MARITIME RADIO COMMUNICATIONS PLAN

December 2017

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) exists to:

- harmonise standards for aids to navigation systems worldwide;
- facilitate the safe and efficient movement of shipping, and;
- enhance the protection of the maritime environment.

This Maritime Radio Communications Plan (MRCP) has been developed by IALA to assist in the selection of radio communication systems required to support e-Navigation and GMDSS. The current status of radio communication in the maritime mobile bands is discussed and forms the basis of projections for future developments needed to support e-navigation, GMDSS and the development of Maritime Autonomous Systems (Surface).

The MRCP provides guidance to IALA members regarding potential future developments, which will enable members to identify areas requiring resource allocation and research activity.

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International Association of Marine Aids to Navigation and Lighthouse Authorities
Association Internationale de Signalisation Maritime

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1 Introduction

1.1 General

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) was formed in 1957 as a non-government, non-profit making, technical association that provides a framework for aids to navigation authorities, manufacturers and consultants from all parts of the world to work with a common effort to:

- harmonize standards for aids to navigation systems worldwide;
- facilitate the safe and efficient movement of shipping; and
- enhance the protection of the marine environment.

The functions of IALA include:

- developing international cooperation by promoting close working relationships and assistance between members;
- collecting and circulating information on recent developments and matters of common interest;
- liaison with relevant inter-governmental, international and other organizations. For example, the International Maritime Organization (IMO), the International Hydrographic Organization (IHO), the International Electrotechnical Commission (IEC), and the International Telecommunication Union (ITU);
- liaison with organizations representing the aids to navigation users;
- addressing emerging navigational technologies, hydrographic matters and vessel traffic management.

1.1.1 e-Navigation

e-Navigation is an International Maritime Organization (IMO) led concept based on the harmonisation of marine navigation systems and supporting shore services driven by user needs.

The working definition of e-Navigation as adopted by IMO is:

> *e-Navigation is the harmonised collection, integration, exchange, presentation and analysis of maritime information onboard and ashore by electronic means to enhance berth to berth navigation and related services, for safety and security at sea and protection of the marine environment.*

There are 3 key elements or strands that must first be in place before e-Navigation can be realized:

- Electronic Navigation Chart (ENC) coverage of navigational areas;
- a robust electronic position, navigation and timing system (with redundancy); and
- an agreed infrastructure of communications to link ship and shore.

1.1.2 Aim and Vision of IALA

The aim of IALA is:

> *Fostering the safe, economic and efficient movement of vessels by improvements and harmonisation of aids to navigation worldwide.*

while the Vision of IALA is:

> *Safe marine navigation in a world of:*
>
> - Larger and faster ships;
> - Changing economy & technology;
> - Stringent standards;
> - Holistic approach (e-Navigation);

- Changing waterway use.

With this in mind, IALA has taken an initiative, as part of the strategy for the future of e-Navigation, by developing a World Wide Radio Navigation Plan (WWRNP). To support the WWRNP IALA developed and is maintaining focus work on maritime radiocommunications to support both the vision of IALA and e-Navigation.

1.2 Scope and Objectives

The core objective of the Maritime Radio Communications Plan (MRCP) is to state the IALA vision for the efficient use of Radio Spectrum in the Maritime Mobile Service. Edition 3 of the MRCP reflects the outcomes of developments in maritime radio communication spectrum.

This document focuses on the need for an agreed infrastructure of communications between ships and ashore. It presents IALA's view on current, developing and future Radio Communication Systems for the maritime sector.

e-Navigation requires appropriately designed radio communication systems for robust and reliable services. This document is aimed at assisting in the formulation of policy for National and International spectrum allocation and usage.

This document is also provided for IALA members and other administrations to assist them in offering their proposed use of radio spectrum as part of the on-going studies at ITU.

2 Background

Digital communications permeate our daily lives – both for work and for recreation. The introduction of 'any-time, any-where' access to information through the internet (IoT); text based or image based communications; geospatial locating and more is driving demand for faster, more robust, and more integrated, communication solutions.

Almost every e-Navigation solution currently foreseen depends upon efficient and robust ship-ship, ship-shore or shore-ship electronic data transfer. Existing communications systems may, in many places, be adequate to serve these needs, but it may be necessary to develop new methods to realise the full potential of e-Navigation. The performance requirements, in particular data capacity, for communications systems to support e-Navigation are, in many cases, unknown and are likely to change over time. However, studies and user requirement workshops have been carried out to better determine the data transfer requirements to address e-navigation elements and facilitate development of digital communications solutions for the maritime environment. This work provides a basis for analysis of candidate technologies and the opportunity to provide strategic guidance on implementation of the technologies in a rapidly changing maritime environment.

A strategy for the implementation of digital communications technologies, and the provision of effective equipment and infrastructure is that the user will not be required to choose a candidate digital communications technology when transferring information; the system will choose the most appropriate means to transfer the data based on the technologies available and the parameters required for the data transmission.

2.1 General

The challenge facing radio communication in the maritime sector is the need to relay more information, more often, on a global basis, which puts pressure on the availability of spectrum.

Spectrum, as a finite resource, is under increasing demand from all users globally. Recent trends from national licensing / regulatory authorities have been to use pricing / cost to drive efficiency improvements.

The move from analogue to digital; and from voice to data; show the way forward for future radio communications.

Experience with AIS has shown that TDMA techniques can enable hundreds of users to effectively and efficiently share vast amounts of data using only four channels – AIS 1, AIS 2 for safety of navigation purposes and AIS channels 75 and 76 for satellite detection of AIS.

Selection of appropriate bandwidth given the constraints of required range, data rates and channel availability means that narrow band techniques should be considered.

2.1 International Organizations

Co-operation and coordination between International, Intergovernmental and other organizations including IMO, ITU, ICAO, WMO, IHO, IALA, IEC, IMEA, CIRM, and RTCM is necessary to ensure an effective approach to maritime communications to support e-Navgation and other developments.

Co-ordination with ITU is required to secure access to radio spectrum to support e-Navigation communications technology.

IALA national administrations are encouraged to ask their national representatives at ITU to support the MRCP.

2.2 Regulatory Developments

The carriage requirement for radio communications equipment on SOLAS convention vessels is identified by the IMO. This includes AIS, DSC, voice communications and radar equipment as well as communications equipment to support GMDSS and LRIT.

In the provision of aids to navigation, IALA has highlighted the requirement to provide an optimum mix of aids to navigation for the users, which can include SOLAS convention vessels; domestic commercial vessels; and recreational craft.

Radio spectrum is regulated by the ITU, which includes not only the frequencies but the technologies and standards for the systems employed.

This MRCP reflects the requirements for communications identified by IMO, in addressing the needs of the maritime industry. This MRCP also takes into account the maritime communications requirements of other users, including domestic commercial vessels and recreational craft.

The IMO's Maritime Safety Committee (MSC) agreed on the need to address different levels of automation, including semi-automatic and unmanned ships. (MSC98). Effective, secure communications will be essential for the safe operation of these vessels.

With a critical focus on safety of navigation and protection of the maritime environment, previous agreements have identified that GMDSS and other safety of navigation related communications, such as AIS, shall be free of charge.

2.3 Commercial

Growth of the world fleet places greater stress on the ability of the existing radio communications systems to cope with the traffic. The commercial aspect includes both commerce and public correspondence.

Voice systems that occupy a channel for the duration of the call can be viewed as an inefficient means of relaying information. As the number of vessels increases, a saturation point on VHF may be reached. There could be a point reached where it may be difficult to make a VHF voice call, specifically if analogue systems are used. To avoid the inherent problems with VHF, AIS transfers packets of digital data using TDMA, which can cope with multiple simultaneous users and is more resistant to overloading due to growth in the number of participants.

AIS is now well recognized in maritime society and widely used as several systems, including class A for SOLAS vessels, class B for non-SOLAS vessels, Aids to Navigation (AtoN), Search and Rescue Transmitter (AIS-SART), and Application Specific Messages (ASM). This wide usage of AIS has caused an increase in the load put on the VHF data link (VDL). The VDL load in some areas has already exceeded 50%. According to IALA Recommendation A-124 Appendix 18 "VDL Loading Management", if the VDL loading exceeds 50%, it may have an impact on smooth transmission of AIS station. It therefore may be necessary to develop a method to mitigate the overload of the VDL.

In addition, increasing demand of digital radiocommunication in all areas, such as land, air, maritime and space, requires more effective use of limited radio resources. The option of more spectrum in the maritime mobile service is not readily available, so alternatives have to be found to support future growth. Existing spectrum allocated to maritime use will need to be fully utilized.

2.4 Operational

There are many changes taking place in the operational environment that present new challenges including:

- the development and implementation of e-Navigation;
- the widespread reliance on GNSS and its role underpinning position, navigation and timing required for situational awareness and communications for e-Navigation;
- growing deployment of local and specific traffic monitoring schemes and Vessel Traffic Services to meet ever more stringent requirements at higher capacity levels; and
- the balance between traditional navigation skills and the role of technological advances such as ECDIS and IBS.

The introduction of GNSS has enabled mariners to navigate more safely. As part of the introduction of e-Navigation, it is essential to understand the consequences when key e-Navigation components fail or are denied (e.g. GNSS or communications capabilities).

Before adopting any technology human factors must be addressed (safety, liability, on-board training and duty of care).

e-Navigation implementation requires the active participation of international bodies such as IMO, ITU, IHO, IALA,, PIANC, IEC, WMO, RTCM, ETSI and CIRM.

2.5 Technical

To ensure networks and technologies seamlessly interconnect, significant changes to underpinning services and systems are expected over the next two decades:

- development of data communication systems;
- development of satellite systems and services (e.g. VDES (including AIS), MeoSAR, broadband);
- development of terrestrial systems and services (e.g. VDES (including AIS), wireless broadband
- spectrum sharing and efficiency;
- compatibility with existing systems and services;
- adding data services to current voice channels;
- change from analogue to digital communications.

3 The IALA Maritime Communications Plan

3.1 Overview

The maritime domain uses a wide range of communications technologies across the radio spectrum in order to support safe navigation, efficient operations and commercial aspects (commerce and public correspondence. However, many of these technologies have been developed with a single application in mind. As a result, a vessel needs to carry many different types of communications equipment, in order to be able to receive relevant data.

In the e-Navigation environment there is the opportunity to plan the maritime communications system architecture afresh. This requires an assessment of the likely communications needs as well as an understanding of the radio spectrum available to the community. This section gives a brief summary of the existing and future radio communication systems.

3.2 Maritime Communication Requirements

The maritime domain uses communication links for essential safety of life applications, routine operational activities to commercial applications (commerce and general correspondence).

When establishing the communication requirements under e-Navigation it is essential to consider safety of life, operational, and commercial applications. In order to achieve the benefits of e-Navigation the design of the communications architecture needs to focus on a small set of known applications with the flexibility to grow and encompass other applications in the future as necessary.

Safety	Operational	Commercial
▪ AIS position reports	▪ Weather data	▪ Voyage orders
▪ AIS AtoN	▪ Ship reporting	▪ Commercial port services
▪ Digital Selective Calling	▪ Notifications to coastal States	▪ Operational reports
▪ Long Range Identification and Tracking	▪ Port arrival notification	▪ Cargo telemetry
▪ Differential GNSS	▪ Maritime Information Overlays	▪ Point of Sale
▪ NAVTEX/SafetyNET	▪ Port & VTS surveillance feeds	▪ Crew personal communications
▪ VTS coordination	▪ Electronic chart updates	▪ Passenger Internet access
▪ SAR	▪ Access to vessel and equipment manuals	▪ Crew training
▪ Distress and Urgency alerting/calling	▪ Remote maintenance and service	Infotainment
	▪ Telemedicine	

Figure 1 Overview of maritime communication applications by type

Figure 1 shows some example applications broken down between the categories of essential communication application to ensure safety, important communication application for efficient operations and possible commercial communication applications.

3.3 General Overview of Existing Communication System Technologies

This section details the current technologies used for maritime communications by frequency band. Please refer to the table in Annex A for system details, Annex B for maritime spectrum allocations and Annex D for specific ITU technical characteristics associated with the systems described in section 3.3 and 3.4.

3.3.1 Propagation

Both analogue and digital communications will suffer from propagation effects. It should be noted that propagation can limit or inhibit the transmission of digital communications. This means that measures may be required to mitigate adverse effects of propagation. Such measures could include automatic carrier selection; or use of 'smart' protocol to send only the unsent information.

3.3.2 Low Frequency Band (LF)

There is some use of the LF radio spectrum by the maritime community. While Loran C is now obsolete, other systems such as eLoran and research projects are underway to evaluate the usage, if any, of this spectrum.

3.3.3 Medium Frequency / High Frequency Band (MF/HF)

Various uses are made of the MF/HF radio spectrum by the maritime community for communication of voice and data, in ship-ship, shore-ship and ship-shore modes of operation. MF/HF transmissions support both general, Maritime Safety Information (MSI) and distress related communications using DSC, NBDP, voice and data. These communications take place across the maritime mobile service bands within 1.6-26.5 MHz as defined in Appendix **17** to the ITU Radio Regulations, whilst distress related communications are consigned to a small set of specific channels as indicated in Appendix **15** to the ITU Radio Regulations. Channel bandwidths are typically 0.5 kHz (DSC and NBDP) and 3 kHz (voice and data).

3.3.3.1 Digital Selective Calling (DSC)

DSC is a technique using digital codes which enables a radio station to establish contact with, and transfer information to, another station or group of stations, for distress or general communications over medium to long range distances. DSC is primarily used for distress alerting, urgency and safety calling within ship-to-ship, ship-to-shore and shore-to-ship prior to initiating distress, urgency and safety communications using radiotelephone or MF/HF radiotelex. DSC distress alerts, which consist of a preformatted distress message, are used to initiate emergency communications with ships and rescue co-ordination centres. DSC is intended to eliminate the need for manual watch keeping on a ship's bridge or on shore to monitor continuously radio receivers on the distress and safety frequencies. Six specific MF/HF frequencies are also set aside for Digital Selective Calling (DSC) distress and safety communications, one in each communication sub-band up to 16 MHz band. DSC is an element of the Global Maritime Distress and Safety System (GMDSS). DSC can also be used to call individual stations, groups of stations, or all stations in radio range. Each DSC-equipped ship, shore station and group is assigned a unique 9-digit Maritime Mobile Service Identity (MMSI) as defined in the Recommendation ITU-R M.585.

3.3.3.2 Voice Communication

Various uses are made of the MF/HF radio spectrum by the maritime community for communication of voice in ship-ship, shore-ship and ship-shore modes of operation. General voice communication takes place across the band 1.6-26.5 MHz Channel bandwidths are typically 3 kHz. Digital communication within the MF/HF bands is a relatively new technology with high potential.

3.3.3.3 Data Communication

Current and emerging HF digital modulation schemes provide new opportunities utilizing data transmission in this frequency band (1.6-26.5 MHz). The relevant technologies are described in the Recommendation ITU-R M.1798. The Recommendation ITU-R M.1798-1, published on April 2010, includes three systems.

System 1 is an HF data services modem protocol using orthogonal frequency division multiplexing (OFDM) and uses 4/8-PSK modulation to 32 sub-carriers.

System 2 is an Electronic mail system using the Pactor-III protocol with QPSK modulation to 18 sub-carriers.

Note - System 1 and System 2 use 3 kHz channels for the data rate of 3 kbps or below.

System 3 is a 10-20 kHz wideband HF data system for internet access and Electronic mail services using OFDM. This system uses QAM modulation to 228 sub-carriers at 10 kHz bandwidth or 460 sub-carriers at 20 kHz bandwidth for the data rate up to 51 kbps. All three systems are IP level-compatible making interoperability possible.

3.3.3.4 Narrowband Direct Printing (NBDP)

NBDP is a technique which automates radio signals to telegraphy. NBDP (also known as radio telex) is FSK modulated onto HF channels of 0.5 kHz and supports low speed data transmissions (100 bps) in the maritime mobile service bands within 1.6-26.5 MHz. NBDP is an element of GMDSS and can be used as the text based distress follow-up communications and general communications between ship-to-ship, ship-to-shore and shore-to-ship to overcome the language difficulties. The use of NBDP for general communication is declining and is now used for

position reporting from ships and promulgation of meteorological warnings and forecasts from coast stations. IMO has indicated that NBDP could be removed as a required system under the GMDSS[1].

3.3.3.5 Navigational Telex (NAVTEX)

NAVTEX is an international, automated system for instantly distributing Maritime Safety Information (MSI) such as maritime navigational warnings, weather forecasts and warnings, search and rescue notices and similar information to ships. A small, low-cost and self-contained smart printing2 radio receiver (NAVTEX receiver) is an element of GMDSS and installed on the ship's bridge. Messages are broadcasted in English on 518 kHz, while 490 kHz and 4209.5 kHz are used to broadcast in English and/or local language. The messages are coded with a header code identified by using alphabets to represent broadcasting stations, type of messages, and followed by two figures indicating the serial number of the message. The time of broadcasting is internationally co-ordinated by areas (NAVAREA) to share the same frequency.

3.3.3.6 Differential Global Navigational Satellite System (DGNSS)

The IALA Differential GNSS coastal radio beacon network broadcasts corrections and integrity information to maritime users in the LF/MF bands (between 283.5 and 325 kHz). Data rates can be 50, 100 or 200 bps. This is a data broadcast system from shore-to-ship.

3.3.4 Very High Frequency Band (VHF)

Voice communication using the maritime VHF band (156.025-162.025 MHz) is prevalent and the primary means of ship-shore, shore-ship and ship-ship communication in the domain. It is used for distress, safety information and general communications. Channel spacing is currently 25 kHz although the use of 12.5 kHz channels on an interleaved basis is allowed within Appendix 18 of the Radio Regulations as described in accordance with Recommendation ITU-R M.1084 to improve spectrum efficiency.

3.3.4.1 Digital Selective Calling (DSC)

DSC is a technique using digital codes which enables a radio station to establish contact with, and transfer information to, another station or group of stations, for distress or general communications using channel 70 (156.525 MHz). DSC is an element of the GMDSS, and is used for distress alerting; urgency and safety calling within ship-to-ship; ship-to-shore and shore-to-ship prior to initiating distress, urgency and safety communications. Additionally, DSC may be used for AIS channel management in specific geographic areas. DSC distress alerts, which consist of a preformatted distress message, are used to initiate emergency communications with ships and rescue coordination centres.

DSC can also be used to call individual stations, groups of stations, or "all stations" in radio range. Each DSC-equipped ship, shore station and group is assigned a unique 9-digit Maritime Mobile Service Identity (MMSI) as defined in the Recommendation ITU-R M.585.

