be managed, and the refreshment time for the screen is equal to a single antenna turn.
(ii) A radar-based system has the capability of detecting all traffic in a given area, including those vessels which are not equipped with a transponder.

The main disadvantages would be:

(i) If two interrogated vessels are within a 1·65 nautical miles range from each other and within the bearing discrimination from the interrogator vessel or the VTS station, their replies will interfere with each other.
(ii) The radar 'is not able to look' round a bend in a river or channel.
(iii) Total coverage for a river, long channel or archipelago is very expensive.

4. DIGITAL SELECTIVE CALL (DSC) TRANSPONDER. IALA established a Vessel Traffic Service (VTS) Committee to solve the problem of vessel identification on Plan Position Indicators (PPI) in VTS stations and define the operating standards for an automatic identification system. The result is a *radio transponder* with a working capacity of at least 20 ships per minute, based on the GMDSS (DSC protocol 825) on VHF channel 70. This system allows the user to identify and assign a label on the screen to any previously selected target, all the vessels sailing in a specific area, a vessel with a given course and speed or with an established position.[11]

A *DSC* transponder allows for interrogation ship-to-ship, when there are not too many ships within the radio coverage. In a crowded VTS area, ship interrogation will be performed only by VTS centres. Otherwise, the VHF channel will quickly become saturated by ship-to-ship communications, due to the low data transfer ratio, around 1200 bits per second, provided by this transponder. VHF DSC technology is well known and has already been accepted by IMO, and is an equipment to be carried on board by all ships by 1999, under the SOLAS convention. Costs are relatively low, and the system operates in VHF channel 70 (established for DSC purposes), a frequency to be listened to by all vessels from 1999 under the SOLAS convention. These seem to be the main reasons why the United Kingdom considers this option the most suitable.[12]

5. OTHER TYPES OF TRANSPONDER. It is difficult to achieve an efficient radar coverage from a VTS centre when dealing with large archipelagos or long channels with several bends or turns. This is one of the reasons why Sweden has tested two different kinds of autonomous transponders in three different places.[13]

The Automatic Vessel Monitoring System (AVMS) was the first to be installed on board 4 ferries plying between Finland and Sweden in 1991; AVMS equipment has also been installed in the Stockholm information centre and a pilot has been using a portable unit. The purpose of the system is to offer continuous traffic surveillance in a specified area, and it is useful not only when two or more vessels approach one another on the high seas, but also in a close quarters situation in restricted waters, when radar coverage is limited. The Swedish Maritime Administration has tested AVMS in depth with excellent results. AVMS provides information to the Officer of the Watch consisting of name, course, speed, type of vessels, and bearing and distance to other vessels. AMVS is made of three main components: a positioning system (normally GPS), a transmitter and a computer.

The positioning system is connected to the transmitter and to a computer. The positioning system has to be equipped with a serial port RS-232, and the information, such as position, course, and speed, must be of the NMEA 0183 type. The transmitting unit is equipped with two processors; one is used for processing data received from the positioning system, and the second is used to process the above-mentioned data and send the output with the time and identification to the transmitter at set intervals. The positioning system and the transmitter operate separately.

Any standard computer located on the bridge for other purposes can be connected to the AMVS and used to present the list of ships with their positions. Ships presented on the screen are listed following a priority protocol. Priority 1 is assigned to those vessels on the starboard bow and within 3 miles distance. Priority 2 is assigned to vessels on the port bow, also in the 3 miles range. Priority 3 are ships on the starboard side within the 12 miles range. Priority 6 is for all vessels beyond the 12 miles range. The current installation shows all vessels on the screen together with an electronic chart.

5.1. GNSS TRANSPONDERS. The concept and technical solutions of the *GNSS transponder* were proposed by the Swedish engineer Häkan Lans. He designed it for the highly demanding specifications of civil aviation, both for ground and air use. However, the Swedish Civil Aviation Administration has experienced some difficulties in continuing the GNSS transponder project. After an exchange of ideas and technical solutions with colleagues in the Maritime Administration, this organisation decided to test the GNSS transponder. However, the system protocol had to be changed to adjust to maritime requirements; thus, the GNSS used for ship-to-ship and ship-to-shore operation became the transponder 4S GNSS. Like AVMS, the 4S GNSS transponder uses time data from GPS satellites in order to divide each second into 2250 time slots. At present, there are two systems in operation on board ferries sailing around the Gothenburg archipelago. In the Trollhatte Channel system there is also a repeater to widen the VTS coverage.

