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Alternative Maritime Radio Solutions for Enhanced GMDSS Network

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ABSTRACT: This paper introduces novel alternative maritime radio solutions for the improved Global Maritime Distress and Safety System (GMDSS) network and equipment within the Very High Frequency (VHF), Medium Frequency (MF) and High Frequency (HF) Ship Radio Station (SRS) terminals. Since its foundiing in 1959, International Maritime Organization (IMO) and its member states, in close co-operation with the International Telecommunication Union (ITU) and other international organizations, notably the World Meteorological Organization (WMO), the International Hydrographic Organization (IHO), the International Mobile Satellite Organization (IMSO) and the Cospas-Sarsat partners, have striven to improve maritime distress and safety radiocommunications, as well as general radiocommunications for operational and personal purposes. This paper also reviews concept of the GMDSS network, an overview of new propsed by author maritime VHF Data Link (VDL), maritime Radio Automatic Dependent Surveillance-Broadcast (RADS-B), an maritime GNSS Augmentation VDL-Broadcast (GAVDL-B). In addition, the type of the current radio Maritime VHF Data Exchange System (VDES), Maritime MF-band Navigational Telex (NAVTEX), and Maritime MF/HF-band Navigation Data (NAVDAT) are also described in this paper.

1 INTRODUCTION

The focus of maritime communications and GMDSS networks these days is concentrated towards satellite communications and IP networking. Many things have changed from even a few decades ago, when radiotelegraphy and radio telex were main method of ship to shore and vice versa radiocommunication systems, so oceangoing ships are now effectively expanding computer LAN over satellite networks. However, VHF, HMF and HF radio communication systems continue to provide huge support for upgrading the GMDS network.

Of course, the driver for all these changes in distress Search and Ressque (SAR) operations was the establishment of the GMDSS network in the early 1990’s, which still uses VHF and HF Digital Selective Calls (DSC), VHF radiocommunication systems and NAVTEX transmissions. After the GMDSS operator onboard ships sends an DSC alert, then it switches to the radiotelephone distress and safety channels and conducts onscene communications with other ships, SAR forces and shore stations. The problem is that these channels are often plagued by interference and that some new and most reliable solutions should be proposed. Here will be shortly introduced new VHF and MF radio systems able to improve radio Communication, Navigation and Surveillance (CNS) requirements for the GMDSS network [01, 02, 03].

2 MARITIME VHF DATA LINK (VDL)

The aim of this section is to present a new proposed marine VHF Data Link (VDL) similar to aeronautical VDL, which can be applied in the future for the CNS service within the GMDSS network in the Sea Area A1. The new VDL service has to improve GMDSS solutions in coastal navigation, inland waters, approaching to anchorage and inside of the harbors as new solution with 3 main objectives:

1. To provide a more reliable and effective ships communications system based on efficient and higher rate digital transmission over VHF radio including International Ship and Port Facility Security Code (ISPS) system in harbors;
2. To improve R-AIS basic functions for ships collision avoidance; and
3. To enhance GMDSS network, Ship Traffic Control (STC) and Ship Traffic Management (STM) through the VDL network, together with the proposed RADS-B network.