3.3.4.2 Voice Communication

Voice communication using the maritime VHF band (156.025 to 162.025 MHz) is prevalent and the primary means of ship to shore, shore to ship and ship-to-ship communication in the domain. It is used for distress, safety and general communications. Hand-held units are generally utilized for on-board communications. Primary channels used for distress and safety communications by voice are Ch 6, Ch 13 and Ch 16. The use of other channels is designated in Appendix **18** to the ITU Radio Regulations. Channel spacing is currently 25 kHz although there is provision in Appendix **18** to use 12.5 kHz interleaved channels as described in Recommendation ITU-R M.1084.

3.3.4.3 121.5 MHz Locating Beacon

The frequency 121.5 MHz is an aeronautical emergency frequency. 121.5 MHz radiobeacons were developed in the mid-seventies for installation on aircraft, as Emergency Locator Transmitters (ELTs). However, they can also be used

1 NCSR 4 / 29 (Report of NCSR 4 to the MSC)

2 The self-contained printer requirement was removed from IMO performance standards (MSC.148 (77)) subject to provision of a dedicated display device and a printer port for the installations on or after 1 July 2005.

on board ship as part of Emergency Position-Indicating Radio Beacons (EPIRBs) or in Personal Locator Beacons (PLBs).

3.3.4.4 Automatic Identification System (AIS)

3.3.4.4.1 Primary Purpose of Automatic Identification System

AIS is a TDMA-based data exchange system used by ships and shore authorities. The main purpose of AIS is to improve the safety of navigation by assisting in the efficient navigation of ships, protection of the environment, and operation of Vessel Traffic Services (VTS), by satisfying the following functional requirements:

1. in a ship-to-ship mode for collision avoidance;
2. as a means for littoral States to obtain information about a ship and its cargo; and
3. as a VTS tool, i.e. ship-to-shore (traffic management).

AIS provides a means for ships to electronically exchange ship data including identification, position, course, and speed with other nearby ships and shore stations. This information can be displayed on a screen display. AIS is intended to assist the vessel's watch keeping officers and allow maritime authorities to track and monitor vessel movements. AIS uses VHF Channels AIS 1 (161.975 MHz) and AIS 2 (162.025 MHz) or regional channels in defined geographical areas. Additionally, AIS has the capability for data exchange by application specific messages for navigation and safety related purposes. The VHF Data link (VDL) loading should be considered when using application specific messages.

3.3.4.4.2 Automatic Identification System Aids to Navigation (AIS AtoN)

AIS is also used on Aids to Navigation, which can include the incorporation in a physical aid to navigation, or the transmission from an AIS base station.

3.3.4.4.3 Automatic Identification System Application Specific Messages

AIS can also be used for the broadcast of navigation information, meteorological and hydrographic data and other application specific messages.

AIS Application Specific Messages (AIS ASMs) are identified in IMO SN.1/Circ. 289, with examples of use of AIS ASM provided in IMO SN.1/Circ. 290. Regionally, ASMs are managed by IALA, through the IALA e-Navigation Portal[3]

3.3.4.4.4 Automatic Identification System Search and Rescue Transmitter (AIS-SART)

AIS-SART is a locating device (alternative to radar SART). As an element of GMDSS, AIS-SART is used to locate survival craft and distressed vessels. The AIS-SART has no receiver and operates up to 96 hours on a primary battery. The position and time synchronization of the AIS-SART is derived from a built-in GNSS receiver.

3.3.4.5 Man Overboard Device (MOB)

There are various systems available that operate on either DSC based or AIS based technology as well as others that utilize Bluetooth or other technologies. The MOB devices must be regarded as location aids in emergency situations and not as distress alert systems.

3.3.4.6 Two-way VHF Radiotelephone Apparatus

Two-way VHF radiotelephone apparatus is defined in SOLAS Chapter III. In practice, this apparatus is used as an element of GMDSS. The apparatus is either a portable or fixed transceiver for use in survival craft. It is used for on scene communications between survival craft, to other vessels and rescue units. Communication is on Ch16 (156.8 MHz) and at least one other simplex channel. The transceiver can be used for on board communications using a secondary battery; however, the primary battery must be used for GMDSS purposes.

3.3.4.7 Regional Data Communication Systems

In various regions, VHF data communication systems exist for data exchange between shore to ship and ship to shore. Those systems are commercial and used primarily for vessel tracking, search areas in SAR operation, etc. An

[3] http://www.iala-aism.org/asm/

example of this technology is the Blue Box used in Italy for vessel monitoring. A further example is a Norwegian system that deploys a network of radio modems capable of switching between nine narrowband duplex VHF channels and is used for general data communication.

3.3.4.8 Satellite Data Communication

Satellite communications in the VHF band are commercially available.

Ship to satellite communications occurs in the maritime VHF band, providing tracking and data messages (AIS, ASM).

There is currently no satellite to ship communications in the maritime VHF band, however services are available for SMS, weather and tracking, and these can be used for maritime purposes. VDES satellite component is in development (Refer to Annex E for further information on VDES).

3.3.5 Ultra High Frequency Band / Super High Frequency Band (UHF/SHF)

3.3.5.1 Emergency Position Indicating Radio Beacon (EPIRB)

Emergency radio beacons are alerting and tracking transmitters which aid in the detection and location of ships, aircraft, and people in distress. They are radio beacons that interface with COSPAS/SARSAT, the international satellite system for search and rescue (SAR). When activated, such beacons send out a distress alert signal that, when detected by non-geostationary satellites, can be located by the combination of Doppler shift measurement and triangulation.

An Emergency Position-Indicating Radio Beacon (EPIRB) is an element of GMDSS and used to send a distress alert signal to the COSPAS/SARSAT satellite system for the purposes of notifying Search and Rescue (SAR) organizations. EPIRBs transmit a 144-bit message including 49 bits of identification plus optionally, GNSS position information originated from a built-in GNSS receiver. Information is retransmitted, at approximately 50 seconds intervals, to the satellites in the frequency band 406.0 to 406.1 MHz. The EPIRB is also equipped with a 121.5 MHz beacon transmitter for homing by SAR aircraft, modulated with a swept audio tone and may also have an incorporated AIS-SART based transmitter (EPIRB AIS).

3.3.5.2 On-board Communication

UHF hand-held and fixed radios are commonly used on vessels for on-board communications including communications with workers on the dock or berth when alongside. These radios are typically constrained to radiating less than 2 W in the band 450-470 MHz and are used for voice and data communication. .

3.3.5.3 Satellite Voice and Data Communication

Satellite communications in the UHF band is commonly deployed on vessels to fulfil a number of distress, safety and general communications purposes.

Satellite communication links are capable of supporting analogue and digital voice, broadband connectivity, e-mail, SMS, crew calling, telex, facsimile, remote monitoring, tracking (position reporting), chart and weather updates and Inmarsat FleetNET services.

Satellite systems are commercially provided services, which may have global or regional coverage. These systems may be geostationary or non-geostationary.

Inmarsat[4], a geostationary satellite system, is an element of GMDSS for distress alerting, urgency and safety calling.

Other Geostationary systems include Thuraya. Non-geostationary satellite systems include Iridium, Globalstar, and Orbcomm.

3.3.5.4 Enhanced Group Call (EGC)

The Inmarsat-C maritime mobile-satellite system is an element of GMDSS and has an inherent capability, known as SafetyNET, via Enhanced Group Calling (EGC), which allows broadcast messages to be made to selected groups of ship stations located anywhere within satellite coverage. Four geostationary satellites provide near worldwide coverage for SafetyNET except for the polar regions. SafetyNET and NAVTEX are recognized by the GMDSS as the

[4] Inmarsat B, C and Fleet 77 are elements of GMDSS

primary means for disseminating maritime safety information. Ships subject to the Safety of Life at Sea Convention (SOLAS) operating outside areas covered by NAVTEX must carry an Inmarsat-C SafetyNET receiver.

3.3.5.5 Long Range Identification and Tracking (LRIT)

LRIT is an IMO-mandated scheme through which all passenger ships, cargo ships and mobile offshore drilling units engaged on international voyages must report their position on a regular basis (at least 4 times a day) to their flag administration. In general satellite communications is used as the method for transmission of these reports, which are received and authenticated by an authorized service provider before being passed to the data centre. The data from the vessel can be augmented with additional information by the shore-based authorities. Other States may be entitled to request this information from the flag administration.

3.3.5.6 Global Navigation Satellite System (GNSS)

Global Navigation Satellite Systems (GNSS) are used for positioning, navigation and timing (PNT) and as an essential input into other ship systems. Current signals are in the frequency-band around 1 GHz to 2.5 GHz.

3.3.5.7 X-Band and S-Band Radar, Radar Beacon (RACON) and Radar SART

Radar systems are commonly deployed and typically operate in two bands: X-band from 9.2 to 9.5 GHz and S-band from 2.9 to 3.1 GHz. The radars are used for target detection and to support identification and for coastal and port navigation. These bands are also used by radar transponders, namely the racon and radar Search and Rescue Radar Transponder (SART) both create identifiable patterns when interrogated by vessel radars. Racons are used to highlight the location of a visual Aid to Navigation (AtoN) or hazards on a ship's radar screen and a radar SART is used to aid in locating a survival craft in a SAR operation. Racons operate in S- and X-band and SARTs are X-band only.

The radar SART is a locating device in the GMDSS and used to locate a survival craft or distressed vessel by creating a series of dots on a rescuing ship's radar display. A radar-SART will only respond to a 9 GHz X-band (3 cm wavelength) radar.

The adoption of new technology radar within the maritime community introduces improvements in radar performance. In addition, the reduced peak transmission power associated with these radars can reduce the triggering range of racons and SARTs.

3.3.5.8 Other Communication Technologies Using the UHF/SHF Band

Various other communication technologies in the UHF to SHF bands are being used (or considered) for general maritime communications, namely GSM/GPRS, 3G, 4G, Wi-Fi, WiMax, and short-range devices like ZigBee and Bluetooth links. These offer the possibility of high speed data transfer. However, it should be noted that the coverage of most of these systems is limited in range and they would therefore be confined to supporting data transfer within a port or harbour environment.

3.4 Future Development of Maritime Radio Communications

This section details future technologies or technologies not widely used for maritime radio communications by frequency band. Please refer to the table in Annex 3 for technical details.

3.4.1 Low Frequency Band (LF)

3.4.1.1 Enhanced Long Range Navigation (eLORAN)

The enhanced Loran (eLoran) system is an experimental system to provide data channel modulated onto the approximately 100 kHz signals. Two formats for this data channel are currently available, known as Eurofix and 9th pulse respectively. Both techniques offer data rates below 100 bps although higher rate concepts have been proposed.

3.4.2 Medium Frequency / High Frequency Band (MF/HF)

3.4.2.1 Digital Data Communication Using MF/HF Band

The likely increase in ship traffic in Polar regions, as a result of receding ice fields, may increase the requirements for HF communications, since geostationary satellites do not cover these areas. Various system operators are studying increased data rates using 3 kHz channels, which may produce data rates of 19.2 kbps, and other solutions to likewise increase data speeds.

Furthermore, a new data communication system using 10-20 kHz bandwidth for data rates up to 51 kbps, has been incorporated in the Recommendation ITU-R M.1798-1. Appendix 17 to the Radio Regulations was revised at the World Radiocommunication Conference 2012 (WRC-12). The revision of AP17 will implement new digital bands for 3 kHz systems as well as wideband systems. WRC-12 has also approved use of band 495-505 kHz for use of high-speed Navigational Data service (NAVDAT).

3.4.2.2 NAVDAT (Navigational Data)

The NAVDAT is an MF radio system, used in the maritime mobile service, operating in the 500 kHz band for digital broadcasting of maritime safety and security related information from shore-to-ship.

WRC-12 approved the worldwide exclusive usage of the frequency band 495 - 505 kHz for the maritime mobile service. The NAVDAT system utilizes an OFDM modulation in this 10 kHz bandwidth which provides a flow rate of about 15/25 Kbit/s (more than 300 times the NAVTEX transmission), featuring:

- Possibility to transmit any type of text, graphs, pictures, data etc with encryption if required;
- Automatic reception;
- Possibility to use Single Frequency Network (SFN) technology, with no need for time slot allocation on the same frequency.

The MF NAVDAT system is described in the Recommendation ITU-R M.2010-0: Characteristics of a digital system, named Navigational Data for broadcasting maritime safety and security related information from shore-to-ship in the 500 kHz band, published by ITU on Mar 2012.

The HF NAVDAT system is described in the Recommendation ITU-R M.2058-0: Characteristics of a digital system, named navigational data for broadcasting maritime safety and security related information from shore-to-ship in the maritime HF frequency band, published by ITU on Feb 2014.

3.4.3 Very High Frequency Band (VHF)

3.4.3.1 Automatic Identification System (AIS)

It is recognized that by design AIS is not an ideal candidate for high speed and/or high volume data communications. However, AIS is a proven maritime data system, with ships equipped and shore infrastructure established. The future AIS channel plan should consider at least the following:

- Channels for Safety of Navigation purposes:
  - AIS 1 and AIS 2 are exclusively allocated to AIS usage in both Region 2 (Americas, effective 2025) and Region 3 (Asian/Pacific, effective 2013), but not in Region 1 (Europe/Africa) where they are still shared with land mobile and fixed services (WRC-12);
  - Taking account of the future agenda item for the modernization of the GMDSS at WRC-18, and if IMO includes AIS as a component of the GMDSS our goal is to apply for exclusive world-wide allocation for AIS 1 and 2 frequencies in the maritime mobile service.
- Channels for satellite detection of AIS.
  - Since the satellites have very wide footprint, the frequencies for satellite detection of AIS are exclusive for maritime mobile service. Appendix **18** of Radio Regulation assigned the CH75 and CH76 for satellite detection of AIS. These channels are guard band channels of CH16 and are the only maritime dedicated channels except CH16 and CH70 within Appendix **18**.

- AIS satellite long range messaging on channels 75 and 76 was approved worldwide effective 1 January 2013 with a primary allocation in Region 2 (Americas), secondary elsewhere (WRC-12)
- Non-AIS operations on channels 75 and 76 were limited to 1watt on 1 January 2013 (WRC-12).
- AIS SARTs are recognised in GMDSS. In the future, other aspects of AIS may be part of GMDSS. The distress alerting, urgency and safety communications should be by both terrestrial and satellite communications; therefore, dedicated maritime frequencies are needed. The satellite detection of AIS is a one-way system (from earth to satellite); however, in the GMDSS, the acknowledgement (from satellite to earth) is essential (a two way system). The CH75 and CH76 could be used for this purpose; however, WRC-12 approved these channels in the Earth-to-space direction. At WRC-12 channels 27, 87, 28 and 88 have been identified for possible testing of AIS, under Note YYY in Appendix **18**.

- Channels for ASM purposes:
  - In considering the future AIS system for terrestrial (non-satellite) data communication purposes, an additional two frequencies will be needed. These frequencies would be used to support the transmission of area warnings and advice, meteorological and hydrographical data, traffic management information and general ship-to-shore data exchanges.
  - At WRC-15 VHF channels 27 and 28 are each split into two simplex channels. The channels 2027 and 2028 designated as ASM 1 and ASM 2 are used for application specific messages (ASM) as described in the most recent version of Recommendation ITU-R M.2092. These channels are envisaged to be part of the VHF Data Exchange System (VDES) (see Annex E).
- Channel for channel management purposes:
  - In order to fully use available VHF spectrum, channel 70 was agreed to manage and co-ordinate usage of the VHF Data Link.

Further details are explained in ANNEX E.

3.4.3.2 Digital Data Communication

The use of VHF for digital data transfer has yet to be broadly implemented by the maritime community. To this end, ITU-R has developed and published Recommendation ITU-R M.1842 – "*Characteristics of VHF radio systems and equipment for the exchange of data and electronic mail in the maritime mobile service RR Appendix **18** channels*". Also, WRC-12 identified digital bands within the Appendix **18** band.

Development of the Recommendation ITU-R M.1842 was originally proposed based on the shore based network system trialled in Norway. This system deploys a network of radio modems capable of switching between nine narrowband duplex VHF channels in the maritime mobile band. These nine channels can be combined into one 225 kHz wideband channel. The wideband radio was proven to have insufficient EMC characteristics, indicated instability and the throughput slowed down when the signal strength was low. This system is described in the Report ITU-R M.2127, but not incorporated in the Recommendation ITU-R M.1842.

Narrowband radio 25 kHz duplex on the other hand has been proven in Norway to be very robust and stable and can perform a variety of services giving good throughput of data. This system is incorporated in Recommendation ITU-R M.1842 together with other techniques to be applied more widely - from 25 kHz bandwidth systems providing 43 kbps data rates through to 100 kHz systems offering 307 kbps. The Recommendation ITU-R M.1842 currently specifies four systems for the modulation schemes and general characteristics for the transceivers. The consideration of the standardized communication protocols is on-going at ITU-R.

ITU has issued new Recommendation ITU-R M.2092-0 - Technical characteristics for a VHF data exchange system in the VHF maritime mobile band. VHF data exchange system (VDES) integrates the components of VHF data exchange (VDE), application specific messages (ASM) and the automatic identification system (AIS) in the VHF maritime mobile band. This recommendation provides the technical characteristics of ASM and VDE.

IALA is aware that further consideration of how best to achieve spectral efficiency in this band is worthwhile. This consideration needs to address coverage range, robustness, channel spacing, and modulation schemes.

The data speed/coverage trade off in the coastal range must be considered to achieve a cost effective service.

WRC-12 VHF Data Results:

- VHF Appendix **18** was modified to permit digital systems on channels: 24, 84, 25, 85, 26 and 86 for Region 2 from 1st Jan 2013 and 80, 21, 81, 22, 82, 23, 83, 24, 84, 25, 85, 26, 86 worldwide except Region 2 and specific countries (footnote *D1)*) from 1 Jan 2017;
- Testing of future AIS applications on channels 27, 28, 87 and 88 is permitted from 1 January 2013;
- 160.9 MHz (channel 2006) is reserved for experimental use for future applications or systems, e.g. MOB and AIS from 1 January 2013.

WRC-15 VHF Data Results:

- VHF Appendix 18 was modified to permit digital systems on channels: 24, 84, 25, 85, 26 and 86 for Region 2 WRC-15 agreed on regulatory provisions and frequency allocations to enable new Automatic Identification System (AIS) applications and other possible new applications to improve maritime radiocommunication. These new applications for data exchange are intended to improve the safety of navigation;
- WRC-15 made new allocations in the bands 161.9375-161.9625 MHz and 161.9875-162.0125 MHz for the maritime mobile-satellite service in the uplink and amended the channelling arrangement for VHF maritime frequencies contained in ITU RR Appendix 18;
- While the proposed allocation for the maritime mobile-satellite service (MMSS) in the downlink in the requested frequency band (161.7875-161.9375 MHz) was not agreed at WRC-15, the use of satellite communications for VHF data exchange was agreed. WRC-15 agreed to further studies of compatibility between MMSS and incumbent services in the same and adjacent frequency bands, for consideration by WRC-19.

