ISSN: 1231-4005
e-ISSN: 2354-0133
DOI: 10.5604/12314005.1213549

COMMUNICATION SYSTEMS FOR SAFETY AND SECURITY OF SHIPS

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Abstract

The article assesses the technical and operational possibilities of the marine communications systems to ensure the safety and security of ships. The basic functional requirements for marine radio communication to ensure the safety and security of ships, resulting from the provisions of the International Convention for the Safety of Life at Sea (SOLAS), have been described. The article presents the marine radio communication systems responsible for the distress alerting. The operation and ways of alerting used in Inmarsat satellite systems, Cospas-Sarsat systems and Digital Selective Calling system (DSC) have been described. The analysis of the systems responsible for broadcasting to the vessels the Maritime Safety Information (MSI) has been made. In this context, the operation, methods and ranges of broadcast of the Maritime Safety Information by the NAVTEX system and Inmarsat SafetyNet system have been described. The systems performing the function of ships security have also been discussed. The operation, application and basic properties of the Ship Security Alert System (SSAS) and Long Range Identification and Tracking system (LRIT) have been presented. In the subsequent part, the article outlines the future of maritime communications systems used to ensure the safety and security of ships. In this context, two projects currently being implemented in the framework of the International Maritime Organization (IMO) by the Sub-Committee on Navigation, Communications, Search, and Rescue (NCSR) have been presented. The first of these projects under the name of e-navigation refers to the use of the latest information and communication technologies in shipping. The second one concerns the modernization of the Global Maritime Distress and Safety System (GMDSS).

Keywords: *communication systems, maritime safety, maritime security*

1. Introduction

Marine radio was first installed on ships around the turn of the 20th century. In those early days, radio was used primarily for transmission and reception of passenger telegrams. The disaster of *RMS Titanic* brought about a number of fundamental changes to maritime radio communication. First of all, the basic principles to ensure the ship‘s distress and safety communication have been established. The *RMS Titanic* disaster also served as the catalyst for the introduction of the International Convention for the Safety of Life At Sea (the SOLAS Convention) of which the maritime radio communication was an important element.

Since that time, the maritime radio communication has developed both in terms of applied technology and communication procedures. In 1988, the Conference of Contracting Governments to the SOLAS Convention on the Global Maritime Distress and Safety System (GMDSS Conference) organized by the International Maritime Organization (IMO) adopted amendments to the SOLAS Convention concerning radio communications for the GMDSS. These amendments entered into force on 1 February 1992, and the GMDSS was fully implemented on 1 February 1999. The basic goal of the introduction of the GMDSS system was to improve the safety of ships in the area of radio communications. Obviously, since implementation of the GMDSS some changes both of technical and regulatory nature have occurred. Recent years have brought a new threat to shipping which are pirate and terrorist attacks. In response to this threat, the IMO has taken action to protect ships, including the use of appropriate communication systems.

Technological advances in the field of radio communications and information also affects the changes in the marine equipment and radio communication systems. Taking into account these changes IMO began work on two projects under the name of „E-navigation“ and „Modernization of the GMDSS“. Without a doubt, the communication systems for safety and security of ships will play a significant role in these projects.

2. Principal functional requirements

The original concept of the GMDSS is that search and rescue authorities ashore, as well as shipping in the immediate vicinity of the ship in distress, will be rapidly alerted to a distress incident so they can assist in a coordinated search and rescue (SAR) operation with the minimum delay. The system also provides for urgency, safety (including the promulgation of maritime safety information – MSI) and public communications.

The GMDSS lays down nine principal communications functions, which all ships, while at sea, need to be able to perform [1]:

1. transmitting ship-to-shore distress alerts by at least two separate and independent means, each using a different radio communication service,
2. receiving shore-to-ship distress alerts,
3. transmitting and receiving ship-to-ship distress alerts,
4. transmitting and receiving search and rescue co-ordinating communications,
5. transmitting and receiving on-scene communications,
6. transmitting and receiving signals for locating,
7. transmitting and receiving maritime safety information,
8. transmitting and receiving general radio communication to and from shore-based radio systems or networks and
9. transmitting and receiving bridge-to-bridge communications.