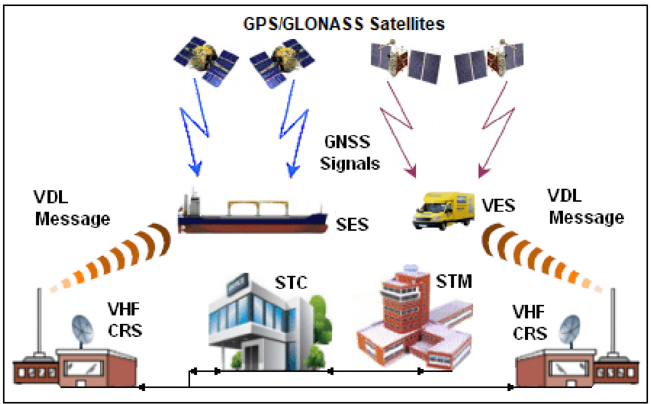

Figure 1. Maritime VDL Radio System for Enhanced GMDSS Network –Source: Ilcev

The ship's VDL system will be similar to R-AIS with the task of improving its capabilities and functionality, the configuration of which is shown in Figure 1. A major improvement of R-AIS requires the installation of VDL transponders onboard ships for improved STC and CTC in coastal waters, approaching anchorages and seaports. In the same way, similar VDL installations will be able to control the movement of land vehicles and rails within seaports. Both ships and vehicles transporters can be integrated with GNSS receivers that can receive navigation signals from GPS or GLONASS satellites and resend them via VHF Coast Radio Stations (CRS) terminals to STC and STM operational centres.

Received Position, Velocity and Time (PVT) data from ships and vehicles within VHF coverage will be processed and displayed on radar like a VDL display unit. In the opposite direction, the ship traffic controller may send PVT to all ships outside seaports and in particular to all ships and land vehicles within the seaport, and manage their movement in a safer manner [04, 05, 06, 07, 08].

3 MARITIME RADIO AUTOMATIC DEPENDENT SURVEILLANCE-BROADCAST (RADS-B)

The Radio Automatic Dependent Surveillance-Broadcast (RADS-B) communication mode has been developed for aeronautical applications, but can also be used for maritime applications, the configuration of which is illustrated in Figure 2. This system can uses radio transmissions from ships, approximately once in a while, to provide PVT and other data that have been detected and captured by onboard ships sensors, such as not-augmented Global Navigation Satellite System (GNSS) receiver (GPS or GLONASS), Automatic Radar Plotting Aid (ARPA) or Gyrocompass.

The RADS-B VHF CRS terminal uses a non-rotating omnidirectional radio antenna to receive VDL messages transmitted from ships in a certain ocean area. The maritime RADS-B network has been proposed as a multiple use surveillance technique for harbour terminals, approaching to anchorage, sea passages and coastal waters in range of VHF CRS terminals and is also applicable to STC, STM and ship-to-ships data transmitting OUT and receiving IN surveillance, known as an Internship RADS-B for enhanced collision avoidance.

The RADS-B transmission is "line of sight" based surveillance and requires CRS terminals to receive data and transmit to STC and STM operational centres. A single CRS can provide coverage out to approximately 250 Nm for coastal enroute, terminals and seaport area surface surveillance. This RADS-B communication network can be integrated with Ground Surveillance Radar (GSR) installations and provide additional surveillance capabilities. In ordet to improve ships surveillance and traffic control in the seaport area, this new system will require a special RADS-B transceivers integrated with GNSS receivers installed onboard ships and land vehicles [02, 04, 09, 10, 11].

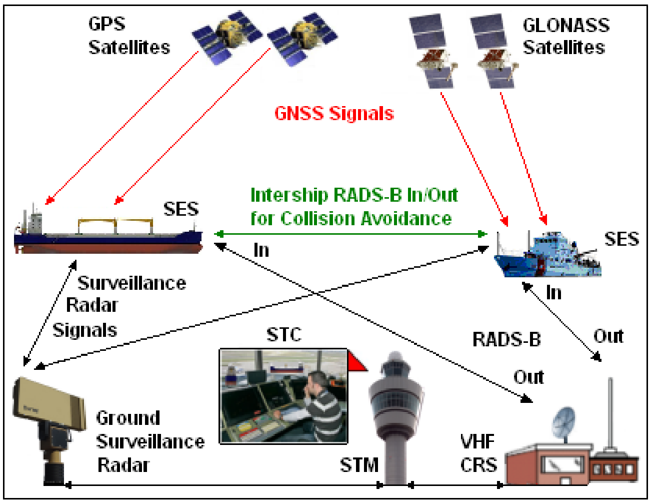

Figure 2. Maritime RADS-B System for Enhanced GMDSS Network –Source: Ilcev

4 MARITIME GNSS AUGMENTATION VDL-BROADCAST (GAVDL-B)

The GNSS-1 network is integral part of all applications where mobile CNS solutions play an important role in the development of modern configurations for enhanced STC and STM, and in particular for improved GMDSS shipborne facilities. In the GNSS-1 satellite network are integrated the US GPS and the Russian GLONASS, while the Chinese BeiDou or Compass and the European Galileo are included in the GMSS-2 network. The GNSS network provides standardized PVT information via VDL to oceangoing ships for more precise navigation and enhanced collision avoidance in global scene, which scheme is shown in Figure 3. The VDL system in the core GNSS constellations broadcast a timing signal and a data messages for differential correction of GPS and GLONASS signals. Shipborne not-augmented GNSS receivers use these signals to calculate their range from each satellite in view and also calculate 3-D position and precise time.