Further details are explained in Annex E – VHF Data Exchange System VDES.

3.4.3.3 Digital Voice Communication

Digital voice communication may, in the long term, replace the present analogue VHF voice communication service, i.e. ship-to-ship/ship-to-shore/shore-to-ship. As this develops, the introduction of mixed digital / analogue equipment should be encouraged. It is recognized that global digitization will make spectrum use more efficient, but this will take some time to complete.

3.4.4 Ultra High Frequency Band / Super High Frequency Band (UHF/SHF)

3.4.4.1 Satellite Communication Using the UHF/SHF Band

In the future, navigational satellite payloads may include transponders connected with GMDSS and may function as additional SAR resources. (i.e. return link capability is possible functionality within Galileo).

3.4.4.2 Public Mobile Wireless Communications

Public mobile wireless communications (public correspondence) such as GPRS, CDMA, 3G, 4G, LTE and LTE-A are being used by mariners in coastal waters and could be further developed to support evolving maritime communication needs. In addition, 5G is expected to be available from 2020.

Recognizing their constraints in open water situations, this type of communications should not be used for regulated maritime services.

3.4.4.3 On-board Communications

Limited availability of spectrum for on-board communications gives rise to congestion and interference. Consideration of this issue at ITU is of utmost importance as well as developing new techniques for communication in this band.

3.5 Overview of the Current and Future Voice and Data Communication Technologies

As explained above, radio communication technologies are characterized by performance parameters. These include range, bandwidth, latency, and the need for shore facilities.

The tables below list, in the column headings, the communications techniques that are presently available for maritime voice and data communications. It also includes some techniques which may become available in the short to medium term. Separate tables are provided for ship-to-shore and for ship-to-ship communications.

Six geographical regions are listed at the left column, defined by the ranges of a selection from the available communications technologies. The GMDSS sea areas, which approximately correspond, are also noted in the second column.

The suggested most likely candidates for voice and data communications, for e-Navigation, in each of the six geographical areas are indicated by yellow colour, with 'E' for existing technologies, and 'F' for future technologies or technologies currently not widely used in the maritime domain.

Table 1 - Geographical Classification of e-Navigation Data and Voice Communication Techniques Ship-Shore

e-NAV Area definitions	GMDSS Sea Area (approx)	Broadband phone line or cable. (When ship at berth)	Wi-Fi	WiMax	Mobile phone technology	AIS	VDE	Digital VHF voice and data	Data by modulated RADAR	Geostationary Satellite	Commercial MEO/LEO satellite comms	MF & HF (including Navtex / MSI)	DGPS beacon data broadcast service	Current MF & HF NBDP	HF digital data service	MF/HF digital data service for MSI (incl NAVDAT)
1 - Inside port	A1	E	F	F	E	E	F	F		E	E	E	F			F
2 - Approaching port area	A1			F	E	E	F	F	F	E	E	E	F			F
3A - Coastal navigation out to cell phone coverage (approx. 5nm)	A1			F	E	E	F	F	F	E	E	E	F		E	F
3B - Coastal navigation VHF coverage range (approx 25nm)	A1			F		E	F	F	F	E	E	E	F		E	F
4 - Coastal approach (approx. 100nm)	A2									E	E	E	F	E	E	F
5 - High seas	A3									E	E	E		E	E	F
6 - Polar regions	A4										E	E		E	E	F

Legend:-

Existing technology	E
Future: Not existing or not widely used	F

Possible preferred technology (Existing, Future)	E	F

Table 2 - Geographical Classification of e-Navigation Data and Voice Communication Techniques Ship-Ship

			Technologies for data transfer **ship <-> ship**, listed generally in order of geographical range													
e-NAV Area definitions	GMDSS Sea Area (approx)	Broadband phone line or cable. (When ship at berth)	Wi-Fi	WiMax	Mobile phone technology	AIS	VDE	Digital VHF voice and data	Data by modulated RADAR	Geostationary Satellite	Commercial MEO/LEO satellite comms	MF & HF (including Navtex / MSI)	DGPS beacon data broadcast service	Current MF & HF NBDP	HF digital data service	MF/HF digital data service for MSI (incl NAVDAT)
1 - Inside port	A1		F	F	E	E	F	F	F	E	E	E				F
2 - Approaching port area	A1			F	E	E	F	F	F	E	E	E				F
3A - Coastal navigation out to cell phone coverage (approx. 5nm)	A1				E	E	F	F	F	E	E	E			E	F
3B - Coastal navigation VHF coverage range (approx 25nm)	A1					E	F	F	F	E	E	E			E	F
4 - Coastal approach (approx. 100nm)	A2					E	F	F	F	E	E	E			E	F
5 - High seas	A3					E	F	F	F	E	E	E			E	F
6 - Polar regions	A4					E	F	F	F		E	E			E	F

Legend:-		
Existing technology	E	
Future: Not existing or not widely used	F	
Possible preferred technology (Existing, Future)	E	F

Table 3 - Comparison of Communications Technologies

Communication Technology	Data rate	Infrastructure	Coverage	Transmission	Maritime / public
NAVDAT	12-18 kbps	Based on NAVTEX	250/300NM	Broadcast	Maritime
VDES VDE	307 kbps	VHF Data link, RR Appendix 18 channels	15NM-65NM Satellite component provides further coverage	Addressed / broadcast	Maritime
VDES ASM	19.2 kbps	VHF Data link, RR Appendix 18 channels	approx 15NM-65NM	Addressed / broadcast	Maritime
Wi-Fi (IEEE 802.11ac)	1,300 kbps	Routers/Access points	50m	Addressed	Public
WiMax	75 Mbps	Routers/Access points	2-5 km	Addressed	Public
Digital VHF	9.6 – 19.2 kbps	Base station/mobile radios	approx 15NM-65NM	Addressed	Maritime
Digital HF	19.2 kbps	Base station/mobile radios	Global	Addressed	Maritime
4G (including LTE)	600 Mbps	4G Base stations	5-30km (3-6 NM)	Addressed	Public
5G	1,200 Mbps	5G base stations	5-30km (3-6 NM)	Addressed	Public
GEO Satellite					
Inmarsat C	600 bps	Satellite service	Global, spot beams	Addressed / broadcast	Maritime
Inmarsat GX	50 Mbps	Satellite functioning on Ka band	Global, spot beams	Addressed / broadcast	Cross Industry
LEO Satellite					
Iridium	Up to 134 kbps	Satellite functioning on L band	Global, dependent on constellation size	Addressed / broadcast	Cross Industry (Iridium Pilot Maritime)

3.6 Vision: Automated Selection Process of Available Communication Technologies

Table 1 and Table 2 identify distinct communication technologies but do not consider the optimization that could be achieved through a system that automatically selects the most appropriate technology for the area of operation and the type of data to be exchanged.

Some existing marine communication technologies, such as AIS, automatically carry out data communications without any need for the ship's crew to intervene in the communications process. In the specific case of AIS, while the crew sets certain voyage parameters at the start of each voyage, and can change the navigational status at any time, the communications process is automatic.) Other existing marine communications technologies, such as VHF voice communications, require the ship's crew to adjust the communications apparatus. In the case of VHF voice this involves deciding on and selecting the appropriate communications channel.

An ideal e-Navigation communications system would operate automatically, selecting the best communications technology, channel, and characteristics in accordance with the ship's location, and the type of data to be exchanged. This automatic process would be managed in accordance with rules and the needs of the mariner that might include the following:

- Need to avoid latency – such as when exchanging safety and navigation data with other vessels or receiving it from electronic systems ashore or on the water surface;
- Ability to delay the sending or receipt of data – such as the sending of non-urgent administrative data, or the receipt of chart corrections for the current voyage, a subsequent voyage or for a port to be visited later in the present voyage;
- Value / Cost of communications;
- Importance of the data for commercial services on board;
- Rate of data transfer (capacity of transmission).

Some of the rules managing seamless data communications would be programmed into the system, for example those concerned with safety of navigation. Other rules might be set by the ship's operator in accordance with their procedures and the operator's commercial model. Further rules might be adjusted, from time to time, by the ship's crew.

3.7 Modernisation of GMDSS

The current GMDSS system was designed over 25 years ago and is currently being reviewed by IMO. This is the first full review since its implementation in 1999, and recognises that technology has developed significantly in that time. Existing technology elements within the GMDSS have also evolved, although the functions have not been altered. The current system remains sound, however there are GMDSS elements where improvement could be made, e.g. managing the cessation of international telex, and reviewing the continued use of narrow-band direct-printing in certain sea areas.

The elements that will be identified may need to be examined and reviewed as a matter of some urgency. The 14th session of IMO Sub-Committee on Radiocommunications and Search and Rescue (COMSAR 14, held on March 2010) initiated a Scoping Exercise and a Work Plan to define the requirements for the GMDSS Review and Modernization. The Scoping Exercise was finalized at COMSAR16 (March 2012) and the Review will be take place over a three-year period (2013-2015).

A further two-year period is envisaged (2015-2017) for the GMDSS modernization plan. This will be followed by development of legal instruments, revision/development of relevant performance standards and an implementation period.

While supporting the IMO's systematic approach, IALA should also be active in the review, push forward initiatives to ITU with a view to the fact that items for consideration at WRC-19 need to be produced as agenda items at WRC-

3.7.1 Current GMDSS System Components

The GMDSS functions are classified into alerting (distress/urgency/safety); communications (distress/urgency/safety), locating in SAR, homing on location in SAR; on scene communications; promulgation of maritime safety information (MSI); and general communications. There are 4 sea areas identified in GMDSS – Sea Area A1; Sea Area A2; Sea Area A3 and Sea Area A4. To achieve the functions of GMDSS, the equipment listed in Table 4 - Current GMDSS System Components is used according to the GMDSS sea areas.

Table 4 - Current GMDSS System Components

Sea area	Distress/Urgency Safety Alerting	Distress/urgency Safety Comms	Locating	Homing	On scene Comms	MSI Promulgation	General Comms
A1	VHF DSC EPIRB	VHF R/T	Radar SART AIS-SART	EPIRB (121.5 MHz)	VHF Rx/Tx	NAVTEX SafetyNET	VHF R/T
A2	VHF DSC MF DSC EPIRB	VHF R/T MF R/T					VHF R/T MF R/T, NBDP
A3	VHF DSC MF DSC HF DSC Inmarsat EPIRB	VHF R/T MF R/T HF R/T, NBDP Inmarsat				NAVTEX SafetyNET HF MSI	VHF R/T HF/MF R/T, NBDP Inmarsat
A4	VHF DSC MF DSC HF DSC EPIRB	VHF R/T MF R/T HF R/T, NBDP				HF MSI	VHF R/T HF/MF R/T, NBDP

R/T – Radio Telephony

GMDSS is under review at the IMO. The problems in the current GMDSS include the following:

- Perceived high rate of false distress alerting by DSC and EPIRB;
- complicated operation of DSC; and
- decline in use of the NBDP

Efforts have been made to address these issues, such as updating ITU-R Recommendations and IEC standards. The AIS-SART was introduced in January 2010 as an alternative to the radar SART. The AIS-SART is defined as a locating device. Field trials have proved that the AIS-SART is detectable by SAR aircraft at a much greater range than 121.5 MHz beacons in 406 MHz EPIRBs and can also be detected by low earth orbit AIS satellites.

3.7.2 Possible System Components for the Modernisation of GMDSS

IMO COMSAR sub-committee finalized the draft work plan on 'Review and modernization of the Global Maritime Distress and Safety System' at its 16th session in March 2012, and this was approved by Maritime Safety Committee at its 90 session in May 2012. The work is continuing and includes a detailed review on a number of items, including: the possible inclusion of AIS functions, LRIT functions and SSAS functions; the role of Narrow Band Direct Printing (NBDP) and MF/HF DSC; expected evolution of satellite EPIRB systems; and the further evolution of Maritime Safety Information broadcast systems.

While AIS (AIS-SART) is currently included in the GMDSS as a locating device[5], the review of possible inclusions of AIS functions in the GMDSS modernization work plan could see additional uses for AIS, which may include homing[6]. Other digital data technologies, such as VDES, may be used to address GMDSS functions.

Distress devices, using AIS or AIS like technology, continue to evolve and are being assessed in the review process of GMDSS. The development of alternative uses of AIS or AIS like technology are being reviewed within ITU under the heading of Autonomous Maritime Radio Devices (AMRD)

WRC-12 allocated 495-505 kHz (plus 505-510 kHz in Region 2) to the maritime mobile service on an exclusive primary basis, this band could be used for promulgation of maritime safety and security related information in accordance with the Recommendation ITU-R M.2010. This could deliver relatively large volumes of information with a high data rate and may be a supplementary system to the current NAVTEX.

5 Locating is defined as 'to find a mobile unit in distress or the location of survivors'.

6 Homing is defined to determine the bearing to the transmitting station.

The VHF Data Exchange System (VDES) may also be a candidate for promulgation of Maritime Safety Information (shore-ship) and emerging ship-ship / ship-shore applications.

The MF/HF data communications and VHF Data Exchange System (VDES) may be candidates for general communications in addition to the existing radiotelephone and satellite communications.

The above ideas are summarized in Table 5

Table 5 - Potential System Components for Modernisation of GMDSS

Sea area	Distress/Urgency Safety Alerting	Distress/urgency Safety Comms	Locating/Homing	On scene Comms	MSI Promulgation	General Comms
A1	AIS *1 EPIRB-AIS *2	VHF R/T, Data	AIS-SART EPIRB-AIS *2	VHF R/T	AIS *4 VDE NAVDAT SafetyNet	VHF R/T, Data MF/HF R/T, Data Satellite *3
A2 A3	AIS *1 EPIRB-AIS *2 MF/HF Data Satellite *4	VHF R/T, Data MF/HF R/T, Data Satellite *2				
A4	AIS *1 EPIRB-AIS *2 MF/HF Data	VHF R/T, Data MF/HF R/T, Data			AIS *4 HF Data	VHF R/T, Data MF/HF R/T, Data

*1 using terrestrial and satellite messages
*2 EPIRB with built-in AIS-SART function
*3 global or regional satellite services
*4 using application specific messages
R/T Radio Telephony

4 Securing the Spectrum

4.1 Situation with Respect to Existing Spectrum Usage

Section 3.3 described the existing maritime technologies, which use the radio spectrum and indicated the bands in which they operate. Whilst there is consideration of variations to the technologies which may be used, all such variations take, as their base assumption, the ongoing use of existing spectrum allocations. These variations may give rise to a need to change the channelization within certain bands.

Please refer to the table in Annex A for system details, Annex B for maritime spectrum allocations and Annex D for specific ITU technical characteristics associated with the systems described in section 3.3 and 3.4.

4.2 WRC-19 Agenda Items

A number of the agenda items for the 2019 World Radiocommunications Conference (WRC-19) may affect the maritime use of the spectrum, namely:

4.2.1 Agenda Item 1.5

Agenda item 1.5 is to consider the use of the frequency bands 17.7-19.7 GHz (space-to-Earth) and 27.5 29.5 GHz (Earth-to-space) by earth stations in motion communicating with geostationary space stations in the fixed-satellite service and take appropriate action, in accordance with Resolution **158 (WRC 15)**;

1 that, taking into account the results of ITU-R studies, WRC-15 consider the possible extension of the current worldwide allocation to the EESS (active) in the frequency band 9 300-9 900 MHz by up to 600 MHz on a primary and/or secondary basis, as appropriate, within the frequency range 8 700-9 300 MHz and/or 9 900-10 500 MHz while ensuring protection of existing services and taking due account of the safety services allocated in the frequency band 9 000 to 9 300 MHz

1 to study the technical and operational characteristics and user requirements of different types of earth stations in motion that operate or plan to operate within geostationary FSS allocations in the frequency bands 17.7-

19.7 GHz and 27.5-29.5 GHz, including the use of spectrum to provide the envisioned services to various types of earth station in motion and the degree to which flexible access to spectrum can facilitate sharing with services identified in recognizing further a) to n);

2 to study sharing and compatibility between earth stations in motion operating with geostationary FSS networks and current and planned stations of existing services allocated in the frequency bands 17.7-19.7 GHz and 27.5-29.5 GHz to ensure protection of, and not impose undue constraints on, services allocated in those frequency bands, and taking into account recognizing further a) to n);

3 to develop, for different types of earth stations in motion and different portions of the frequency bands studied, technical conditions and regulatory provisions for their operation, taking into account the results of the studies above,

4.2.2 Agenda Item 1.8

Agenda item 1.8 is to consider possible regulatory actions to support Global Maritime Distress Safety Systems (GMDSS) modernization and to support the introduction of additional satellite systems into the GMDSS, in accordance with Resolution **359 (Rev.WRC 15)**;

1 to conduct studies, taking into consideration the activities of IMO, as well as information and requirements provided by IMO, in order to determine the regulatory provisions to support GMDSS modernization;

2 to conduct studies, taking into consideration the activities of IMO and the recognition of additional satellite systems for use in the GMDSS, including consideration of the mobile-satellite service (MSS) allocations used and the potential impact of possible modifications to the provisions of the Radio Regulations on sharing and compatibility with other services and systems in the frequency band and adjacent frequency bands,

4.2.3 Agenda Item 1.9

Agenda item 1.9 is to consider, based on the results of ITU-R studies:

1.9.1 regulatory actions within the frequency band 156-162.05 MHz for autonomous maritime radio devices to protect the GMDSS and automatic identifications system (AIS), in accordance with Resolution **362 (WRC 15)**;

- to consider the results of ITU-R studies and take appropriate actions,

1.9.2 modifications of the Radio Regulations, including new spectrum allocations to the maritime mobile-satellite service (Earth to space and space-to-Earth), preferably within the frequency bands 156.0125-157.4375 MHz and 160.6125-162.0375 MHz of Appendix **18**, to enable a new VHF data exchange system (VDES) satellite component, while ensuring that this component will not degrade the current terrestrial VDES components, applications specific messages (ASM) and AIS operations and not impose any additional constraints on existing services in these and adjacent frequency bands as stated in recognizing d) and e) of Resolution **360 (Rev.WRC 15)**;

- to consider, based on the results of ITU-R studies, modifications of the Radio Regulations, including new spectrum allocations to the maritime mobile-satellite service (MMSS) (Earth-to-space and space-to-Earth), preferably within the frequency bands 156.0125-157.4375 MHz and 160.6125 162.0375 MHz of Appendix **18**, to enable a new VDES satellite component, while ensuring that this component will not degrade the current terrestrial VDES components, ASM and AIS operations and not impose any additional constraints on existing services in these and adjacent frequency bands as stated in recognizing d) and e),

4.3 Preliminary Agenda for WRC-23

Resolution 810 (WRC-15)has a direct affect for maritime spectrum use:

- to consider possible spectrum needs and regulatory actions to support Global Maritime Distress and Safety System (GMDSS) modernization and the implementation of e navigation, in accordance with Resolution **361 (WRC 15)**

5 Summary

The IALA Maritime Radio Communications Plan identifies current and future technologies used for maritime communication and addresses the IALA position regarding maritime related agenda items for WRC-15 and WRC-19, and also looks ahead to WRC-23.

e-Navigation is a driving factor for a digital concept for the maritime sector. Developments in digital communications have a profound and long-term impact on the way the maritime sector operates. It is foreseen that e-navigation will be supported by many current and future technologies identified in this plan. The communications infrastructure should be designed to enable authorized seamless information transfer on board ship, between ships, between ship and shore and between shore authorities and other parties. This infrastructure will have to be capable of not only supporting future e-Navigation applications, but will also have to support legacy applications. It will therefore be bandwidth intensive and possibly rely upon a range of technologies.