From the point of view of the safety of navigation, among above-mentioned functions, the most important functions are to provide distress alerts and transmission/ reception of maritime safety information (MSI).

Distress alerting is the rapid and successful reporting of a distress incident to a unit, which can provide or co-ordinate assistance. This would be a rescue co-ordination centre (RCC) or another ship in the vicinity. When an alert is received by an RCC, normally via a coast station or a land earth station (LES), the RCC will relay the alert to SAR units and to ships in the vicinity of the distress incident.

Ships need to be provided with up-to-date navigational warnings, meteorological warnings, forecasts, and other urgent maritime safety information (MSI). MSI is made available by promulgation by the responsible maritime administration means.

Following the events of September 11, 2001, the IMO had adopted new regulations to enhance maritime security through amendments to SOLAS Convention. These amendments also included the use of new communication systems to ensure shipping security.

In the GMDSS, a distress alert function is implemented by Digital Selective Calling (DSC), Cospas-Sarsat and Inmarsat systems, while the function of the transmitting and receiving MSI is implemented by Navtex and Inmarsat systems. A new communications function concerning the maritime security is implemented by Ship Security Alert System (SSAS) and Long-Range Identification and Tracking (LRIT) of ships.

Up to date equipment and systems used in the maritime radio communications for safety and security of ships are showed in Fig. 1. Unexplained earlier abbreviations used in Fig. 1 stand for:

- MES – Inmarsat Mobile Earth Station,
- EPIRB – Emergency Position Indicating Radio-Beacon,
- LUT – COSPAS/SARSAT Local User Terminal,
- MCC – COSPAS/SARSAT Mission Control Centre,

– GNSS – Global Navigation Satellite System – for support (mainly GPS – Global Positioning System),
– NAVTEX System,
– SAR – Search and Rescue Service.

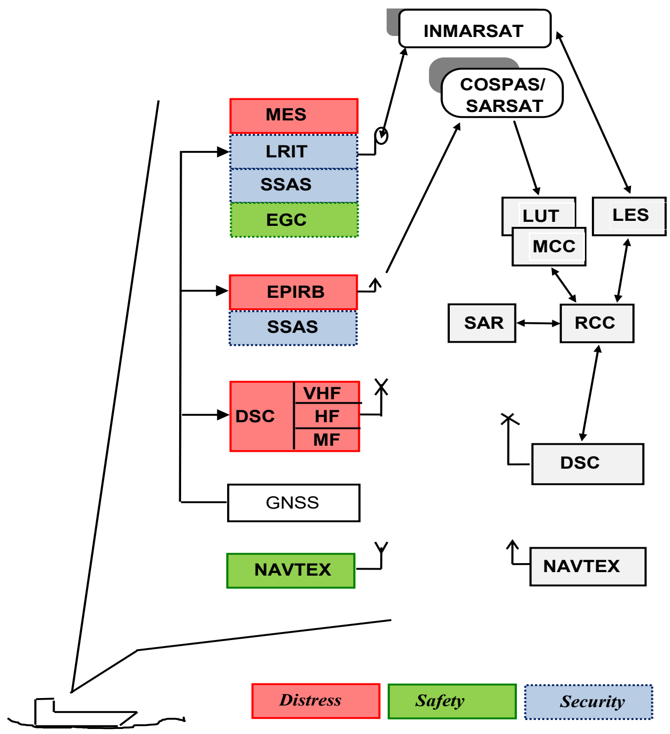

Fig. 1. Radio communication equipment and systems used for safety and security of ships

3. Distress alerting

Distress alert is a short message indicating that the ship is in distress situation, contains only ship's identification, position and, if time permits, nature of distress. The list of nature of distress is approved by IMO and includes:

– Undesignated distress,
– Fire, explosion.
– Flooding,
– Collision,
– Grounding,
– Listing, danger of capsizing,
– Sinking,
– Disabled and adrift,
– Abandoning ship,
– Piracy/armed robbery attack,
– Man overboard,
– EPIRB emission.

Distress alert is transmitted in a very simple way just by pressing so called „distress button" (sometimes also called „a red button"). As already mentioned, a distress alert function is implemented by the DSC, Cospas-Sarsat and Inmarsat systems.