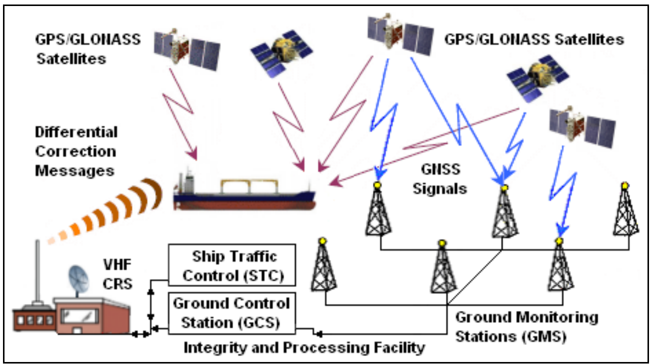

Figure 3. Maritime GAVDL-B System for Enhanced GMDSS Network – Source: Ilcev

In this way, the current radio navigation system can be replaced by a modern GNSS solution that will be capable to guide ships in more safe way. As stated above, the GAVDL network is providing GNSS data via GPS and GLONASS satellites for Ground Monitoring Stations (GMS) known as Reference Stations (RS), which provide determination of integrity, correction information, processing facility and precise accuracy with position errors below 1 meter, and forward them to Ground Control Station (GCS) or Master Station (MS). The GCS terminal augments primary GNSS constellations by providing Very High Speed (VHS) ranging, integrity and correction information. Accordingly, GCS receives GPS measurements from GMS and calculates clock and ephemeris corrections for each monitored GPS satellite, ephemeral information for each GEO satellite, and Ionosphere Grid Points (IGP) at an altitude of 350 km above the Earth's surface.

Any Regional Satellite Augmentation System (RSAS) as a civilian mobile safety-critical network that supports the regional or wide area augmentation through the use of GEO satellites only to broadcast the augmentation information received from GCS terminal. However, in the case of GAVDL system, a Local VHF Augmentation System (LVAS) is used here for ranging, monitoring and transmission of GAVDL signals to oceangoing ships. In the reverse direction, ships can send their GNSS augmented signals derived from GPS or GLONASS receivers directly via VHF CRS to STC stations. The STC processor will process received PVT data, displayed it on the screen like a radar display and use it for enhanced collision avoidance. In that manner, at the request of ship navigation officers, the operator in SCS can send them PVT data of nearby ships or the navigator can use data reporting and polling service and pools this data himself [02, 04, 05, 09, 10, 11].

5 MARITIME VHF DATA EXCHANGE SYSTEM (VDES)

The new VHF Data Exchange System (VDES) network was developed by the International Association of Maritime Aids to Navigation and Lighthouse Authorities (IALA) to address the emerging signs of data transmission channel overload in the AIS (VDL) band and at the same time provides more wide and unhindered data exchange for the maritime community. The initial concept of VDES includes the function of an AIS (R-AIS), Application Specific Messages (ASM), VHF terrestrial and satellite communication segments.

The VDES radio network is one of the potential elements of maritime E-navigation, which will exchange ASM transmission, thereby arranging operation of numerous applications to ensure safety, security, efficiency and protection of shipping and environment. In the future, this modern network will have a significant positive impact on the Maritime Safety Information (MSI) network, including Navigation Assistance Services (NAS) and the Vessel Traffic Management System (VTMS) for oceangoing ships.