Securing spectrum, or changing the use of spectrum within existing allocations, is important for e-Navigation and other developments due to the planning timescales required to protect or extend the use of the radio spectrum through the ITU WRC.

Modern services on land request a ubiquitous connectivity on the vessel which is not addressed by current maritime networks. Dedicated service connectivity to improve services (for example logistic chain or port arrival and clearance) would benefit from the concept of a network at sea. The network at sea defines a fully meshed connectivity between all vessels and land stations which covers direct and multi-hop connections. The network comprises of a terrestrial and a satellite component and both components are currently developed with a long-range connectivity through the new VDES system for terrestrial and satellite connectivity. In the near future increasing demands, such as the maritime connectivity platform, require a broadband connectivity that requires to being developed. In the future, it is envisioned that there will be a network on the sea connecting the shore and vessels, and between vessels themselves, using digital technologies such as VDES, broadband maritime and satellite communications.

In general, there are ongoing concerns relating to spectrum allocation and management for e-Navigation. Protection of the maritime mobile service spectrum allocation needs to continue. Particular emphasis should be given to following items:

- development of frequency plans for the 450 to 470 MHz band so as to protect on-board use; and
- the use of PLT/PLB at a national level as and when the possibility or necessity arises;

In relation to the forthcoming WRC meeting, spectrum requirements to support e-Navigation should be addressed. In particular:

- on board communications needs;
- the requirements for VDES, including VDE-SAT;
- protection of HF RT/WT allocations.

Finally, the plan recognises the need for maritime communications to develop automated processes for selecting the best communications technology, channel, and characteristics in accordance with the ship's location, and the type of data to be exchanged.

The plan also suggests modernization of GMDSS could include the modern digital technologies such as VHF Data exchange System (VDES), AIS, and data and voice communications in MF/HF and VHF bands.

The e-Navigation concept and future user requirements are rapidly being developed but it is difficult to speculate what specific systems and spectrum will be required to achieve e-Navigation. As e-Navigation develops the IALA Maritime Radio Communication Plan, as a living document, needs to be reviewed and updated.

6 Glossary of Terms

AIS	Automatic Identification System
AMRD	Autonomous Maritime Radio Devices
ARPA	Automatic Radar Plotting Aid
AtoN(s)	Aid(s) to Navigation
BeiDou	China Navigation Satellite System
BPL	Broadband over Power Line
CDMA	Code Division Multiple Access
CS	Coastal Surveillance (Radar)
DGNSS	Differential Global Navigation Satellite System
DGPS	Differential Global Positioning System
DRM	Digital Radio Mondiale
eANSI	Electronic Aids to Navigation System Information
ECDIS	Electronic Chart Display Information System
EGC	Enhanced Group Call
EGNOS	European Geostationary Navigation Overlay System
eLoran	Enhanced Loran
ELT	Emergency Locator Transmitters
ENC	Electronic Navigation Chart
EPIRB	Emergency Position-Indicating Radio Beacon
EPIRB AIS	Emergency Position-Indicating Radio Beacon with AIS
ESIM(s)	Earth Stations in Motion
ESOPMP(s)	Earth Stations on Mobile Platform
ESV(s)	Earth Stations on board vessels
ETSI	European Telecommunications Standards Institute
FAA	(US) Federal Aviation Authority
FDD	Frequency Division Duplex
GAGAN	GPS-Aided Geo Augmented Navigation (System) (India)
GALILEO	European GNSS (not an acronym)
GBAS	Ground Based Augmentation System
GEO	Geostationary Orbit
GMDSS	Global Maritime Distress and Safety System
GLN	Global Link Network
GLONASS	Global Navigation Satellite System (Russian Federation)
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GPS	Global Positioning System (US)
GSM	Global System for Mobile Communications

HF	High Frequency (3 – 30 MHz)
HSDPA	High Speed Downlink Packet Access
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
IBS	Integrated Bridge System
ICAO	International Civil Aviation Organization
IEC	International Electrotechnical Commission
IGSO	Inclined Geosynchronous Orbit
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IMEA	International Maritime Electronics Alliance
INS	Integrated Navigation System
IP	Internet Protocol
IPBC	Internet Protocol for Boat Communications
IRNSS	Indian Regional Navigational Satellite System
ITU	International Telecommunication Union
ITU-R	ITU Radiocommunication Sector
LEO	Low Earth Orbit
LF	Low Frequency (30 – 300 kHz)
LORAN	Long Range Navigation system
LRIT	Long Range Identification and Tracking
LTE	Long Term Evolution
MASS	Maritime Autonomous Systems (Surface)
MBOC	Multiplex Binary Offset Carrier
MEO	Medium Earth Orbit
MF	Medium Frequency (300 – 3 000 kHz)
MMS	Maritime Mobile Service
MMSS	Maritime Mobile Satellite Service
MRCP	Maritime Radio Communications Plan
MSAS	Multi-Satellite Augmentation System (Japan)
NBDP	Narrow Band Direct Printing
NAVDAT	Navigational Data (the system name)
NAVTEX	Navigational Telex (the system name)
OFDM	Orthogonal Frequency Division Multiplexing
PIANC	Permanent International Association of Navigation Congresses
PLB	Personal Locator Beacon
PLT	Power Line Transmission
PMR	Private Mobile Radio
PNT	Position, Navigation and Timing
QAM	Quadrature Amplitude Modulation

QPSK	Quadrature Phase Shift Keying
QZSS	Quasi-Zenith Satellite System
RACON	RAdar BeaCON
RCC	Rescue Coordination Center
RAIM	Receiver Autonomous Integrity Monitoring
RNAV	Radionavigation
RR	Radio Regulations
SBAS	Satellite Based Augmentation System
SDCM	System for Differential Corrections and Monitoring (Russian Federation)
SHF	Super High Frequency (3 – 30 GHz)
SMS	Short Message Service
SOLAS	Safety of Life at Sea (IMO Convention)
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TETRA	Terrestrial Trunked Radio
UHF	Ultra High Frequency (300 – 3 000 MHz)
UMB	Ultra Mobile Broadband
UMDM	Universal Maritime Data Model
UMTS	Universal Mobile Telecommunications System
UWB	Ultra Wideband
VDE	VHF Data Exchange
VDE-ASM	VHF Data Exchange System – Application Specific Messages
VDES	VHF Data Exchange System
VDE-SAT	VHF Data Exchange System – Satellite
VDE-TER	VHF Data Exchange System - Terrestrial
VDL	VHF Data Link
VDR	Voyage Data Recorder
VHF	Very High Frequency (30 – 300 MHz)
VTS	Vessel Traffic Service
WAAS	Wide Area Augmentation System (US)
Wi-Fi	Wireless Fidelity
WiMax	Worldwide Interoperability for Microwave Access
WWRNP	World Wide Radio Navigation Plan
WWRNS	World Wide Radio Navigation System

ANNEX A – System Description

Table 6 - System Description Table

System	Band	Frequency Channel	Bandwidth Data rate	Status	Life Span	Ownership	Mode	Service	Purposes	Notes
Distress and safety communication within GMDSS										
MF/HF Voice	MF/HF	2182 kHz 4125 kHz 6215 kHz 8291 kHz 12290 kHz 16420 kHz	3 kHz	Current	Long	Regional and International	Analogue voice.	Mobile to mobile Fixed to mobile Mobile to fixed	Distress communication	Long distance, > 250 nm
MF/HF DSC	MF/HF	2187.5 kHz 4207.5 kHz 6312.0 kHz 8414.5 kHz 12577 kHz 16804.5 kHz	0.5 kHz 100 bps	Current	Long	International	Data (Digital)	Mobile to mobile Fixed to mobile Mobile to fixed.	Distress alerting	Long distance > 250 nm
121.5 DF	VHF	121.5 MHz		Current	Short	International	Carrier (Analogue)	Mobile to mobile	Location.	Line of sight
VHF DSC	VHF	156.525 MHz (Ch 70)	25 kHz 1200 bps	Current	Long	International	Data (Digital)	Mobile to mobile Fixed to mobile Mobile to fixed	Distress alerting	approx 15NM-65NM

System	Band	Frequency Channel	Bandwidth Data rate	Status	Life Span	Ownership	Mode	Service	Purposes	Notes
VHF voice	VHF	156.300 MHz (Ch 06) 156.650 MHz (Ch 13) 156.800 MHz (Ch 16)	25 kHz	Current	Long	International	Voice	Mobile to mobile Fixed to mobile Mobile to fixed	Distress communication	Line of sight
Two way VHF voice	VHF	156.025 - 161.950 MHz	25 kHz	Current	Long	International	Voice	Mobile to mobile	On scene communication	Line of sight
AIS-SART	VHF	161.975 MHz, 162.025 MHz	25 kHz 9600 bps/ TDMA	Current	Long	International	digital	Mobile to mobile	Location	approx 15NM-65NM
EPIRB	UHF	406 MHz		Current	Long	International	Digital	Mobile to satellite	Distress alerting / Location / Homing	COSPAS-SARSAT Satellite; Global coverage
Satellite INMARSAT C, B, F	UHF	Tx 1626.5 to 1646.5 MHz Rx 1525.0 to 1545.0 MHz		Current	Long	3rd party	Digital. Voice and data.	Satellite to earth Earth to satellite	Distress alerting, distress communication.	Global coverage
RADAR SART, X-Band	SHF	9.2 – 9.5 GHz		Current	Medium	International	analogue	Mobile to mobile	Homing	Line of sight
EPIRB-AIS	UHF / VHF	406 MHz 161.975 MHz (AIS 1) 162.025 MHz (AIS 2)		Current	Long	International	Digital	Mobile to satellite Mobile to mobile	Distress alerting / Location / Homing	COSPAS-SARSAT Satellite; Global coverage

System	Band	Frequency Channel	Bandwidth Data rate	Status	Life Span	Ownership	Mode	Service	Purposes	Notes
Maritime safety information promulgation										
NAVTEX	MF/HF	518 kHz 490 kHz and 4209.5 kHz (for local language)	0.5 kHz	Current	Medium	International	Text	Fixed to mobile	Reception of maritime safety information.	Long distance, > 250 nm Broadcast to mobile only.
Narrow band direct printing. (NBDP)	HF	4210 kHz 6314 kHz 8416.5 kHz 12509 kHz 16806.5 kHz 19680.5 kHz 22376.0 kHz 26100.5 kHz	0.5 kHz	Current	Medium	International.	Text	Mobile to mobile Fixed to mobile Mobile to fixed	Reception of maritime safety information	Long distance, > 250 nm
EGC	UHF	Tx 1626.5 - 1646.5 MHz Rx 1525.0 - 1545.0 MHz		Current	Long	International	Digital data.	Satellite to mobile	Reception of maritime safety information (Safety Net)	Global coverage
Safety of navigation										
Loran and eLoran	LF	90-110 KHz		Current	Very Long	Regional	Carrier (Analogue)	Fixed to mobile	Positioning	Long distance
DGNSS	MF	283.5 to 325 kHz	50/100 bps	Current	Medium.	Regional.	Digital	Fixed to mobile	Augmentation of positioning	Medium distance

System	Band	Frequency Channel	Bandwidth Data rate	Status	Life Span	Ownership	Mode	Service	Purposes	Notes
AIS	VHF	161.975 MHz (AIS 1) 162.025 MHz (AIS 2)	25 kHz 9600 bps/ TDMA	Current	Long	International	Data (Digital)	Mobile to mobile Fixed to mobile Mobile to fixed	Collision avoidance, Environmental protection, Security, VTS Augmentation of positioning, communication for navigational and safety related purposes.	approx 15NM-65NM LEO Satellite detection for tracking Part of VDES
Satellite AIS	VHF	Channels 75 & 76 within RR App 18	25 kHz 9600 bps TDMA	Current	Long term	International	Data (Digital)	Mobile to satellite.	Security. Environmental protection. Vessel tracking.	Closely related to current AIS. Global Same transponder on ship Part of VDES
AIS MMS channel management	VHF	Channel 70 (AIS 1 and AIS 2)	25kHz 9600bps TDMA	Current	Long term	International	Data (Digital)	Mobile to mobile. Fixed to mobile.	To manage data transfer over channels in the MMS.	E.g. “go to channel XX to get chart update for Tokyo Bay.
AIS AtoN	VHF	161.975MHz (AIS 1) 162.025MHz (AIS 2)	25 kHz 9600 bps/ TDMA	Current	Long	International	Data (Digital)	AtoN (fixed/floating) to mobile/shore	Navigational aid	approx 15NM-65NM

System	Band	Frequency Channel	Bandwidth Data rate	Status	Life Span	Ownership	Mode	Service	Purposes	Notes
VHF voice	VHF Mobile	156.025 to 161.950 MHz	25 kHz	Current	Long	International	Voice	Mobile to mobile. Fixed to mobile. Mobile to fixed.	communication for navigational and safety related purposes	Line of sight
GNSS	UHF	GPS: 1227.6 MHz 1575.42 MHz GLONASS: 1559-1610 MHz 1240-1260 MHz BeiDou 1.561098 GHz 1.589742 GHz 1.20714 GHz 1.26852 GHz Galileo 1.164-1.215 GHz 1.260-1.300 GHz 1.559-1.592 GHz		Current Current Current Future	Long Long Long Long	International International Regional International	Digital	Satellite to earth	Positioning	Global coverage
LRIT	Satellite	Tx 1626.5 to 1646.5 MHz Rx 1525.0 to 1545.0 Mhz		Current	Short	3rd party	Data (Digital)	Inmarsat	Security. Vessel tracking. Environmental protection.	Global coverage
Radar S Band		2.9 to 3.1 GHz		Current	Long	International		Mobile and fixed	Collision avoidance, Navigational aid.	Line of sight
Radar X Band		9.2 to 9.5 GHz		Current	Long	International		Mobile and fixed.	Collision avoidance, Navigational aid	Line of sight

System	Band	Frequency Channel	Bandwidth Data rate	Status	Life Span	Ownership	Mode	Service	Purposes	Notes
racon		2.9 to 3.1 GHz and 9.2 to 9.5 GHz		Current	Long	International		Fixed.	Navigational aid	Line of sight
General communication										
HF Voice	MF/HF	1.6 to 26.5 MHz	3 kHz	Current	Long	Regional and International	Analogue voice. (ALE)	Mobile to mobile Fixed to mobile Mobile to fixed	General voice communication	Long distance, > 250 nm
Narrow band direct printing (NBDP)	MF & HF.	1.6 to 26.5 MHz	0.5 kHz	Current	Long for GMDSS Short for general commun-ication	International	Text	Mobile to mobile. Fixed to mobile. Mobile to fixed.	General text communication	Long distance, > 250 nm
HF Data	MF/HF	1.6 to 26.5 MHz	0.5 – 3 kHz	Current	Long	Regional and International	Digital data	Fixed to mobile Mobile to fixed	General data communication	Long distance, > 250 nm
VHF voice	VHF	156.025 to 161.950 MHz	25 kHz	Current	Long	international	Voice	Mobile to mobile Fixed to mobile Mobile to fixed	General voice communication	Line of sight
VHF data	VHF	156.025 - 161.950 MHz	25 kHz	Current	Long	regional	data	Mobile to mobile Fixed to mobile Mobile to fixed	General data communication	approx 15NM-65NM
UHF on-board	UHF	457.5125-457.5875/ 467.5125-467.5875 MHz	6.25/12.5/25 kHz	Current	Long	International	Analogue voice/ Digital voice/ data	Mobile to mobile. Internal comms.	On-board communication	Line of sight

System	Band	Frequency Channel	Bandwidth Data rate	Status	Life Span	Ownership	Mode	Service	Purposes	Notes
Satellite	UHF	Tx 1626.5 - 1646.5 MHz Rx 1525.0 - 1545.0 MHz		Current	Long	global 3rd party	Digital. Voice and data.	Satellite to earth Earth to satellite	General voice and data communication	Global coverage
GSM	UHF			Current	Long	regional 3rd party	Digital. Voice and data.	Cellular Mobile-fixed-mobile.	General voice and data communication	Medium range in locality
GPRS	UHF			Current	Long	regional 3rd party	Digital Voice and data	Cellular Mobile-fixed-mobile.	General voice and data communication	Short range in locality
UMTS/3G	UHF			Current	Long	regional 3rd party	Digital. Voice and data.	Cellular. Mobile-fixed-mobile.	General voice and data communication	Short range in locality
IEEE 802.11 (Wi-Fi)	UHF/ SHF	2.4 – 2.5 GHz 5.17 – 5.33 GHz 4.9 GHz	11 Mbps 54 - 300 Mbps 54 Mbps	Current	Long	local 3rd party	Digital data	LAN Peer-to peer	Internet access	Sort in locality < 100m <10 km
IEEE 802.16 (WiMax)	UHF/ SHF	2.5 GHz 3.3 GHz	75 Mbps	Current	Long	local 3rd party	Digital data	LAN Peer-to peer	Internet access	Short range in locality < 50 km
IEEE 802.15.4 (ZigBee)	UHF	868-870 MHz 902 – 928 MHz 2.4 GHz	20 kbps 40 kbps 250 kbps	Current	Long	local 3rd party	Digital data			Short range in locality < 30 km

Future development										
HF Digital data	HF	4 to 26 MHz	10 to 20 kHz.	On and after 1 Jan 2017	Long term	International	Data (Digital)	Mobile to mobile Fixed to mobile Mobile to fixed	Binary data communication for navigational and safety related purposes.	KENTA (France) Has range advantage over VHF 40 to 250 NM (>250 sky wave)
ASM	VHF	161.950 MHz (ASM 1) 162.000 MHz (ASM 2)	25 kHz Min 9600 bps TDMA	On and after 1 Jan 2019	Long term	International	Data (Digital)	Mobile to mobile Fixed to mobile Mobile to fixed Mobile to satellite	Binary data communication for navigational and safety related purposes. Security and tracking.	Closely related to current AIS. Same transponder on ship Part of VDES
VHF Digital data. • ECDIS chart data • Digital voice • Virtual channels • UMDM support • Internet access	VHF Mobile	156.025 to 161.950 MHz	25[7] to 100 kHz.	On and after 1 January 2013 in Region 2, 1 January 2017 in Regions 1 & 3	Long term	International	Data (Digital)	Mobile to mobile Fixed to mobile Mobile to fixed	Binary data communication for navigational and safety related purposes.	Rec. ITU-R M.1842-1 Rec. ITU-R M.2092- Managed or autonomous systems. Relates to VDES

[7] Note, there may be benefit in using less than 25kHz, however this is not yet identified in ITU-R M.1842.