Digital selective calling (DSC) is designed for automatic station calling and distress alerting. Each call consists of a packet of a digitized information. DSC calls can be routed to all stations (e.g. when distress alert is transmitted), to an individual station or to a group of stations.

The system is used by ships and coast stations in the MF (Medium Frequency), HF (High Frequency) and VHF (Very High Frequency)) maritime communication bands. Ships's DSC distress alert via the MF, HF or VHF coast stations is passed to the associated Rescue Coordination Centre (RCC) – (Fig. 1).

Cospas-Sarsat system is a satellite system designed to provide distress alert and location data to assist SAR operations, using spacecraft and ground facilities to detect and locate the signals of distress beacons operating on 406 Megahertz (MHz). The position of the distress and other related information is forwarded by the responsible Cospas-Sarsat Mission Control Centre (MCC) to the appropriate RCC (Fig. 1). The Cospas-Sarsat System is composed of:

- radio beacons carried aboard ships – EPIRBs (Emergency Position Indicating Radio Beacons), aircraft– ELTs (Emergency Locator Transmitters), or used as personal locator beacons – PLBs,
- polar-orbiting satellites in low Earth orbit from the LEOSAR system and geostationary satellites from the GEOSAR system,
- the associated Local User Terminals (LUTs) for the satellite systems (referred to as LEOLUTs or GEOLUTs) and Mission Control Centres (MCCs).

The Cospas-Sarsat LEOSAR system uses polar-orbiting satellites and, therefore, operates with basic constraints, which result from non-continuous coverage provided by LEOSAR satellites. The use of low-altitude orbiting satellites provides for a strong Doppler effect in the up-link signal thereby enabling the use of the Doppler positioning techniques. It also provides global coverage.

The GEOSAR system consists of repeaters carried on board various geostationary satellites and the associated GEOLUTs, which process the satellite signal. Since GEOSAR satellites remain fixed relative to the Earth, there is no Doppler effect on the received frequency and, therefore, the Doppler positioning technique cannot be used to locate distress beacons. To provide rescuers with position information, the beacon location must be acquired by the beacon through an internal or an external navigation receiver and encoded in the beacon message. It provides near-global coverage.

Inmarsat is the only satellite operator that meets GMDSS requirements. The Inmarsat system has three major components: the space segment provided by Inmarsat, the Land Earth Stations (LESs) provided by Inmarsat signatories and Mobile Earth Stations (MESs) located e.g. on board ships. The nerve centre of the system is the operations control centre (OCC), located at Inmarsat's headquarters in London. The OCC is responsible for controlling the Inmarsat system operation as a whole. Four satellites in geostationary orbit 36,000 km above the equator cover four ocean regions, namely AOR-E (Atlantic Ocean Region-East), AOR-W (Atlantic Ocean Region-West), IOR (Indian Ocean Region) and POR (Pacific Ocean Region), and provide near-global coverage. In every ocean region, communication is coordinated by the Network Coordination Station (NCS). The coverage of the Inmarsat system is given in Fig. 2 [7].

GMDSS-compliant ships are able to send a distress alert – which is automatically given priority access to an RCC on shore – by pressing (and holding for six seconds) a dedicated distress button (Fig. 1). Among the various Inmarsat systems, these requirements meet only Inmarsat B, Inmarsat C and Inmarsat Fleet 77. It should be noted that the Inmarsat-B system will be withdrawn at the end of 2016 and Inmarsat has now informed of its intention to close, with effect from 1 December 2020, the Inmarsat F77 service.

4. Maritime Safety Information

The Maritime Safety Information (MSI) service of the GMDSS is the internationally and nationally coordinated network of broadcasts containing information, which is necessary for safe navigation, received on ships by equipment, which automatically monitors the appropriate transmissions, displays information that is relevant to the ship and provides a print capability. There are no charges for receipt of MSI messages by a ship.

Two principal methods are used for broadcasting MSI in accordance with the provisions of the SOLAS Convention, in the areas covered by these methods, as follows [2] (Fig. 1):

– NAVTEX: broadcasts to coastal waters,
– SafetyNET: broadcasts, which cover all the waters of the globe, covered with Inmarsat system.