Therefore, VDES network has been developed with the purpose of resolving problems regarding AIS channel congestion and efficiency degradation. Namely, today AIS is being used beyond the identification and tracking ships. More precisely, besides standard AIS data reports include the following features: static, dynamic and voyage related data; there are also general data exchange on maritime VHF band; data transmission between ships and satellite communication satellites; AIS-based Aids to Navigation (AIS-AtoN), AIS-SART, and AIS-EPIRB applications; Application Specific Messages (ASM), and since recently Maritime Service Portfolio (MSP).

Due to some of existing analogue channels of maritime VHF band have been relocated to AIS. The use of additional channels and digital VHF system will improve AIS services, thus in parallel modernize GMDSS network and support development of Maritime Cloud and e-Navigation. Within the context of e-Navigation, in the short term, mandatory reporting from ships might be encapsulated into ASM.

On the other side, MSP will cover a number of Vessel Traffic Service (VTS) related and other information services. The scope of the MSP concept is to align maritime networks with the need for information and communication services in a clearly defined operational area. Therefore, the maritime VTS network will play a central role in the coordination of

MSP information (i.e., information service, traffic organization service, ship navigation assistance services, ships security and the like).

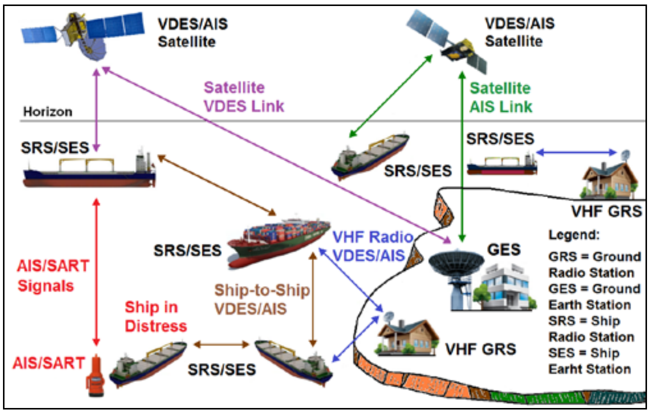

Figure 4. New Concept of VDES/AIS Network – Source: Ilcev

In Figure 4 is illustrated the new concept of an integrated VDES/AIS Network, which consists an VDES/AIS space segment, ground segment integrated with GES and VHF GRS terminals, and users segment containing SRS/SES terminals and AIS/SART beacons. The VDES/AIS Network provides satellite and VHF radio VDES/AIS links, inter-ship (ship-to-chip) communications, and AIS/SART signals. Thus, AIS signals can be received by the R-AIS receiver, and SART signals can be received by the onboard ships radars.

In this context, it should be pointed out that the new VDES will provide two-way communication at considerably higher data rate than previously used AIS systems. Within the VHF maritime frequency band (156.025-162.025 MHz), VDES integrates AIS with ASM and MSP to enhance smooth distribution of maritime data, including extensive meteorological and traffic data.

By enabling VDES to use a satellite platform, global data exchange between ships and the shore via satellites, will be provided in the future. It is also expected that future ship VDES transceivers will be combined with S-AIS into a single device. Thus, WRC-15 recognized that the VDES satellite component is necessary to expand the system from coastal coverage to global one, and recommend the further research for future developments.

However, the use of the VDES network can potentially provide local VTMS, however VDES may also include the concept of deploying the space (satellite) segment for global coverage. The space segment of the system can be used for VTMS transmission in remote areas [Recommendation ITU-R M.2092-0, 2015]. Insufficient study and proposals of the issue for sharing and comparability between the new developed satellite segment of the VDE system and the existing services in the same and adjacent frequency ranges caused the operating frequency range to not be determined at the World Radiocommunication Conference in 2015 (WRC-2015).

As a result, VDES as a whole is still not a complete functional system. As part of the 2015 IGC, the ITU approved the standard for VDES in the form of Recommendation ITU-R M.2092-0 [PP, 2015].