Annex B – Maritime Frequency Allocations

The table below sets out the various current maritime frequency allocations as allocated by ITU Radio Regulations. Due to the size, footnotes to the allocation in the ITU Radio Regulation are not included. Please refer to Article 5 in the ITU Radio Regulation, Edition of 2016.

Table 7 - Maritime Frequency Allocations

Frequency	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
90 – 110 kHz	RADIONAVIGATION 5.62 Fixed 5.64			No constraints
285 – 315 kHz	AERONAUTICAL RADIONAVIGATION MARITIME RADIONAVIGATION (radiobeacons) 5.73 5.74	AERONAUTICAL RADIONAVIGATION MARITIME RADIONAVIGATION (radiobeacons) 5.73		No constraints
315 – 325 kHz	AERONAUTICAL RADIONAVIGATION Maritime radionavigation (radiobeacons) 5.73 5.75	MARITIME RADIONAVIGATION (radiobeacons) 5.73 Aeronautical radionavigation	AERONAUTICAL RADIONAVIGATION MARITIME RADIONAVIGATION (radiobeacons) 5.73	Secondary in Region 1
415 – 435 kHz	MARITIME MOBILE 5.79 AERONAUTICAL RADIONAVIGATION	MARITIME MOBILE 5.79 Aeronautical radionavigation 5.80		No constraints
435 - 472	MARITIME MOBILE 5.79 Aeronautical radionavigation 5.77 5.82	 5.77 5.78 5.82		No constraints
472 - 479	MARITIME MOBILE 5.79 Amateur 5.A123 Aeronautical radionavigation 5.77 5.80 5.82 5.B123			
479 – 495 kHz	MARITIME MOBILE 5.79 5.79A Aeronautical radionavigation 5.77 5.82	MARITIME MOBILE 5.79 5.79A Aeronautical radionavigation 5.80 5.77 5.82		No constraints

Frequency	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
495 – 505 kHz	MARITIME MOBILE			No constraints
505 – 510 kHz	MARITIME MOBILE 5.79 5.79A 5.84 AERONAUTICAL RADIONAVIGATION	MARITIME MOBILE 5.79	MARITIME MOBILE 5.79 5.79A 5.84 AERONAUTICAL RADIONAVIGATION Aeronautical mobile Land mobile	No constraints
510 – 526.5 kHz	MARITIME MOBILE 5.79 5.79A 5.84 AERONAUTICAL RADIONAVIGATION	510 – 525 KHz MARITIME MOBILE 5.79A 5.84 AERONAUTICAL RADIONAVIGATION	MARITIME MOBILE 5.79 5.79A 5.84 AERONAUTICAL RADIONAVIGATION Aeronautical mobile Land mobile	No constraints
1606.5 – 1625 kHz	FIXED MARITIME MOBILE 5.90 LAND MOBILE 5.92	1605 – 1625 kHz BROADCASTING 5.89 5.90	FIXED MOBILE RADIOLOCATION RADIONAVIGATION 5.91	Region 1 only and subject to restrictions on permitted coverage area
1635 – 1705 kHz	FIXED MARITIME MOBILE 5.90 LAND MOBILE 5.92 5.96	FIXED MOBILE BROADCASTING 5.89 Radiolocation 5.90	FIXED MOBILE RADIOLOCATION RADIONAVIGATION 5.91	Region 1 only and subject to restrictions on permitted coverage area
1705 – 1800 kHz	FIXED MARITIME MOBILE 5.90 LAND MOBILE 5.92 5.96	FIXED MOBILE RADIOLOCATION AERONAUTICAL RADIONAVIGATION	FIXED MOBILE RADIOLOCATION RADIONAVIGATION 5.91	Region 1 only and subject to restrictions on permitted coverage area
2045 – 2065 kHz	FIXED MARITIME MOBILE LAND MOBILE 5.92	FIXED MOBILE		Region 1 only
2065 – 2107 kHz	FIXED MARITIME MOBILE LAND MOBILE 5.92	MARITIME MOBILE 5.105 5.106		No constraints

Frequency	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
2107 – 2160 kHz	FIXED MARITIME MOBILE LAND MOBILE 5.92	FIXED MOBILE		Region 1 only
2170 – 2173.5 kHz	MARITIME MOBILE			No constraints
2173.5 – 2190.5 kHz	MOBILE (distress and calling) 5.108 5.109 5.110 5.111			Distress and calling
2190.5 – 2194 kHz	MARITIME MOBILE			No constraints
2625 – 2650 kHz	MARITIME MOBILE MARITIME RADIONAVIGATION 5.92	FIXED MOBILE		Region 1 only
4000 – 4063 kHz	FIXED MARITIME MOBILE 5.127 5.126			No constraints
4063 – 4438 kHz	MARITIME MOBILE 5.79A 5.109 5.110 5.130 5.131 5.132 5.128			No constraints
6200 – 6525 kHz	MARITIME MOBILE 5.109 5.110 5.130 5.132 5.137			No constraints
8100 – 8195 kHz	FIXED MARITIME MOBILE			No constraints
8195 – 8815 kHz	MARITIME MOBILE 5.109 5.110 5.132 5.145 5.111			No constraints
12230 – 13200 kHz	MARITIME MOBILE 5.109 5.110 5.132 5.145			No constraints
16360 – 17410 kHz	MARITIME MOBILE 5.109 5.110 5.132 5.145			No constraints
18780 – 18900 kHz	MARITIME MOBILE			No constraints
19680 – 19800 kHz	MARITIME MOBILE 5.132			No constraints
22000 – 22855 kHz	MARITIME MOBILE 5.132 5.156			No constraints
25070 – 25210 kHz	MARITIME MOBILE			No constraints
26100 – 26175 kHz	MARITIME MOBILE 5.132			No constraints

Frequency	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
154 – 156.4875 MHz	FIXED MOBILE except aeronautical mobile (R) 5.226 5.A114	FIXED MOBILE 5.226	FIXED MOBILE 5.226 5.A114	Operation protected by footnote 5.226
156.4875 – 156.5625 MHz (CH10, 70, 11)	MARITIME MOBILE (distress and calling via DSC) 5.111 5.226 5.227			No constraints for CH70 CH10 and CH11 are protected by footnote 5.227
156.5625 – 156.7625 MHz	FIXED MOBILE except aeronautical mobile (R) 5.226	FIXED MOBILE 5.225 5.226		Operation protected by footnote 5.226
156.7625 – 156.7875 MHz (CH75)	MARITIME MOBILE Mobile-satellite (Earth-to-space) 5.111 5.226 5.G110 (Ch 75)	MARITIME MOBILE MOBILE-SATELLITE (Earth-to-space) 5.111 5.226 5.G110 (Ch 75)	MARITIME MOBILE Mobile-satellite (Earth-to-space) 5.111 5.226 5.G110 (Ch 75)	Operation protected by footnote 5.226
156.7875 – 156.8125 MHz (CH16)	MARITIME MOBILE (distress and calling) 5.111 5.226			No constraints
156.8125 – 156.8375 MHz (CH76)	MARITIME MOBILE Mobile-satellite (Earth-to-space) 5.111 5.226 5.G110 (Ch 76)	MARITIME MOBILE MOBILE-SATELLITE (Earth-to-space) 5.111 5.226 5.G110	MARITIME MOBILE Mobile-satellite (Earth-to-space) 5.111 5.226 5.G110	Operation protected by footnote 5.226
156.8375 - 161.9625 MHz	FIXED MOBILE except aeronauticalmobile 5.226	FIXED MOBILE 5.226		Operation protected by footnote 5.226
161.9375-161.9625 MHz	FIXED MOBILE except aeronautical mobile Maritime mobile-satellite (Earth-to-space) 5.228AA 5.226	FIXED MOBILE Maritime mobile-satellite (Earth-to-space) 5.228AA 5.226		Operation protected by footnote 5.226
161.9625 - 161.9875 MHz	FIXED	AERONAUTICAL MOBILE (OR)	MARITIME MOBILE	No constraints in Region 2.

Frequency	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
(AIS 1)	MOBILE except aeronautical mobile Mobile-satellite (Earth-to-space) 5.F110 5.226 5.A110 5.B110	MARITIME MOBILE MOBILE-SATELITE (Earth-to-space) 5.C110 5.D110	Aeronautical mobile (OR) 5.E110 Mobile-satellite (Earth-to-space) 5.F110 5.226	Operation protected by footnote 5.226 in Regions 1 and 3
161.9875 - 162.0125 MHz	FIXED MOBILE except aeronautical mobile Maritime mobile-satellite (Earth-to-space) 5.228AA 5.226 5.229	FIXED MOBILE Maritime mobile-satellite (Earth-to-space) 5.228AA 5.226		Operation protected by footnote 5.226
162.0125 - 162.0375 MHz (AIS 2)	FIXED MOBILE except aeronautical mobile Mobile-satellite (Earth-to-space) 5.F110 5.226 5.229 5.A110 5.B110	AERONAUTICAL MOBILE (OR) MARITIME MOBILE MOBILE-SATELITE (Earth-to-space) 5.C110 5.D110	MARITIME MOBILE Aeronautical mobile (OR) 5.E110 Mobile-satellite (Earth-to-space) 5.F110 5.226	No constraints in Region 2. Operation protected by footnote 5.226 in Regions 1 and 3
162.0375 - 174 MHz	FIXED MOBILE except aeronautical mobile 5.226 5.229	FIXED MOBILE 5.226 5.230 5.231 5.232		Operation protected by footnote 5.226
406 – 406.1 MHz	MOBILE-SATELLITE (Earth-to-space) 5.265 5.266 5.267			No constraints
456 – 459 MHz	FIXED MOBILE 5.286AA 5.271 5.287 5.288			Footnote 5.287 specifies maritime mobile use
460 – 470 MHz	FIXED MOBILE 5.286AA Meteorological-satellite (space-to-Earth) 5.287 5.288 5.289 5.290			Footnote 5.287 specifies maritime mobile use
1525 – 1530 MHz	SPACE OPERATION (space-to-Earth) FIXED	SPACE OPERATION (space-to-Earth)	SPACE OPERATION (space-to-Earth) FIXED	Complex

Frequency	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
	MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A Earth exploration-satellite Mobile except aeronautical mobile 5.349 5.341 5.342 5.350 5.351 5.352A 5.354	MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A Earth exploration-satellite Fixed Mobile 5.343 5.341 5.351 5.354	MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A Earth exploration-satellite Mobile 5.349 5.341 5.351 5.352A 5.354	
1530 – 1535 MHz	SPACE OPERATION (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A 5.353A Earth exploration-satellite Fixed Mobile except aeronautical mobile 5.341 5.342 5.351 5.354	SPACE OPERATION (space-to-Earth) MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A 5.353A Earth exploration-satellite Fixed Mobile 5.343 5.341 5.351 5.354		Complex
1535 – 1559 MHz	MOBILE-SATELLITE (space-to-Earth) 5.208B 5.351A 5.341 5.351 5.353A 5.354 5.355 5.356 5.357 5.357A 5.359 5.362A			Complex
1616 – 1610.6 MHz	MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.371 5.372	MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION RADIODETERMINATION-SATELLITE (Earth-to-space) 5.341 5.364 5.366 5.367 5.368 5.370 5.372	MOBILE-SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION Radiodetermination-satellite (Earth-to-space) 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.372	Complex
1610.6 – 1613.8 MHz	MOBILE=SATELLITE (Earth-to-space) 5.351A RADIO ASTRONOMY AERONAUTICAL RADIONAVIGATION	MOBILE=SATELLITE (Earth-to-space) 5.351A RADIO ASTRONOMY AERONAUTICAL RADIONAVIGATION RADIODETERMINATION-SATELLITE (Earth-to-space)	MOBILE=SATELLITE (Earth-to-space) 5.351A RADIO ASTRONOMY AERONAUTICAL RADIONAVIGATION Radiodetermination-satellite (Earth-to-space)	Complex

Frequency	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
	5.149 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.371 5.372	5.149 5.341 5.364 5.366 5.367 5.368 5.370 5.372	5.149 5.341 5.355 5.359 5.364 5.366 5.367 5.368 5.369 5.372	
1613.8 – 1626.5 MHz	MOBILE=SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION Mobile-satellite (space-to-Earth) 5.208B 5.341 5.355 5.359 5.364 5.365 5.366 5.367 5.368 5.369 5.371 5.372	MOBILE=SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION RADIODETERMINATION-SATELLITE (Earth-to-space) Mobile-satellite (space-to-Earth) 5.208B 5.341 5.364 5.365 5.366 5.367 5.368 5.370 5.372	MOBILE=SATELLITE (Earth-to-space) 5.351A AERONAUTICAL RADIONAVIGATION Mobile-satellite (space-to-Earth) 5.208B Radiodetermination-satellite (Earth-to-space) 5.341 5.355 5.359 5.364 5.365 5.366 5.367 5.368 5.369 5.372	Complex
1626.5 – 1660 MHz	MOBILE-SATELLITE (Earth-to-space) 5.351A 5.341 5.351 5.353A 5.354 5.355 5.357A 5.359 5.362A 5.374 5.375 5.376			Complex
2900 – 3100 MHz	RADIOLOCATION 5.424A RADIONAVIGATION 5.426 5.425 5.427			No constraints
9200 – 9300 MHz	EARTH EXPLORATION-SATELLITE (active) 5.474A 5.474B 5.474C RADIOLOCATION MARITIME RADIONAVIGATION 5.472 5.473 5.474 5.474D			No constraints
9300 – 9500 MHz	RADIONAVIGATION EARTH EXPLORATION-SATELLITE (active) SPACE RESEARCH (active) RADIOLOCATION 5.427 5.474 5.475 5.475A 5.475B 5.476A			No constraints

Annex C – Current and Evolving Wireless Telecommunications Technologies in the Maritime Environment

There is an ever increasing number of wireless technologies that aim to deliver voice and data connectivity to mobile users and which may be of use in the maritime environment. Aside from their technical capabilities, there may be regulatory issues and associated technical restrictions which prevent them being fully exploited. Such issues may include:

- the ITU Radio Regulations do not permit maritime mobile operation in the frequency bands concerned;
- frequencies are licensed on a national basis, such that there is no continuity of operation from country to country (this may even require equipment to be switched off when entering certain jurisdictions);
- the system parameters may have the potential to cause interference to ship-borne equipment;
- planning parameters may make use at sea (or even in ports) complex or difficult.

The following terrestrial technologies are currently in the process of either being rolled-out or standardized on an international basis and thus may be candidates for use in the maritime environment, particularly for commercial port services:

- digital PMR (to replace analogue PMR for on-board communications): TETRA, TETRAPOL, P25, dPMR, DMR, TDMA;
- 3G Mobile: UMTS (TDD & FDD), cdma2000, TD-SCDMA, IEEE802.20 (including iBurst), HSDPA;
- 3.5G Mobile: WiMax;
- 4G Mobile: LTE, UMB.

In addition to these commercial service technologies, there are various technologies which may offer potential solutions under the banner of 'license exempt' or 'low-power' technologies such as Wi-Fi, Bluetooth, ZigBee and UWB. The range of such services, however, is exceptionally limited (normally to 100 meters or much less) and the frequencies employed are globally allocated for the purpose (e.g. the 2.4 GHz ISM[8] band) such that there is no need for a specific consideration of the impact on spectrum of their usage in a maritime environment.

Table 8 details, for each of the commercial technologies, the frequency band(s) in which they 'prefer' to operate, i.e. those for which there are known services, as well as the general range of frequencies over which they are specified to operate.

Table 8 - Summary of Spectrum Requirements of New Commercial Data Links

Technology	Frequency Range	Notes
TETRA[9]	380 – 400 MHz 410 – 430 MHz 450 – 470 MHz 806 – 821 // 851 – 866 MHz	EN 300 392
TETRA 2 (TEDS)		EN 302 561
TETRAPOL	70 – 933 MHz	
P25	136 – 870 MHz	
DMR	30 – 900 MHz	TS 102 361
dPMR	30 – 900 MHz	EN 301 166

8 Industrial, Scientific and Medical. These bands are used by devices such as industrial heaters and driers and domestic equipment such as microwave ovens.

9 This technology is widely used for government agencies and may not be available to commercial enterprise.

Technology	Frequency Range	Notes
GSM (incl EDGE)[10]	380 – 400 MHz 410 – 430 MHz 450 – 470 MHz 478 – 496 MHz 698 – 746 MHz 747 – 792 MHz 806 – 866 MHz 824 – 894 MHz 870 – 921 MHz 876 – 925 MHz 880 – 960 MHz 1710 – 1880 MHz 1850 – 1990 MHz	
CDMA2000 W-CDMA (UMTS)	450 – 470 MHz 790 – 862 MHz 824 – 894 MHz 880 – 960 MHz 1710 – 1880 MHz 1850 – 1990 MHz 1820 – 2170 MHz 2300 – 2400 MHz 2500 – 2690 MHz	
TD-CDMA TD-SCDMA	1900 – 1920 MHz 2010 – 2025 MHz (2570 – 2620 MHz)	'TDtv' applications have been trialed in some EU countries
WiMax	2 – 11 GHz 10 – 66 GHz	3400 – 3600 MHz is being seen as a potential target following WRC-07 and EU WAPECS moves
802.20 (MBWA)	Below 3.5 GHz	
WiBro	2.3 – 2.4 GHz	Currently Korea only
iBurst (HC-SDMA)	Below 3.5 GHz	Often uses 1785 – 1805 MHz or 1900 – 1920 MHz

LTE and UMB are 4G extensions to UMTS and CDMA2000 respectively. At present, it is envisaged that existing spectrum assignments will be re-farmed such that no new spectrum will be necessary.