Communications technology developed and tested for the GNSS transponder is named GNSS-time synchronised self-organising time division multiple access (TDMA), a union of data available during all navigation phases. The communications technology used in the GNSS data network was designed with the necessary capability and redundancy required in the demanding applications of the civil aviation industry.

5.1.1. *Main functions*. The basic functions of the 4S GNSS transponder (at the present time only GPS is used) are to determine the position, course, direction and navigation status of vessels and transmit this information by VHF, together with their identity. As an option, with a lower report rate, a satellite communication system can be used (such as INMARSAT). It is obvious that the report rate through SatCom must be lower since the satellite covers a large part of the earth, whereas VHF is basically limited to visual range.

When a 4S GNSS transponder is activated, the GPS receiver begins to track satellites. At the same time, the communications processor listens to the traffic in the data net for approximately 4 minutes in order to establish a dynamic 'telephone directory' for all users of the system. In this way, all data transmitted by users on VHF are stored in each 4S GNSS transponder. After that, the transponder will transmit all data in one or more free time slots. Within each particular area, there are always new members entering and leaving the network. To avoid a situation where two or more members block or systematically distort communications within the network, each user periodically and independently changes the time slots during which their transmissions are performed. Every message lasts 26·666 milliseconds. There are 225 different types of messages available in the present system, but currently only about 10 percent are used. Consequently, there is a great capacity for a future development of the system and for additional messages.

With the addition of a processor connected to a high resolution colour screen, the 4S GNSS transponder and the digital information stored in each message can be used for many different purposes such as: surveillance, collision avoidance, traffic management, ships messages, Search and Rescue, etc. The potential applications are endless.

6. PROPOSED MINIMUM STANDARDS FOR TRANSPONDERS.

a. The transponder must be capable of performing ship-to-ship, ship-to-shore, shore-to-ship, surveillance and SAR missions (preferably with compatibility with the aircraft and helicopters involved).
b. The transponder must automatically record all ships within VHF range, including those not detected by radar due to the presence of islands, bends in a channel or heavy rain squalls.
c. Data transferring from the ship with a transponder on board must be autonomous and continuous at pre-programmed intervals, depending on the speed.
d. The system must be capable of receiving and processing data from similar capacity vessels in heavy traffic levels that are expected in any geographical area (including Dover and Singapore Straits).
e. Basic data from transmitted messages must include:
   (i) Ship's identity or call sign
   (ii) Position in latitude and longitude
   (iii) Course over the ground, heading and speed
   (iv) Status (underway, hampered by deep draught, at anchor…)
f. The ship identification system must operate continuously, both when the ship is sailing or at anchor.

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g. The system must be capable of being interrogated to provide additional information which it is not necessary to send continuously, such as name of the vessel, length, beam, draught and cargo.
h. The system should be easily available to the users by integrating the transponder system with radar and ARPA presentations or on ECDIS (Electronic Chart Display Information Service.)
i. Remote stations must be available to extend the coverage area of a VTS centre.
j. A VHF channel should be assigned.

7. THE EFFECT OF TRANSPONDERS ON MARINE NAVIGATION. Clearly some form of radio transponder will become mandatory for most vessels which sail both in the high seas and in restricted and crowded waters. The problem is to choose the most suitable transponder, which is capable of being improved on vessels and in VTS stations and thus be part of a long lasting system.

The 4S GNSS transponder seems to be the best and most capable of all the transponders analysed, and it offers an attractive solution for future development. A lower capacity system would mean that certain ships must carry on board various and different transponders, such as the DSC transponder. The problem of this option is that the limitations implied in the system will not allow the necessary flow of data in a ship-to-ship communication, when sailing in restricted waters.

If maritime and aviation industries choose a similar system, aviation and maritime units should be able to interchange information in an emergency situation, in Search and Rescue operations, etc. This could contribute to a significant improvement in the efficiency of such missions.

We do not wish to express any final views on the respective merits of radar, radio transponders. The decisions on the system to be adopted should be taken objectively, taking into account compatibility with existing equipment on the ship and on shore and with coastal radar and radio systems: transponders should be able to transmit information to computer controlled radar systems so that blips on screens can be easily identified, but should be equally usable with non-radar information systems. As the IMO Sub-Committee on Safety of Navigation (NAV) – 43rd session (14–18 July 1997) demonstrated, the adoption of transponders will be a controversial issue; however, we believe that in the future, all vessels larger than 300 tons GRT will probably be equipped with a transponder. In those areas where traffic density is not very intense, these systems could allow traffic management and surveillance without the need of a VTS centre. For those areas where the traffic flow is very high, and there is a clear need for maritime traffic control, the transponder will undoubtedly facilitate the tasks of a VTS controller.[14]

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