Only the issue of satellite segment approval for VHF (VDE) data exchange channels remains unresolved. Approval of this issue is one of the goals of the 2019 World Radiocommunication Conference (WRC-2019). The study of the vacant frequency ranges 156.0125-157.4375 MHz and 160.6125-162.0375 MHz will mainly concern interaction with existing mobile services, primarily for land and sea mobile services, as well as services within adjacent lower (from 154 MHz up to 156 MHz) and high (from 162 MHz to 164 MHz) frequency ranges. The concept of a VDES will be developed under agenda item 1.9.2 at WRC-19:

1. Amendments to the ITU Radio Regulations and new spectrum allocations to the mobile two-ways satellite service, preferably in the VHF- bands 156.0125 to 157.4375 MHz and 160.6125 to 162.0375 MHz of Appendix 18, are established to create conditions for the operation of the VDES, while ensuring that this segment does not impair the operation of existing VDES terrestrial segments, ASM, S-AIS and does not impose any additional restrictions on existing services in these and adjacent frequency bands referred to in d) and e) of the section, recognizing ITU Resolution 360 (Rev. WRC-15).
2. Among other applications, the use of VDES must be considered in all kinds of future VTMS dissemination mechanisms.

In this context, it should be noted that the new VDES will provide two-way communication at considerably higher data rate than previously used AIS systems. Within the VHF maritime frequency band (156.025-162.025 MHz), VDES integrates AIS with ASM and MSP to enhance smooth distribution of maritime data including extensive meteorological and traffic data. By enabling VDES to use a satellite platform, a global data exchange between ships and shore via satellites, will be enabled. It is also expected that future ship VDES transceivers will be combined with AIS into a single device. The WRC-15 recognized that the VDES satellite component is necessary to expand the system from coastal coverage to global one, and recommend that further research is to be done in order to decide on the further development of satellite VDES, during the upcoming WRC-19.

The new VDES network will undoubtedly support developing concepts of Maritime Cloud and e-Navigation, where VTS will play a key role in enabling team work between the crew and the personnel ashore. This service will make a shift from ship-to-ship, shore-to-ship, or VTS-centric navigation and relieve considerably seafarers in the future. Also, this will open the whole panoply of ICT jobs ashore dealing with navigation, meteorology, hydrographs, ecology, and provide path towards ashore assisted navigation and autonomous ships [02, 07, 08, 11, 12, 13, 14, 15].

6 MARITIME MF-BAND NAVIGATIONAL TELEX (NAVTEX)

In SOLAS regulation IV/12.2 is stated: “Every ship, while at sea, shall maintain a radio watch for broadcasts of maritime safety information on the appropriate frequency or frequencies on which such information is broadcast for the area in which the ship is navigating”. The radio watch can be maintained via NAVigational TEleX (NAVTEX) an international Narrow Band Direct Printing (NBDP) telex for transmitting MSI, such as navigational (NX) and meteorological warnings (WX), and other maritime safety-related messages emitted by hydrographic or meteorological offices, Rescue Coordination Centre (RCC), etc.

The NAVTEX maritime radio system has been developed to provide a low-cost, easy and automated means of receiving MSI onboard ships in coastal waters (about 200 nautical miles off shore, or maximum up to 400 nautical miles by CES terminals). The NAVTEX information may be relevant to all types of ships to receive broadcasts that suit well their particular needs, which provides automatic display or printout from a dedicated receiver. This service means the coordinated broadcast and on and automatic reception on 518 kHz (MF) of maritime safety information by means of NBDP telegraphy using English language. There are two additional frequencies for transmitting MSI within this system: 490 KHz (MF) and 4209.5 kHz (HF) for safety messages in national languages.

The NAVTEX network is a part of GMDSS, which is global communication system based upon automated terrestrial and satellite telecommunication sub-systems, to provide distress alerting and propagation of MSI at sea. There are 24 active NAVTEX transmission stations (A-X) and one backup station (Z), i.e., in total, 25 stations within each NAVAREA and/or METAREA. All NAVTEX stations transmit in the period of 10 minutes every 4 hours according to predefined timetable, and with limited transmission power in order to avoid interference. The NAVAREA radio network means particular geographical sea area identified with the aim of coordinating the broadcast of navigational warnings.