From the above, the bands of particular interest, and where there are most likely to be mobile communication systems providing value in maritime applications are:

- 380 to 400 MHz;
- 410 to 430 MHz;
- 450 to 470 MHz;
- 790 to 862 MHz (the 'Digital Dividend');
- 824 to 849 // 869 to 894 MHz (US '800 MHz' cellular band);

[10] According to 3GPP TS 45.005

- 880 to 915 // 925 to 960 MHz (EU '900 MHz' cellular band);
- 1710 to 1785 // 1815 to 1880 MHz (EU '1800 MHz' cellular band);
- 1850 to 1910 // 1930 to 1990 MHz (US '1900 MHz' cellular band);
- 1880 to 1920 MHz (EU '3G TDD' band);
- 1920 to 1980 // 2110 to 2170 MHz (EU '3G' band);
- 2010 to 2015 MHz (EU '3G TDD' band);
- 2400 to 2483.5 MHz ('2.4 GHz' license exempt, low-power band);
- 2500 to 2690 MHz ('3G expansion' band);
- 3400 to 3600 MHz

Table 9 shows, based on the latest version of the ITU Radio Regulations, the allocations in those bands (including any footnotes), highlighting the position of maritime services in those bands.

Table 9 - Summary of Maritime Radio Spectrum

Frequency (MHz)	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
380 – 387	FIXED MOBILE 5.254			No constraints
387 – 390	FIXED MOBILE Mobile-satellite (space-to-Earth) 5.208A 5.208B 5.254 5.255			No constraints
390 – 399.9	FIXED MOBILE 5.254			No constraints
410 – 420	FIXED MOBILE except aeronautical mobile SPACE RESEARCH (space-to-space) 5.268			No constraints
420 – 430	FIXED MOBILE except aeronautical mobile Radiolocation 5.269 5.270 5.271			No constraints
450 – 455	FIXED MOBILE 5.286 AA 5.209 5.271 5.286 5.286A 5.286B 5.286C 5.286D 5.286 E			No constraints
455 – 456	FIXED MOBILE 5.286AA 5.209 5.271 5.286A 5.286B 5.286C 5.286 E	FIXED MOBILE 5.286AA MOBILE-SATELLITE (Earth-to-space) 5.286A 5.286B 5.286C 5.209	FIXED MOBILE 5.286AA 5.209 5.271 5.286A 5.286B 5.286C 5.286 E	No constraints
456 – 459	FIXED MOBILE 5.286AA			No constraints

Frequency (MHz)	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
	5.271 5.287 5.288			
459 – 460	FIXED MOBILE 5.286AA 5.209 5.271 5.286A 5.286B 5.286C 5.286 E	FIXED MOBILE 5.286AA MOBILE-SATELLITE (Earth-to-space) 5.286A 5.286B 5.286C 5.209	FIXED MOBILE 5.286AA 5.209 5.271 5.286A 5.286B 5.286C 5.286 E	No constraints
460 – 470	FIXED MOBILE 5.286AA Meteorological-satellite (space-to-Earth) 5.287 5.288 5.289 5.290			No constraints
790 – 806	FIXED BROADCASTING MOBILE except aeronautical mobile 5.316B 5.317A 5.312 5.314 5.315 5.316 5.316A 5.319	BROADCASTING Fixed MOBILE 5.313B 5.317A 5.293 5.309 5.311A	FIXED MOBILE 5.313A 5.317A BROADCASTING 5.149 5.305 5.306 5.307 5.311A 5.320	No constraints
806 – 862	FIXED BROADCASTING MOBILE except aeronautical mobile 5.316B 5.317A 5.312 5.314 5.315 5.316 5.316A 5.319	FIXED MOBILE 5.317A BROADCASTING 5.317 5.318	FIXED MOBILE 5.313A 5.317A BROADCASTING 5.149 5.305 5.306 5.307 5.311A 5.320	No constraints
862 – 890	FIXED MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322 5.319 5.323	FIXED MOBILE 5.317A BROADCASTING 5.317 5.318	FIXED MOBILE 5.313A 5.317A BROADCASTING 5.149 5.305 5.306 5.307 5.311A 5.320	No constraints
890 – 902	FIXED MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322 Radiolocation 5.323	FIXED MOBILE except aeronautical mobile 5.317A Radiolocation 5.318 5.325	FIXED MOBILE 5.317A BROADCASTING Radiolocation 5.327	No constraints
902 – 928	FIXED	FIXED Amateur	FIXED MOBILE 5.317A	No constraints

Frequency (MHz)	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
	MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322 Radiolocation 5.323	MOBILE except aeronautical mobile 5.325A Radiolocation 5.150 5.325 5.326	BROADCASTING Radiolocation 5.327	
928 – 942	FIXED MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322 Radiolocation 5.323	FIXED MOBILE except aeronautical mobile 5.317A Radiolocation 5.325	FIXED MOBILE 5.317A BROADCASTING Radiolocation 5.327	No constraints
942 – 960	FIXED MOBILE except aeronautical mobile 5.317A BROADCASTING 5.322 5.323	FIXED MOBILE 5.317A	FIXED MOBILE 5.317A BROADCASTING 5.320	No constraints
1710 – 1930	FIXED MOBILE 5.384A 5.388A 5.388B 5.149 5.341 5.385 5.386 5.387 5.388			No constraints
1930 – 1970	FIXED MOBILE 5.388A 5.388B 5.388	FIXED MOBILE 5.388A 5.388B Mobile-satellite (Earth-to-space) 5.388	FIXED MOBILE 5.388A 5.388B 5.388	No constraints
1970 – 1980	FIXED MOBILE 5.388A 5.388B 5.388			No constraints
1980 – 2010	FIXED MOBILE MOBILE-SATELLITE (Earth-to-space) 5.351A 5.388 5.389A 5.389B 5.389F			No constraints
2010 – 2015	FIXED MOBILE 5.388A 5.388B 5.388	FIXED MOBILE MOBILE-SATELLITE (Earth-to-space) 5.388 5.389C 5.389E	FIXED MOBILE 5.388A 5.388B 5.388	No constraints
2110 – 2120	FIXED			No constraints

Frequency (MHz)	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
	MOBILE 5.388A 5.388B SPACE RESEARCH (deep space) (Earth-to-space) 5.388			
2120 – 2160	FIXED MOBILE 5.388A 5.388B 5.388	FIXED MOBILE 5.388A 5.388B Mobile-satellite (space-to-Earth) 5.388	FIXED MOBILE 5.388A 5.388B 5.388	No constraints
2160 – 2170	FIXED MOBILE 5.388A 5.388B 5.388	FIXED MOBILE MOBILE-SATELLITE (space-to-Earth) 5.388 5.389C 5.389E	FIXED MOBILE 5.388A 5.388B 5.388	No constraints
2400 – 2450	FIXED MOBILE 5.384A Amateur Radiolocation 5.150 5.282 5.395	FIXED MOBILE 5.384A RADIOLOCATION Amateur 5.150 5.282 5.393 5.394 5.396		No constraints
2450 – 2483.5	FIXED MOBILE Radiolocation 5.150	FIXED MOBILE RADIOLOCATION 5.150		No constraints
2500 – 2520	FIXED 5.410 MOBILE except aeronautical mobile 5.384A 5.412	FIXED 5.410 FIXED-SATELLITE (space-to-Earth) 5.415 MOBILE except aeronautical mobile 5.384A 5.404	FIXED 5.410 FIXED-SATELLITE (space-to-Earth) 5.415 MOBILE except aeronautical mobile 5.384A MOBILE-SATELLITE (space-to-Earth) 5.351A 5.407 5.414 5.414A 5.404 5.415A	No constraints
2520 – 2535	FIXED 5.410 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.413 5.416	FIXED 5.410 FIXED-SATELLITE (space-to-Earth) 5.415 MOBILE except aeronautical mobile 5.384A	FIXED 5.410 FIXED-SATELLITE (space-to-Earth) 5.415 MOBILE except aeronautical mobile 5.384A	No constraints

Frequency (MHz)	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
	5.339 5.405 5.412 5.417C 5.417D 5.418B 5.418C	BROADCASTING-SATELLITE 5.413 5.416 5.339 5.417C 5.417D 5.418B 5.418C	BROADCASTING-SATELLITE 5.413 5.416 5.403 5.414A 5.415A	
2535 – 2655	FIXED 5.410 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.413 5.416 5.339 5.412 5.417C 5.417D 5.418B 5.418C	FIXED 5.410 FIXED-SATELLITE (space-to-Earth) 5.415 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.413 5.416 5.339 5.417C 5.417D 5.418B 5.418C	FIXED 5.410 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.413 5.416 5.339 5.417A 5.417B 5.417C 5.417D 5.418 5.418A 5.418B 5.418C	No constraints
2655 – 2670	FIXED 5.410 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.208B 5.413 5.416 Earth exploration-satellite (passive) Radio astronomy Space research (passive) 5.149 5.412	FIXED 5.410 FIXED-SATELLITE (Earth-to-space) (space-to-Earth) 5.415 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.413 5.416 Earth exploration-satellite (passive) Radio astronomy Space research (passive) 5.149 5.208B	FIXED 5.410 FIXED-SATELLITE (Earth-to-space) 5.415 MOBILE except aeronautical mobile 5.384A BROADCASTING-SATELLITE 5.413 5.416 Earth exploration-satellite (passive) Radio astronomy Space research (passive) 5.149 5.208B 5.420	No constraints
2670 – 2690	FIXED 5.410 MOBILE except aeronautical mobile 5.384A Earth exploration-satellite (passive) Radio astronomy Space research (passive) 5.149 5.412	FIXED 5.410 FIXED-SATELLITE (Earth-to-space) (space-to-Earth) 5.208B 5.415 MOBILE except aeronautical mobile 5.384A Earth exploration-satellite (passive) Radio astronomy Space research (passive) 5.149	FIXED 5.410 FIXED-SATELLITE (Earth-to-space) 5.415 MOBILE except aeronautical mobile 5.384A MOBILE-SATELLITE (Earth-to-space) 5.351A 5.419 Earth exploration-satellite (passive) Radio astronomy Space research (passive) 5.149	No constraints

Frequency (MHz)	Region 1 Allocation	Region 2 Allocation	Region 3 Allocation	Status of Maritime Use
3400 – 3500	FIXED FIXED-SATELLITE (space-to-Earth) Mobile 5.430A Radiolocation 5.431	FIXED FIXED-SATELLITE (space-to-Earth) Amateur Mobile 5.431A Radiolocation 5.433 5.282	FIXED FIXED-SATELLITE (space-to-Earth) Amateur Mobile 5.432B Radiolocation 5.433 5.282 5.432 5.432A	Secondary
3500 – 3600	FIXED FIXED-SATELLITE (space-to-Earth) Mobile 5.430A Radiolocation 5.431	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile Radiolocation 5.433	FIXED FIXED-SATELLITE (space-to-Earth) MOBILE except aeronautical mobile 5.433A Radiolocation 5.433	Secondary in Region 1

None of the footnotes relating to the use of these bands specifically preclude any use for maritime services.

With the exception of the band 3400 – 3600 MHz, the mobile service (which includes, unless explicitly stated, the maritime mobile service) has a primary allocation meaning that the use of these bands for maritime applications will pose no regulatory issues at the ITU. In the band 3400 – 3600 MHz, many of the footnotes relate to the upgrading of the mobile service from secondary to primary status, however it is known that in some parts of the world (especially in high rainfall areas such as around the equator) this band is still heavily used for satellite downlinks and as such its development for mobile services is likely to remain constrained.

Conclusions

There does not appear to be any necessity to expend significant effort on the standardization or regulation of these mobile communication technologies to make them suitable for the maritime community.

Annex D – Development of New Characteristics

The following tables summarizes the status of the various ITU technical characteristics relating to maritime communication applications both for those already existing as well as for those foreseen in e-Navigation. They outline where existing characteristics are likely to need updating or elsewhere new characteristics need to be developed. If changes are required they will take place through the appropriate ITU Study Groups.

ITU Study Groups (SG) are responsible for developing and maintaining Recommendations, some of which are used as technical background for amending the frequency allocations at the periodic World Radiocommunications Conferences (WRC). Study groups are established and assigned study questions by a Radiocommunication Assembly (RA) to prepare Recommendations for approval by ITU Member States. In the case of e-Navigation two SG's are likely to be involved in the development of material to be agreed at WRC, namely SG4 and SG5.

SG4 relates to satellite services, covering systems and networks for the following service:

- Fixed-satellite service;
- Mobile-satellite service;
- Broadcasting-satellite service; and
- Radiodetermination-satellite service.

SG5 relates to terrestrial services, covering systems and networks for the following services:

- Fixed service;
- Mobile service;
- Radiodetermination service;
- Amateur service; and
- Amateur-satellite service.

Below the SG's there are subgroups, such as Working Parties (WP) and Task Groups (TG) that are established to study the questions assigned to the different Study Groups. For example, SG4 has the following WP's:

- Working Party 4A - Efficient orbit/spectrum utilization for Fixed Satellite Service (FSS) and Broadcasting Satellite Service (BSS);
- Working Party 4B - Systems, air interfaces, performance and availability objectives for FSS, BSS and Mobile Satellite Service (MSS), including IP-based applications and satellite news gathering;
- Working Party 4C - Efficient orbit/spectrum utilization for MSS and Radiodetermination Satellite Service (RDSS);

SG5 has the following WP's:

- Working Party 5A - Land mobile service above 30 MHz excluding IMT; wireless access in the fixed service; amateur and amateur-satellite services;
- Working Party 5B - Maritime mobile service including Global Maritime Distress and Safety System (GMDSS); aeronautical mobile service and radiodetermination service;
- Working Party 5C - Fixed wireless systems; HF and other systems below 30 MHz in the Fixed and Land Mobile Services;
- Working Party 5D - IMT Systems;
- Task Group 5/1 (TG 5/1) - WRC-19 agenda item 1.13

For maritime GMDSS and e-Navigation applications any necessary revision to, or creation of, technical characteristics will take place in one of two WP's – SG4 WP4C and SG5 WP5B.

Table 10 - ITU Recommendations and Reports for Maritime Radio Applications

Application		Current characteristics		Amendments	Mechanism
DSC	**VHF**	Recommendation ITU-R M.493-14	Digital selective-calling system for use in the maritime mobile service.	The revision work on Recommendation ITU-R M.493-13 is on going at WP 5B in cooperation with IMO, IALA, IEC and CIRM	N/A
		Recommendation ITU-R M.541-10	Operational Procedures for the Use of Digital Selective-Calling Equipment in the Maritime Mobile Service		
		Recommendation ITU-R M.693-1	Technical characteristics of VHF emergency position-indicating radio beacons using digital selective calling (DSC VHF EPIRB)		
		Recommendation ITU-R M.689-3	International Maritime VHF Radiotelephone Systems with Automatic Facilities Based on DSC Signaling Format		
		Recommendation ITU-R M.821-1	Optional Expansion of the Digital Selective-Calling System for Use in the Maritime Mobile Service		
	MF/HF	Recommendation ITU-R M.493-14	Digital selective-calling system for use in the maritime mobile service.	The revision work on Recommendation ITU-R M.493-13 is on going at WP 5B in cooperation with IMO, IALA, IEC and CIRM	N/A
		Recommendation ITU-R M.541-10	Operational Procedures for the Use of Digital Selective-Calling Equipment in the Maritime Mobile Service		
		Recommendation ITU-R M.1173-1	Technical characteristics of single-sideband transmitters used in the maritime mobile service for radiotelephony in the bands between 1 606.5 kHz (1 605 kHz Region 2) and 4 000 kHz and between 4 000 kHz and 27 500 kHz		

Application		Current characteristics		Amendments	Mechanism
		Recommendation ITU-R M.1082-1	International maritime MF/HF radiotelephone system with automatic facilities based on DSC signaling format		
		Recommendation ITU-R M.476-5	Direct-Printing Telegraph Equipment in the Maritime Mobile Service		
	Satellite	Recommendation ITU-R M.541-10	Operational Procedures for the Use of Digital Selective-Calling Equipment in the Maritime Mobile Service	DSC over satellite is not currently defined explicitly through a technical characteristic. However, it could be appropriate to develop a complementary characteristic to those available for VHF and HF.	This task should be coordinated through WP4C/SG4 under existing question 227/4.
LRIT	**HF**			The use of HF and Satellite data links to support the LRIT application should not need a new technical characteristic, as they are simply applications supported by existing data links. However, there may be merit in amending the existing recommendations in relation to HF and satellite communications to explicitly recognize the use of LRIT.	The work would have to be addressed through WP4C/SG4 Questions 84-4/4 (Iridium), 87-4/4 (satellite) coordinating with WP5B/SG5 for HF.
	Satellite				

Application		Current characteristics		Amendments	Mechanism
AIS		Recommendation ITU-R M.1371-5	Technical characteristics for an automatic identification system using time division multiple access in the VHF maritime mobile band	WRC-12 allocated two channels for satellite detection of AIS, six channels for possible testing of future AIS applications and one channel for experimental use for future applications.	WRC-15 agreed that VHF channels 27 and 28 are each split into two simplex channels from 1 January 2019. The channels 2027 and 2028 designated as ASM 1 and ASM 2 are used for application specific messages (ASM) as described in the most recent version of Recommendation ITU-R M.2092. .
VHF Comms	**Voice**	Recommendation ITU-R M.1084-5	Interim solutions for improved efficiency in the use of the band 156-174 MHz by stations in the maritime mobile service	Under e-Navigation, a general push to make more efficient use of the spectrum available for maritime voice communications may take place as existing channels are increasingly allocated to digital services. The existing characteristics (e.g. M.1084) propose possible interim solutions such as the use of 12.5 kHz channel spacing. It may be desirable to develop a new technical characteristic to describe a permanent solutions for e.g. 12.5 kHz or 8.33 kHz voice channels in the future communication environment.	This task should be coordinated through WP5B/SG5.
		Recommendation ITU-R M.489-2	Technical characteristics of VHF radiotelephone equipment operating in the maritime mobile service in channels spaced by 25 kHz		

Application		Current characteristics		Amendments	Mechanism
	Data	Recommendation ITU-R M.1842-1	Characteristics of VHF radio system and equipment for the exchange of data and electronic mail in the maritime mobile service RR Appendix 18 channels	A new technical characteristic will be required to support the use of VHF channels for digital data transmission – assuming that AIS is not selected as the maritime domain datalink of choice. The current characteristic for VHF data exchange refers to the specific solution implemented by Telenor in Norway. If this solution is accepted by the maritime community, this characteristic could be amended. However, in the more likely scenario of a new datalink technology being proposed a new characteristic will be required. WP 5B is working on the standardization of communication protocols for full implementation of standardized VHF data communications.	This task should be coordinated through WP5B/SG5.
		Recommendation ITU-R M.2092-0	Technical characteristics for a VHF data exchange system in the VHF maritime mobile band	VHF data exchange system (VDES) integrates the components of VHF data exchange (VDE), application specific messages (ASM) and the automatic identification system (AIS) in the VHF maritime mobile band. This recommendation provides the technical characteristics of ASM and VDE.	