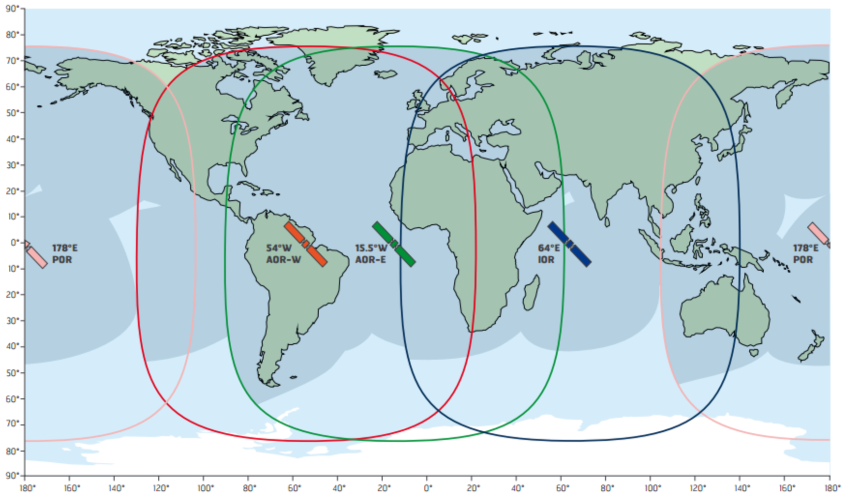

Fig. 2. The Inmarsat satellite coverage [7]

International NAVTEX service means the coordinated broadcast and automatic reception on 518 kHz of maritime safety information by means of narrow-band direct-printing telegraphy. Besides frequency 518 kHz, for national services, the frequencies 490 kHz and 4209.5 kHz may be used for NAVTEX broadcasts. Experience indicates that the average communication range for international frequency 518 kHz is about 250 to 400 nautical miles from transmitting coast station.

International SafetyNET service means the coordinated broadcast and automatic reception of maritime safety information via the Inmarsat Enhanced Group Call (EGC) system. This MSI concept is illustrated in Fig. 3 [3].

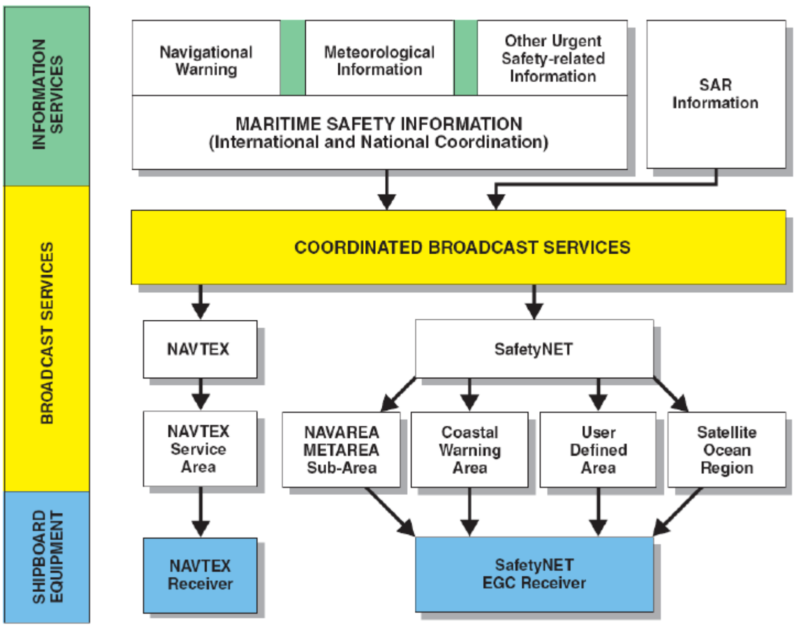

Fig. 3. The maritime safety information service of the GMDSS [3]

The combination of 518 kHz NAVTEX and the international SafetyNET service through the Inmarsat EGC service provides a highly reliable method of distributing navigational warnings, weather forecasts and other urgent information all over the world.