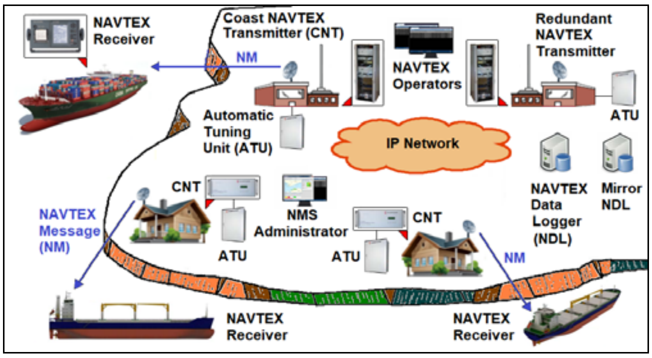

Figure 5. Current Concept of NAVTEX Network – Source: Ilcev

Otherwise, METAREA meteorological messaging service means a geographical sea area established for coordinating the broadcast of marine meteorological and warnings data for oceangoing ships. It is also important to note that different NAVTEX navigation messages are labeled with letters of English alphabet, which concept is shown in Figure 5. In other words, each NAVTEX message class carries a different topic indicator symbol that allows the operator on board the vessel to program the receiver and discard certain classes of suspicious NAVAREA or METAREA data that are not needed.

The maritime NAVTEX Network Management System (NMS) provides the ultimate overview of the site locations and simple network management of the entire NAVTEX messaging system. It enables monitoring and configuration of each individual NAVTEX transmitter to avoid failed transmissions. For a complete overview the system provides all relevant data including message transmissions, temperature and forward and reflected power readings. In case of failure, the system offers visual and audible alarms and ready redundant NAVTEX transmiter. Transmitter works independently of network functionality. It ensures messages can be sent even if a reverse power fault is observed. The fail-safe transmission is ensured by planned messages generated by remote control at preselected times, frequencies and output power.

The operator in the NAVTEX network can choose to schedule messages within selected time-slots or transmit urgent information immediately. All messages are automatically transmitted and logged and the interface is operated by either touch screen or keyboard. Therefore, the operator cannot refuse navigation and meteorological warnings, including search and rescue information. Also, the receiver cannot reject the item indicators related to the letters A, B, D and L and they will always be printed and/or displayed.

Basically, the NAVTEX network is a maritime radiotelex system for transmission of navigation meteorological information, which works at both MF and HF- bands. It operates in the Forward Error Correction (FEC) mode in which the source (transmitter) sends redundant data and the destination (receiver) recognizes only the portion of the data that contains no apparent errors. This broadcating system does not allow two-way communication between two stations, ie it is used only for broadcasting messages.

Thus, NAVTEX belongs to the systems known as a telex Narrow Band Direct Printing (NBDP), which refers to channel bandwidth of 500 Hz, and it is based on Frequency Shift Key (FSK) modulation, while the shift between carrier frequencies is 170 Hz, and data rate is approximately 100 bit/sec. It communicates with text messages rather than by voice. It is said that NBDP was introduced in the GMDSS to help seafarers whose first language was not English.

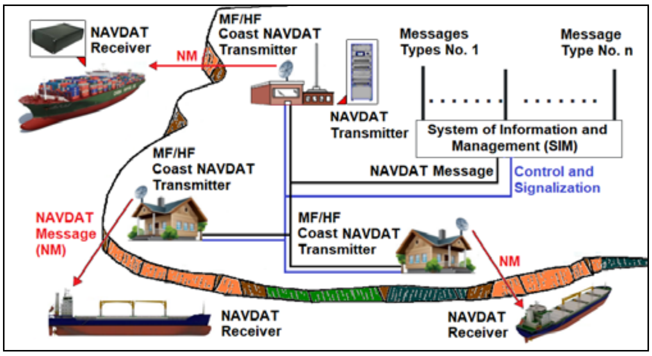

Figure 6. New Concept of NAVDAT Network – Source: Ilcev

Because of such low data rate NAVTEX might be treated as outdated, particularly within the context of developing complex e-Navigation, so called system-of-systems. Thus, NAVTEX cannot transfer large amounts of data in real time for the needs of berth-to-berth navigation, including possibilities of advanced route exchange mechanism. Due to some technical problems, the NAVDAT system was recently developed with the intention of replacing the NAVTEX syste [02, 07, 10, 12, 13, 15, 16, 17, 18].