Application		Current characteristics		Amendments	Mechanism
	SAR	Recommendation ITU-R M.489-2	Technical characteristics of VHF radiotelephone equipment operating in the maritime mobile service in channels spaced by 25 kHz	No e-Nav related comms change is anticipated for the use of 121.5 MHz for short range SAR purposes. However, were the VHF channels to be revised the SAR associated characteristic (M.489) would in any event be updated.	N/A
HF Comms	**Voice**	Recommendation ITU-R M.1173-1	Technical characteristics of single-sideband transmitters used in the maritime mobile service for radiotelephony in the bands between 1 606.5 kHz (1 605 kHz Region 2) and 4 000 kHz and between 4 000 kHz and 27 500 kHz	No e-Nav related comms change is envisaged for HF voice services. However, if there is a broad encroachment of digital techniques into the band there may be a need to revise existing voice characteristics to accommodate data.	N/A
		Recommendation ITU-R M.1082-1	International maritime MF/HF radiotelephone system with automatic facilities based on DSC signalling format		
	Data	Recommendation ITU-R M.1081-1	Automatic HF facsimile and data system for maritime mobile users	There are a number of existing technical characteristics relating to data exchange in the HF band that include both outmoded legacy technologies as well as candidate future technologies. There needs to be either an update to M.1798, or else a new characteristic to describe the selected HF digital data scheme to be used under e-Navigation. Currently M.1798 and F.1821 describes multi-channel HF data links such as the system currently deployed by Globe Wireless for commercial services (email, etc.).	WRC-12 decided channelling arrangements in AP17, effecting on 1 January 2017 for the implementation of HF data communications.
		Recommendation ITU-R M.1798-1	Characteristics of HF radio equipment for the exchange of digital data and electronic mail in the maritime mobile service		
		Recommendation ITU-R M.627-1	Technical characteristics for HF maritime radio equipment using narrow-band phase-shift keying (NBPSK) telegraphy		
		Recommendation ITU-R F.1821-0	Characteristics of advanced digital high frequency (HF) radiocommunication systems		

Application		Current characteristics		Amendments	Mechanism
NAVTEX / NBDP	**MSI**	Recommendation ITU-R M.625-4	Direct-Printing Telegraph Equipment Employing Automatic Identification in the Maritime Mobile Service	If under e-Navigation the NAVTEX data is carried across different communication links there may be a need to provide a new characteristic to accommodate it. For this purpose, WP 5B developed Recommendation M.2010. Also, WRC-12 exclusively allocated 495-505 kHz to MMS for digital broadcasting of maritime safety and security related information using M.2010.	
		Recommendation ITU-R M.540-2	Operational and Technical Characteristics for an Automated Direct- Printing Telegraph System for Promulgation of Navigational and Meteorological Warnings and Urgent Information to Ships - Section 8B - Maritime Mobile Service; Telegraphy and Related Subjects.		
		Recommendation ITU-R M.688-0	Technical characteristics for a high frequency direct-printing telegraph system for promulgation of high seas and NAVTEX-type maritime safety information		
		Recommendation ITU-R M.492-6	Operational procedures for the use of direct-printing telegraph equipment in the maritime mobile service		
		Recommendation ITU-R M.476-5	Direct-Printing Telegraph Equipment in the Maritime Mobile Service		
NAVDATA	**Data**	Recommendation ITU-R M.2010-0	Characteristics of a digital system, named Navigational Data for broadcasting maritime safety and security related information from shore-to-ship in the 500 kHz band	This technical characteristic may be used for e-Navigation for digital broadcasting maritime safety and security related information from shore to ship on 495-505 kHz with high data rate.	WRC-12 allocated 495-505 kHz to the MMS exclusively for the high speed digital broadcasting, effective on 1 January 2013.

Application		Current characteristics		Amendments	Mechanism
		Recommendation ITU-R M.2058-0	Characteristics of a digital system, named navigational data for broadcasting maritime safety and security related information from shore-to-ship in the maritime HF frequency band	This technical characteristic may be used for e-Navigation for digital broadcasting maritime safety and security related information from shore to ship on 4, 6, 8, 12, 16 and 22 MHz bands with high data rate.	
On board Comms	**UHF**	Recommendation ITU-R M.1174-3	Technical characteristics of equipment used for on-board vessel communications in the bands between 450 and 470 MHz	WRC-15 Agenda Item 1.15 will consider spectrum demands for on-board communication and there may be a need to update the existing characteristics to support the implementation of digital PMR.	This task should be coordinated through WP5B/SG5 most likely under a new question.
	Wi-Fi	Report ITU-R F.2086-1	Technical and operational characteristics and applications of broadband wireless access in the fixed service	If Wi-Fi stations are to be adopted for on-board data communications there may be a need for a new characteristic associated with is use in the maritime mobile domain.	This task should be coordinated through WP5B/SG5 most likely under a new question.
Satellite Comms	**Broadband**	Recommendation ITU-R S.1709-1	Technical characteristics of air interfaces for global broadband satellite systems	Broadband over satellite is an existing application of current satellite systems and does not warrant a specific characteristic for the maritime domain	N/A
	MSI	Recommendation ITU-R S.1709-1	Technical characteristics of air interfaces for global broadband satellite systems	The transmission of MSI over broadband may warrant a characteristic to define the data layers.	This task should be coordinated through WP4C/SG4 under existing question 87-4/4.
DGNSS		Recommendation ITU-R M.823-3	Technical characteristics of differential transmissions for global navigation satellite systems from maritime radio beacons in the frequency band 283.5-315 kHz in Region 1 and 285-325 kHz in Regions 2 and 3	The current characteristic M.823-3 will ultimately need to be updated to accommodate new developments in GNSS such as Galileo and COMPASS.	This task should be coordinated through WP5B/SG5.

Application		Current characteristics		Amendments	Mechanism
Port Services	**WiMax / 2G / 3G / 4G**			The maritime community will make use of technologies developed and standardized for other applications in port. No maritime specific characteristics are required.	N/A
Inter-Ship Broadband	**WiMax**	Recommendation ITU-R M.1801-2	Radio interface standards for broadband wireless access systems, including mobile and nomadic applications, in the mobile service operating below 6 GHz	Under e-Navigation, ad-hoc mesh WiMax networks could be deployed to provide broadband coastal networks. This would require a specific form of implementation of WiMax that would necessitate a specific technical characteristic.	This task should be coordinated through WP5B/SG5 possibly under existing questions 212/8 and 238/8.
Loran	**eLoran data channel**	Recommendation ITU-R M.589-3	Technical characteristics of methods of data transmission and interference protection for radionavigation services in the frequency bands between 70 and 130 kHz	The existing technical characteristic will need to be revised to accommodate the definitive 9th pulse, Eurofix and/or new modulation schemes selected for the eLoran data channel.	This task should be coordinated through WP5B/SG5 under a new question.
Radar	**SART**	Recommendation ITU-R M.628-5	Technical Characteristics for Search and Rescue Radar Transponders	Relates to 9 GHz SART, so no change required.	N/A
	Racon	Recommendation ITU-R M.824-4	Technical parameters of radar beacons (Racons)	No e-Nav related comms change.	N/A
	Radio determination	Recommendation ITU-R M.1460-2	Technical and operational characteristics and protection criteria of radiodetermination radars in the 2 900-3 100 MHz band	No e-Nav related comms change.	N/A
EPIRB	**VHF**	Recommendation ITU-R M.690-3	Technical characteristics of emergency position-indicating radio beacons (EPIRBs) operating on the carrier frequencies of 121.5 MHz and 243 MHz	No e-Nav related comms change.	N/A

Application		Current characteristics		Amendments	Mechanism
	Satellite (COSPAS / SARSAT)	Recommendation ITU-R M.633-4	Transmission characteristics of a satellite emergency position-indicating radio beacon (satellite EPIRB) system operating through a satellite system in the 406 MHz band	No e-Nav related comms change.	N/A
	Satellite	Recommendation ITU-R M.632-3	Transmission Characteristics of a Satellite Emergency Position Indicating Radio Beacon (Satellite EPIRB) System Operating Through Geostationary Satellites in the 1.6 GHz Band	No e-Navigation related communications change.	N/A

Annex E – VHF Data Exchange System VDES

AIS is well recognized and accepted as an important tool for safety of navigation and is a carriage requirement for SOLAS vessels (Class-A). With increasing demand for maritime VHF data communications, AIS has become heavily used for maritime safety, maritime situational awareness and port security. As a result, overloading of AIS 1 and AIS 2 created a need for additional AIS channels. Using the VHF marine band (International Radio Regulations Appendix 18) AIS can transmit data to vessels in the vicinity of the AIS unit as well as to vessels in an addressed group.

International Telecommunications Union (ITU) has recognised the efficiency and the necessity for digital communications, has produced technical standards and has revised the VHF marine band (Radio Regulations Appendix 18) to designate channels for data transmission. It is recognized that both analogue voice communications and digital communications will share the band. The VDES, as envisioned by IALA and presented to ITU, addresses the identified need to protect AIS along with essential digital communications contributions for e-Navigation and GMDSS Modernization.

The VHF marine band (Radio Regulations Appendix 18) was initially used for transmission of voice communications on 25 kHz channels. The ITU introduced the first marine data transmission system, DSC (Digital Selective Calling)[11] to help ensure that calling and distress communications attempts were successful. VHF DSC transmits data at 1.2 kbps, slow by modern data standards, but very robust. At the request of the IMO to improve safety of navigation, ITU introduced another VHF data transmission system, AIS[12], which provides navigation and identification data for ships, shore stations, aids to navigation and search and rescue devices at 9.6 kbps.

ITU introduced a standard[13], with options for 25 kHz, 50 kHz and 100 kHz channels at data rates up to 307.2 kbps in order to improve spectrum efficiency in 2012. Both voice and data communications coexist in the VHF marine band. The developments in maritime radio technology, including the introduction of software defined radios (SDR) coupled with enhanced capabilities for digital data exchange over existing VHF marine band spectrum resulted in the development of the VHF Data Exchange System (VDES). VDES builds on the experience gained through the development of AIS, and also provides the capability to transmit to a specific vessel (addressed); to all units in the vicinity (broadcast); to a group of vessels (addressed); or to a fleet of vessels (addressed).

Consequential to WRC-15, the ITU standard for VDES, Recommendation ITU-R M.2092-0, was approved. A remaining outstanding issue is the approval of the satellite component for the VDE channels which is targeted for approval at WRC-19.

The system concept, including VDES functions and frequency usage are illustrated pictorially in (full system).

[11] Recommendation ITU-R M.493

[12] Recommendation ITU-R M.1371

[13] Recommendation ITU-R M.1842

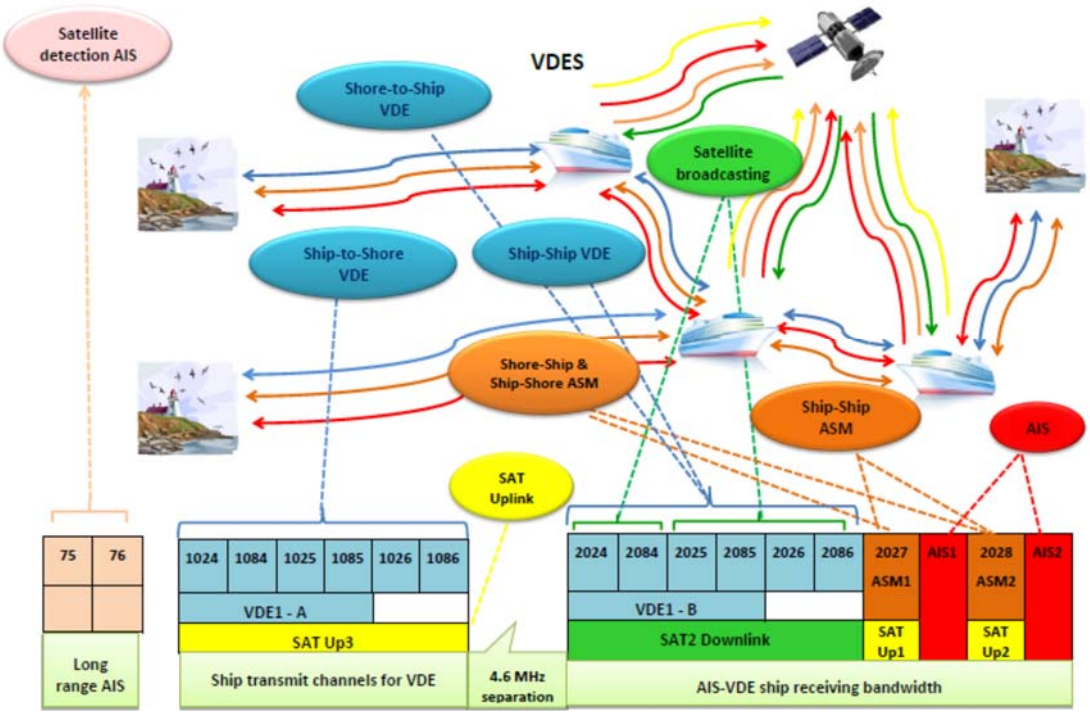

Figure 1- VDES functions and frequency use – full system

E1 VHF Data Exchange System channel usage (Radio Regulations Appendix 18)

E1.1 VHF data exchange system: data exchange between terrestrial stations

– AIS 1 (channel 2087) and AIS 2 (channel 2088) are AIS channels, in accordance with Recommendation ITU-R M.1371

– ASM 1 (channel 2027) and ASM 2 (channel 2028) are the channels used for application specific messages (ASM)

– VDE1-A lower legs (channels 1024, 1084, 1025, 1085) are ship-to-shore VDE

– VDE1-B upper legs (channels 2024, 2084, 2025, 2085) are shore-to-ship and ship-to-ship VDE.

E1.2 VHF data exchange system: data exchange between satellites and terrestrial stations

– AIS 1 (channel 2087) and AIS 2 (channel 2088) are terrestrial AIS channels that are also used as uplinks for receiving AIS messages by satellite

– Long Range AIS using channel 75 and channel 76 are specified channels to be used as uplinks for receiving AIS messages by satellite. SAT Up1 (channel 2027) and SAT Up 2 (channel 2028) are used for receiving ASM by satellite

E2 AIS for e-Navigation

AIS is a proven technology suitable for playing a significant role in data communications for e-Navigation. However:

i) by design AIS is not an ideal candidate for high speed and/or high volume data communications;

ii) high speed digital data communications for e-Navigation is better handled by using multiple 25 kHz channels;

iii) the IMO/ITU Joint Experts Group has recognized that more than 200 kbps will be necessary for e-Navigation.

This document proposes a vision for technology to efficiently handle new applications as well as low volume data communications for e-Navigation.

E3 AIS Today

AIS is technically defined by Recommendation ITU-R M.1371, mandatory for SOLAS vessels and for other vessels on a regional basis, and used voluntarily;

AIS has proved to be a powerful tool for various applications in the field of navigation, and distribution of safety related information, however these applications have not yet fully been exploited;

Radio Regulations Appendix 15 (WRC-07) defines the frequencies used for GMDSS, and this includes the frequencies AIS1 and AIS 2 used by AIS-SART stations.

E4 Increasing Use of AIS

The use of AIS is increasing rapidly, threatening to degrade the performance or to overload the current AIS frequencies AIS 1 and AIS 2.

E4.1 Number of ships

Full implementation of SOLAS requirement for AIS is completed. Increased use of mandatory AIS on non-SOLAS vessels is evident:

i) USA (USA commercial vessels);

ii) Europe (EU Directive for fishing vessels requiring Class-A AIS);

iii) Europe (EU Directive for inland vessels requiring Inland AIS (Class-A derivative));

iv) Korea;

v) India;

vi) Mexico;

vii) Australia.

Increased voluntary use of AIS:

i) both Class-A and Class-B units used on smaller vessels including rapidly increasing numbers of pleasure vessels.

Class-B increasing use:

i) Class-B (CSTDMA) visibility will eventually be reduced due to polite behaviour;

ii) Class-B (SOTDMA) has been introduced.

E4.2 AIS Base Stations

Coastal and inland AIS infrastructure continues to grow. This growth is driven by safety, security and environmental protection considerations. The use of AIS data gathered over time is now integrated into many analysis systems both for trend analysis and to determine possible anomalous vessel behaviours.

In addition, within Europe, EU Directive 59 requires that all EU member countries maintain coastal AIS coverage.

E4.3 Airborne AIS

More SAR aircraft are being fitted with AIS stations.

E4.4 AIS AtoN, Real or Virtual, and AtoN Monitoring

AIS AtoN – real and virtual – are being used or approved by competent authorities.

A separate message for AtoN monitoring (often Message 6) is being used in most cases where an AIS AtoN station is deployed.

In addition, AIS AtoN stations are being deployed by commercial organizations to mark offshore platforms, wind farms, etc.

E4.5 AIS-SART

IMO carriage option for the AIS-SART started in January 2010. AIS-SART broadcasts eight times per minute on AIS 1 and AIS 2. :

E4.6 SAR Related Equipment Using AIS-SART Technology

Several kinds of AIS-MOB using AIS-SART technology have been deployed on the market and this device is identified to use unique IDs as defined in Recommendation ITU-R M.585-6.

EPIRB-AIS, AIS-MOB and Diver device using AIS-SART technology are being introduced on the market. IMO NAV58 considered the issue relating to these devices and decided that diver locating devices should not operate on the frequencies AIS 1 and AIS 2 for routine diver locating. It was further considered that the frequencies AIS 1 and AIS 2 should only be used when a diver was in a non-routine situation, that in these cases the device was similar to a MOB device and, therefore, the parameter and appropriate message for MOB should apply.

E4.7 Application-Specific Messages

Application specific messages are being used more on AIS1 and 2; this leads to future developments under a combined application.

WRC-15 agreed that VHF channels (duplex) 27 and 28 are to be split into two simplex channels from 1 January 2019. The channels 2027 and 2028 have been designated as ASM 1 and ASM 2, and are to be used for application specific messages (ASM) as described in the most recent version of Recommendation ITU-R M.2092.

E4.7.1 International

IMO SN/Circ.289 provides guidance on the use of international application specific messages. This circular retains most of the international application-specific messages that were developed for trial and the addition of new messages were created such as;

i) a new meteorological-hydrographic message with a dynamic length of 2 to 5 slots;

ii) an area message for navigational warnings.

E4.7.2 Regional

There is extensive use of safety-related ASM regionally, including the use of AMSs for the monitoring of Aids to Navigation (AtoN). In addition, there are uses of ASM within certain waterways such as the St. Lawrence Seaway and the River Thames.

IALA maintains a registry of these regional application specific messages.

E4.7.3 Mandatory Application Specific Messaging in Certain Regions

Additional application specific messages are being used for inland AIS in Europe. These include the development of dedicated ship stations, which have been type approved.