5. Communication ships and ports security systems

The IMO still aims to strengthen maritime security and suppress acts of terrorism and piracy against shipping. This effort was sped up drastically in reaction to the September 11, 2001 attacks and the bombing of the French oil tanker *Limburg* in 2002. As a result of this work "International Ship and Port Facility Security (ISPS) Code" was agreed in December 2002. The measures agreed under the Code were brought into force on July 1, 2004. One of the measure of this Code is Ship Security Alert System (SSAS). Further IMO work led to the approval in 2007 of Long Range Identification and Tracking (LRIT) of ships system. SSAS and LRIT systems are not part of the GMDSS communication requirements but its equipment is used to support these systems.

The SSAS is provided to a ship for the purpose of transmitting a security alert to the shore to indicate to a competent authority that the security of the ship is under threat. It comprises a minimum of two activation points, one of which is on the navigation bridge. These initiate the transmission of a ship security alert. The system is intended to allow a covert activation to be made which alerts the competent authority ashore and does not raise an alarm on board ship nor alert other ships. SSAS beacons can only be activated manually. The transmission includes only the ship identity and current position [4]. Ship security alerts can be transmitted with the use of the Inmarsat satellite terminals or Cospas-Sarsat beacons (Fig. 1).

The Long-Range Identification and Tracking (LRIT) system provides for the global identification and tracking of ships. Figure 4 provides an illustration of the LRIT system architecture.

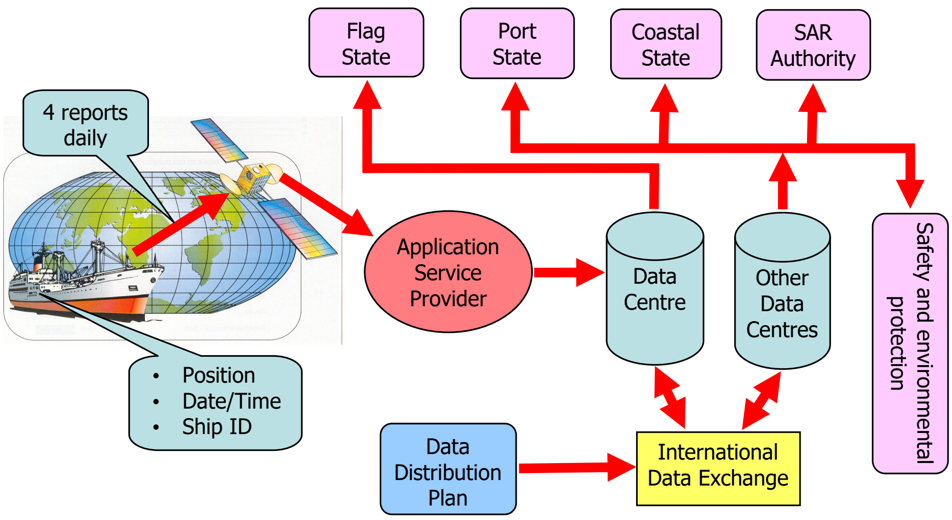

Fig. 4. LRIT system architecture

Under SOLAS regulations, ships are required to report their position (LRIT information) automatically, to a special shore data collection, storage and distribution system, at least four times a day. LRIT information is provided to users entitled to receive the information, upon request, through a system of National, Regional, and Cooperative LRIT Data Centres (DCs), using where necessary, the International LRIT Data Exchange (IDE) [5]. Individual Flag States are expected to publish specific regulations for the ships on their Register providing detailed guidance on the implementation of LRIT, including ship equipment conformance test arrangements, and the Application Service Provider (ASP) and DC chosen by the Flag concerned. The shipborne equipment used for LRIT can be any communications terminal but most often, it is Inmarsat C.

The Communication Service Provider (CSP) provides the communications services, which transfer LRIT data securely from ship to the ASP on shore. The ASP receives the LRIT reports, adds certain additional information to each report, and forwards the reports to the DC nominated by the ship's Flag State. The IDE exists to route LRIT information between LRIT DCs using the information provided in the LRIT Data Distribution Plan (DDP). It is therefore connected via the internet to all LRIT DCs and the LRIT DDP server. The DDP is principally a database that holds information needed to allow the international LRIT system to operate correctly. The DDP is consulted by any DC in order to determine whether a request for LRIT information should be allowed under the rules for the distribution of LRIT data [5].