7 MARITIME MF/HF-BAND NAVIGATION DATA (NAVDAT)

The NAVDA MF radio system is designed for use in the maritime mobile service operating in the 500 kHz band for digital broadcasting of information relating to maritime safety and security in the coast-to-ship direction. The NAVDAT HF ship receiver specifications are between 4 to 22 MHz maritime band, such as: 4,226; 6 337.5, 8,443; 12,663.5; 16,909.5 and 22,450.5 kHz. The new concept of NAVDAT network is shown in Figure 6.

The maritime NAVDAT System of Information and Management System (SIM) provides the NAVDAT message types 1 and n, and transmits them via coast NAVDAT transmitters to the shipborne NAVDAT receivers. The control and signalization system provide a superior overview of site locations and simple network management of the entire NAVDAT system. In this way, special marine NAVDAT receivers onboard oceangoing ships use the MF and HF frequency bands to receive free any kind of NAVDAT messages with possibility of encryption.

The international digital radio broadcast standard Digital Radio Mondiale (DRM) is used for digital

radio broadcasting at MF and HF band. The DRM standard is a proven technology that provides superior coverage, improves signal fidelity (through digital error correction coding), eliminates multi-path interference (including sky-wave interference) and thus extends coverage from sky-wave propagated signals. Thus, the DRM system broadcasts are implemented in both 16-QAM (Quadrature Amplitude Modulation) and 64-QAM modulation modes, depending on coverage requirements, transmitter location, power and antenna height.

The NAVDAT radio system uses a time slot allocation similar to the International Automated Alert System known as Navigational Telex (NAVTEX), which IMO can coordinate in the same way. The NAVDAT system can also operate in Single Frequency Network (SFN) mode. In this case, the transmitters are synchronized in frequency, and the data for transmission should be the same for all transmitters. Thus, the digital NAVDAT 500 kHz system provides broadcast transmission of any type of message in the shore-to-ship direction with encryption capability.

Any broadcast message must come from a secure and managed source. Types of NAVDAT radio messages for broadcast include, but are not limited to the following particulars: 1) Navigation safety; 2) Security Issues; 3) Data on piracy event; 4) SAR; 5) Meteorological reports; 6) Pilot or port communications; and 7) File transfer of the ship traffic system. These messages broadcast information for vessels, groups of vessels, or in certain areas of navigation. Besides, these messages can be addressed to a single vessel using the Maritime Mobile Service Identity (MMSI).

These messages broadcast information for vessels, groups of vessels, or in certain areas of navigation. Besides, these messages can be addressed to a single vessel using the Maritime Mobile Service Identity (MMSI). The organization of the NAVDAT system is determined by five factors that ensure the performance of the following functions:

1. System of Information and Management (SIM) – Collects and manage all types of information, creates message files to be transmitted and creates transmission programs in accordance with the priority of message files and the needs of the replay;
2. Coastal Network – Provides transportation of message files from different sources to relevant transmitters;
3. Shore Transmitter – Accepts message files from SIM, converts message files to a signal with Orthogonal Frequency Division Multiplexing (OFDM) and transmits an RF ;
4. Transmission Channel – Transmits radio frequency signals at 500 kHz; and
5. Ship Receiver – Ships NAVDAT receives and demodulates an RF signal with OFDM modulation mode, restores and sorts message files and makes them available to the target equipment in accordance with the application of the message files [02, 07, 10, 12, 16, 18, 19].

8 CONCLUSION

The future enhanced GMDSS network has to provide integration of radio and satellite CNS systems, which have to ensure rapid automated alerting and Search and Rescue (SAR) operations of ships in distress at sea and inland waters. The main maritime systems, networks and equipment that can be integrated into the GMDSS infrastructure are the existing and new projected Radio Distress and Safety Systems (RDSS) and Satellite Distress and Safety Systems (SDSS).

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