E4.8 AIS Messages (23, 24, 25, 26 and 27)

Messages 23, 24, 25, 26 and 27 were added in recent editions of Recommendation ITU R M.1371;

Additional frequencies were approved at WRC12 for receiving Message 27 by Satellites (Channels 75 and 76).

E4.9 GNSS Differential Corrections

Use of Message 17 for GNSS correction data dissemination is increasing. Message 17 is already being broadcast in the Gulf of Finland and Tokyo Bay. Germany, the Netherlands and England are planning the introduction of message 17.

E4.10 FATDMA Usage

Competent authorities are increasingly using FATDMA slot allocations for various uses:

i) AIS AtoN;

ii) base station slot reservation broadcasts (Message 20);

iii) base station regular broadcasts (Message 17);

iv) reserved slots for ship replies;

v) safety text messages;

vi) meteorological and hydrographic messages (Message 8).

There is an indication that the VHF Data Link will become more crowded and competent authorities resort to FATDMA reservations to ensure that their services are protected.

E5 Additional Future Use of AIS / VDES

E5.1 Increased Use of AIS Shore to Ship Data Transmissions

In a future e-Navigation scenario, the transmission of data from shore-to-ship is expected to increase significantly with the advent of mandatory ECDIS, which provides a graphical display of information. There could be opportunities for transmission of this data by AIS or by VDE, as part of VDES.

Examples:

i) Ship off track warning;

ii) Territorial water advice;

iii) Environmental area warning;

iv) Navigational hazards;

v) Weather warnings;

vi) Military test ranges and submarine exercises.

It is anticipated that some of the present voice communications between shore and ship will move to data messaging:

i) ship reporting;

ii) routing information.

E5.2 Increased Use of Ship-to-Shore Data Transfer

– Ship reporting (by AIS or VDE):

– Requesting data:

i) weather data;

ii) docking data;

iii) routing information.

E5.3 Increased Use of Ship-to-Ship Data Transmissions

– Reduced use of voice communications in favour of data messages.

E5.4 Base Stations

– There will be more fixed stations, some of these being private;

– Development of limited base stations will be driven by:

  i) private ports;

  ii) bridges and locks;

  iii) canals;

  iv) offshore commercial facilities.

E5.5 Repeater Stations

– Repeaters will be used to extend coverage of shore AIS base station networks, ship-ship AIS communications, and AIS AtoN range:

  i) requiring double the VDL slot count to transfer data;

  ii) and are deployed to extend base station coverage when the usual base station-to- base station data links are unavailable.

  VDE may assist with mitigating the impact on the VDL.

E5.6 Future Messaging

– Will be required as the suite of Recommendation ITU-R M.1371 messages increases:

  i) Originally 22 message types, now 27 have been defined.

– Improved set of messages are expected:

  i) replacement for some old messages, when they have proved not to support proper data modelling (e.g. static ship data);

  ii) reduction of “tailored messages” to “essentially needed messages”;

  iii) new flexibility for applications.

E5.7 Satellite Detection of AIS

– Satellite detection of AIS messages is now an accepted capability.

– Separate frequencies for satellite detection of AIS were requested from within Appendix 18 because the tuning range of the shipborne AIS Class A is limited to these frequencies. Report ITU-R M.2084 indicated that the interference environment resulting from the existing services in those bands must be taken into account in determining the feasibility of accommodating satellite AIS, due to the large satellite antenna footprint that overlaps both land and sea. Separate operating frequencies in addition to AIS 1 and AIS 2 are needed that are not subject to terrestrial use.

– Appendix 18 contains only 4 frequencies (channels 16, 70, 75 and 76) that are exclusively dedicated to maritime use (channels 75 and 76 have been approved to be shared with this service). This proposal meets the intent of footnote *n)* to Appendix 18 for interference mitigation.

– Based on the above situation, WRC-12 approved the use of channels 75 and 76 for this purpose (long range AIS) and assigned these channels to the maritime mobile satellite service.

E5.8 Future GMDSS Platform

– IMO modified the performance standard for the 406 MHz EPIRB to include use of AIS. This suggests the use of AIS, when combined with another technology, may be useful as a GMDSS locating / homing device.

– IMO has recognized AIS-SART as part of GMDSS. The potential for additional use of AIS and VDE as a SAR tool is being considered as part of GMDSS modernization review being carried out by the IMO.

E5.9 PLB (Personal Locating Beacon)

– There are initiatives to develop a PLB / MOB / Diver applications based on the AIS-SART technology. These may be considered as part of the development of AMRDs.

E5.10 Use of AIS for PNT (Position, Navigation and Timing) and Ranging

– Improved time transfer capabilities shore to ship by using high precision time bases has been proposed.

– The e-Navigation Committee envisages a "Ranging" mode for AIS and trials were undertaken in Northern Europe as part of ACCSEAS project

i) where the timing of AIS messages are used for position determination;

ii) by ship and shore.

E5.11 Coordinated Channel Management for Future e-Navigation VHF Digital Data Communications

– Channel management should be relocated to other channels such as 28B (2028) and 27B (2027) protecting distress and safety messaging on channel 70 and avoiding interference from other services.

– Designation of additional AIS frequencies may enhance the coordination of regional channel management.

– Using TDMA protocol to coordinate the usage of the VHF data link will enable channel management for other e-Navigation data services as well as AIS.

– Any additional protocols on Channel 70 are required to co-exist and not interfere with current DSC requirements and operation.

E6 Strategy for Future AIS and VDE

E6.1 General Thoughts

– AIS is a proven maritime data system, with ships equipped and shore infrastructure established, the full potential of AIS is yet to be achieved.

– AIS is the quickest path for handling the increasing low volume data exchange needs described above. Therefore, in order to meet the data communications needs set out above, IALA envisages that the present AIS system will need to be supplemented with VDE.

E6.2 "VHF Data Exchange" (VDE) Plan

Six VHF data channels 24, 84, 25, 85, 26, and 86, plus channels 27 and 28 (which have been identified globally for "data communications" and "possible testing of future AIS applications"), have been agreed for an international scheme known as "**VHF Data Exchange System**" (VDES).

E7 Description of VHF Data Communications Requirements

E7.1 Background

Prior to WRC-12, IALA created ITU document 5B/801 "Three essential elements of e-Navigation communications", which originated in IALA as output document e-Nav10-output-18.

Two of these essential elements were concerned with AIS and with VHF channels for data exchange. The third of these essential elements is MF radio communications, near 500 kHz. It is not considered in this ANNEX, which is restricted to VHF matters.

The objective of this document 5B/801 was to secure at WRC-12 additional AIS channels for satellite detection, and additional VHF channels to relieve the loading on AIS1 and AIS2 with the objective of optimizing the use of AIS1 and AIS2 for their original purpose. The result of WRC-12 was in accordance with these objectives.

E7.2 VHF Data Communications

VHF data communications will provide robust high-speed/large volume data exchange between ships and between ship and shore. The AIS system is not capable of handling, nor is intended for, this high-speed/large volume data exchange.

Taking into account the channels identified by WRC-12 as described above, channels channels 80, 21, 81, 22, 82, 23, 83, 24, 84, 25, 85, 26, and 86 will use the modulation technique described in ITU-R M.1842-1, and WRC-19 agreed channels 24, 84, 25, 85, 26, and 86 will use the modulation technique described in Recommendation ITU-R M.2092-0 rather than Recommendation ITU-R M.1842-1..

These may be used as discrete data communications channels, or a number may be combined into a single wide-bandwidth channel.

- From 1 January 2019, the channels 24, 84, 25 and 85 may be merged in order to form a unique duplex channel with a bandwidth of 100 kHz in order to operate the VDES terrestrial component described in the most recent version of Recommendation ITU R M.2092.

All VHF data communication channels are illustrated in the Figure 2.

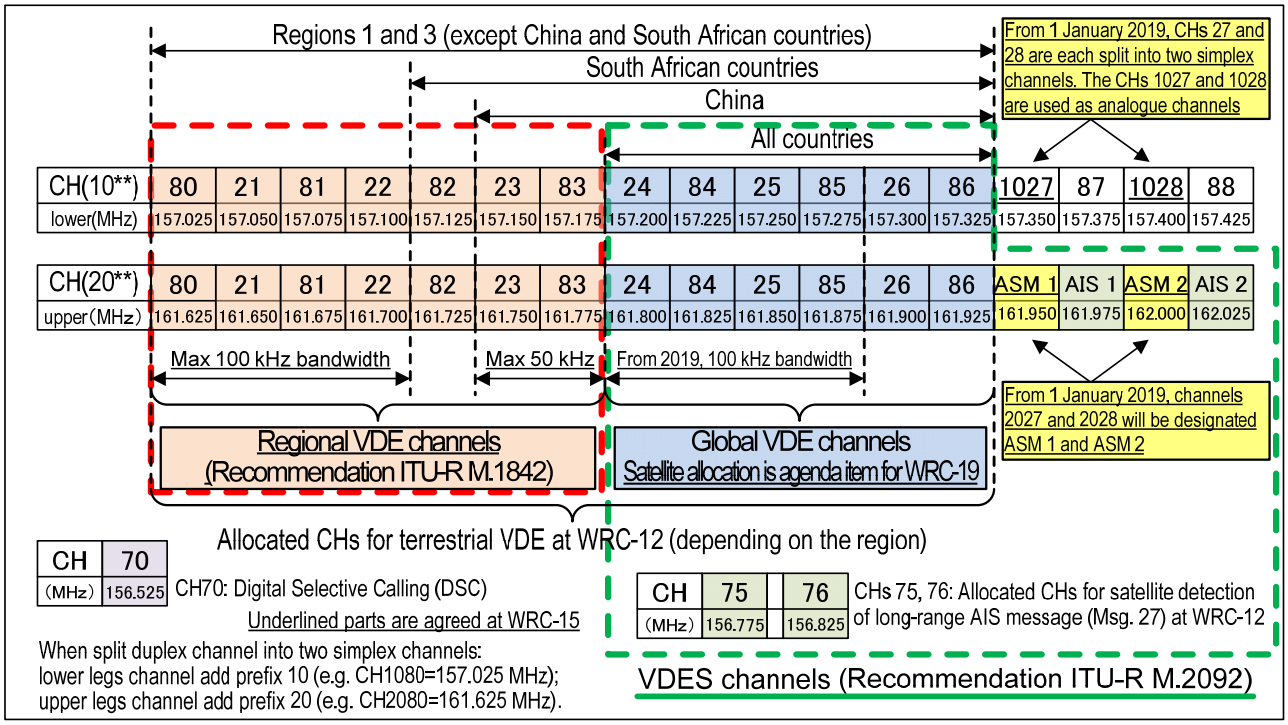

Figure 2 – VHF Data Communications Channel

E7.3 AIS and VDE Channel Plan

– Safety of Navigation purposes

i) The AIS 1 and AIS2 are internationally allocated on a sharing basis. However, WRC-12 allocated these frequencies exclusive to maritime mobile service in both Region 2 effective in 2025 and Region 3 effective in 2013, but not in Region 1 (sharing basis continues).

– Satellite detection of AIS and future GMDSS

i) VHF Channels 75 and 76, dedicated maritime frequencies, have been approved for monitoring from space of Message 27, sharing with low power devices for navigational related communications only.

ii) in the future GMDSS could include AIS technologies. The distress alerting, urgency and safety communications may be by both terrestrial and satellite communications; therefore exclusive maritime mobile service frequencies are needed. The satellite detection of AIS is a one way system (Earth-to-

space) and could be considered as an additional alerting means. Methods of acknowledgement via alternative return links may also be considered but will require RR modifications by future WRC.

– Data communication purposes.

In considering the future AIS system for terrestrial (non-satellite) low volume data communication purposes, an additional two frequencies will be needed. These frequencies have already been selected within the Appendix 18. These are shown in Table 10.

Also, the Appendix 18 covers 156-162.025 MHz; however the current channeling arrangements only apply to limited parts of the band. As shown in the figure below, the blue bands (sharing basis) and red bands (maritime exclusive) are channelized. The yellow bands (sharing basis) are not channelized. The yellow bands are available for maritime mobile as well as terrestrial services and candidate frequencies may be selected on a sharing basis.

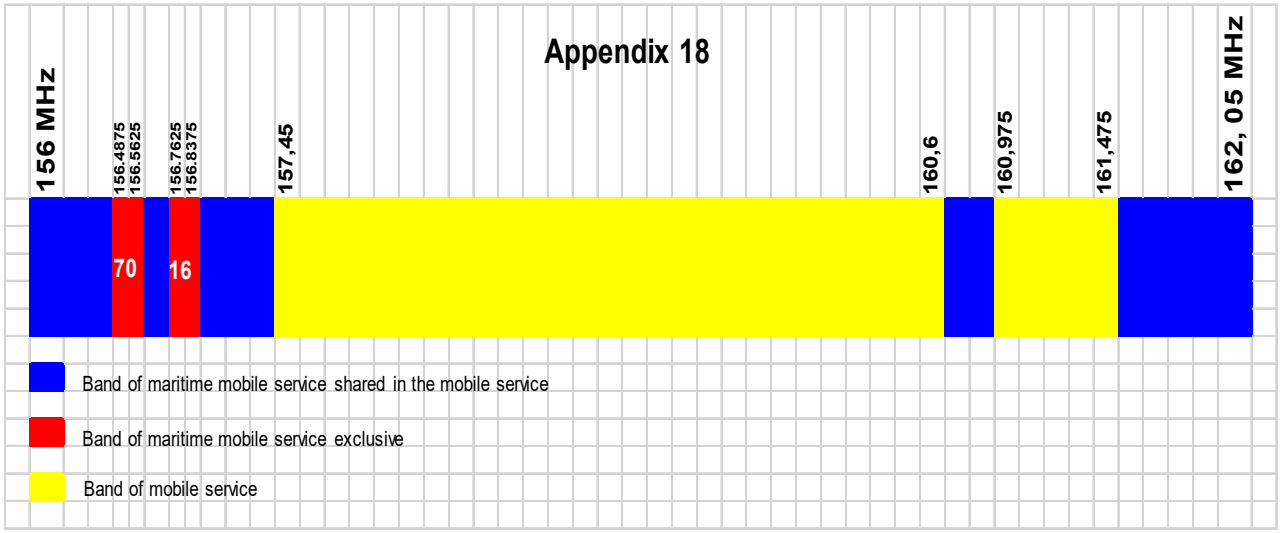

Figure 3 - Appendix 18 to the ITU Radio Regulations

Table 11 - VHF Data Exchange System (VDES)

	VHF Data Exchange System (Recommendation ITU-R M.2092-0)		VHF Data Exchange System (Recommendation ITU-R M.1371-5)	
Sub-group	***Application Specific Message (ASM)***	***VHF Data Exchange (VDE)***	***AIS for safety of navigation***	***AIS long range***
Radio channels	▪ *Channels ASM 1 and ASM 2* ▪ *World-wide dedicated channels (WRC-15 agreed, including Sat uplink)*	▪ *Channels 24,84, 25, 85, 26, 86 (WRC-15 agreed VDE-TER; target VDE-SAT WRC-19)*	▪ *AIS-1 & AIS-2 (simplex)*	▪ *Channels 75 and 76 (simplex)* • *WRC-12*
Functionality	▪ *Marine safety information* ▪ *Marine security information* ▪ *SSRMs* ▪ *General purpose information communication*	▪ *General purpose data exchange* ▪ *Robust high speed data exchange*	▪ *Safety of navigation* ▪ *Maritime and inland distress and safety communications (Subject to inclusion in GMDSS Modernization by IMO)*	▪ *Space detection of AIS* ▪ *Future SAR*
Message types for AIS protocol	▪ *IMO SN.1/ Circ.289 international application specific messages* ▪ *Regional application specific messages* ▪ *Base Station*		▪ *Vessel identification* ▪ *Vessel dynamic data* ▪ *Vessel static data* ▪ *Voyage related data* ▪ *Aids to Navigation* ▪ *Base Station*	▪ *Space detection of AIS* ▪ *Other messages for support of future SAR*
Sub functionality	▪ *Area warnings and advice* ▪ *Meteorological and hydrological data* ▪ *Traffic management* ▪ *Ship-shore data exchange* ▪ *Channel management*	▪ *High message payload*	▪ *Ship to ship collision avoidance* ▪ *VTS* ▪ *Tracking of ships* ▪ *Locating in SAR* ▪ *VDL control (by Base Station)*	▪ *Detection of vessels by coastal states beyond range of coastal AIS base stations* ▪ *Future distress alerting (Subject to inclusion in GMDSS Modernization by IMO)*

'VDES provides a summary of the technical assignment of various VHF channels for communication including protocol and types of messages to meet the functionality required by user needs.

E7.4 VDE, ASM and their Relationship with AIS

To summarize the VDE plan and its relationship with AIS:

- VHF Data Exchange (VDE)
  - The four contiguous channels 25, 85, 26, 86 will be used for data exchange using the modulation technique described in ITU-R M.1842-1 Annex 4:
    - These may be used as separate channels or combined into a single 100 KHz broadband channel.
  - The two contiguous channels 24 and 84 may also be used for data exchange along the coastlines and waterways using the modulation techniques described in ITU-R M.1842-1 Annex 1 or Annex 3.
  - Application Specific Message (ASM)
    - The duplex channels 27 and 28 are each split into two simplex channels from 1 January 2019. The channels 2027 and 2028 designated as ASM 1 and ASM 2 are used for application specific messages (ASM) as described in the most recent version of Recommendation ITU-R M.2092.
- AIS
  - The existing AIS frequencies AIS-1 and AIS-2 (both are simplex channels) will be used exclusively for safety of navigation, primarily position reporting and identification, ship to ship and ship to shore;

- the simplex channels 75 and 76 will be used for satellite detection of AIS using AIS Message 27, long range AIS broadcast message.

E7.5 Legacy Strategy

– Future advances in AIS will require updates to legacy systems.

– Legacy AIS functionality will be maintained.

– AIS channel management, using Channel 70, already available internationally, should be maintained until it is replaced by another internationally agreed method of channel management.

E7.6 Benefits of Future AIS / VDE for the Users

– Dedicated frequencies will provide for greater safety and integrity of data link, providing better protection for the transfer of safety related messages.

– Use of AIS for maritime information dissemination will mean that NAVTEX / NAVDAT could be supplemented and enhanced by VDE

– The possibility will be created to support the future function of AIS in GMDSS, with the benefit of making distressed vessels visible to all resources (land, sea and air) in the vicinity.

– Future shipboard AIS / VDE installations could provide seamless communication means, supporting a modular concept for communication needs in the VHF band, and enabling scalability and inter-operability of communication solutions intended for SOLAS and well as Non-SOLAS vessels while remaining backward compatible with existing AIS equipment.

– Satellite detection of AIS will be facilitated.

– The rapidly increasing use of data transfer for the efficiency of navigation will be facilitated.