Governments are entitled to receive LRIT information, if they wish to do so, for security and other purposes, in four basic situations [2]:

- as a Flag State – about ships entitled to fly its flag irrespective of where such ships may be located,
- as a Port State – about ships which have indicated their intention to enter a port facility,
- as a Coastal State – about ships navigating within a distance not exceeding 1,000 nautical miles of its coast,
- the Search and Rescue Service may receive, free of any charges, LRIT information in relation to the search and rescue of persons in distress at sea.

6. Future of the communication systems for safety and security of ships

The above presented analysis shows, that today communication systems for safety and security of ships, as a whole, are a complementary system well fulfilling the expected goals. Further increase of the safety and security of navigation can only be achieved by implementing new communication and information technology. Considering the above, in 2006, IMO began work on the „E-navigation“ project. Doubtless, one of the fundamental elements of e-navigation will be a data communication network based on the GMDSS infrastructure so, in 2012, IMO decided to start work on the new project: „Modernization of the GMDSS“.

E-navigation is defined as *the harmonised collection, integration, exchange, presentation and analysis of maritime information by electronic means to enhance berth-to-berth navigation for safety and security at sea and protection of the marine environment*. IMO has set a strategy on five solutions to provide a basis for supporting e-navigation [6]:

- S1: Improved, harmonization and user friendly bridge design,
- S2: Means for standardized and automatic reporting,
- S3: Improved reliability, resilience and integrity of bridge equipment and navigational information,
- S4: Integration and presentation of available information in graphical displays received via communication equipment,
- S5: Improved communication of VTS service portfolio.

The solutions S2, S4 and S5 are designed to improve communication between ship and shore for safety purposes. These initiatives will have implications for ship energy efficiency through better routing and reducing delays. The implementation of e-navigation involves the development of on-board communication and navigation systems that integrate all relevant ships sensors and supporting information. It should be noted that the IMO considers the implementation of e-navigation in the world's fleet as a long-term objective rather than a short-term fix.

The Global Maritime Distress and Safety System (GMDSS) is an integrated communication system using satellite and terrestrial radio communications to ensure that, no matter where a ship in distress may be, its call for assistance can be properly received and acted upon. The GMDSS was developed by IMO during 1980s and fully implemented on 1 February 1999. Therefore, in 2012, a draft timetable for bringing the GMDSS up to date was agreed by the IMO. Modernization plan envisages a fully comprehensive review of the GMDSS requirements, contained in SOLAS chapter IV (Radio communications), to take place over a three-year period (2013–2016), followed by a further two-year period (2016-2018) for the GMDSS modernization plan, to be succeeded by the development of legal instruments, the revision or development of relevant performance standards and an implementation period.

Parallel to the work on the above-mentioned projects, the work on new, specific solutions for these projects is underway. An example of such a solution can be NAVDATA system. It is a medium frequency (MF) radio system operating in the 500 kHz band for digital broadcasting of maritime safety and security related information from shore-to-ship. NAVDAT coverage is similar to the global system NAVTEX coverage. The technology allows important data rate with regard to the frequency band: rates up to 18 kbit/s are possible with NAVDAT, to compare to the 50 bit/s of NAVTEX. There is a possibility of encryption of NAVDAT messages, if necessary [8].

7. Conclusions

The analysis indicates that today's communication systems for safety and security of ships, as a whole, are a complementary system well fulfilling the expected goals. It should be noted that the Inmarsat systems play a key role in the subject. A major benefit of the Inmarsat distress priority systems is to render it unnecessary to allocate dedicated frequencies for distress, safety and security communications.

The combination of 518 kHz NAVTEX and the international SafetyNET service through the Inmarsat EGC service provides a highly reliable method of distributing navigational warnings, weather forecasts and other urgent information all over the world as well.

According to the author, further increase of the safety and security of navigation can only be achieved by implementing new communication and information technology. It will be possible within the framework of two projects carried out by the IMO on „E-navigation" and „Modernization of the GMDSS". A good example of the implementation of these projects can be NAVDAT system. The examples of the use of NAVDAT system show that this system has a significant interest in improving the safety and security of navigation. In this sense, it can be seen as a means of broadcasting of maritime safety and security-related information that will help to develop the GMDSS and to structure the architecture of e-navigation.

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