TC03-10.7.1

MARITIME RADIO COMMUNICATIONS MANUAL (MARCOM)

10, rue des Gaudines - 78100 Saint Germain en Laye, France
Tel. +33 (0)1 34 51 70 01- contact@iala.int
www.iala.int

International Organization for Marine Aids to Navigation

DOCUMENT HISTORY

Date	Details	Approval
December 2009	1st issue of the Maritime Radio Communications Plan (MRCP)	Council 46
December 2012	Entire document General revision to update terminology Sections 3.4.3 (VHF) and 4 (securing spectrum) Changes to status of e-navigation and maturing communications concepts Outcomes of WRC-12 / preparation for WRC-15	Council 54
December 2017	Entire document General revision to reflect outcomes of WRC-15 / preparation for WRC-19	Council 65
December 2024	Entire document reviewed and revised, evolved from the MRCP to the MarCom Manual	Transition Council 3

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 Introduction

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. In 2024 IALA status changed from a non-governmental organization to an inter-governmental organization (IGO). The focus of IALA is on the harmonisation of standards, the safe and efficient movement of shipping and enhancing the protection of the maritime natural environment.

1.1 IALA strategic Vision

The aim of IALA is to foster the safe, economic and efficient movement of vessels, through improvement and harmonisation of aids to navigation worldwide and other appropriate means, for the benefit of the maritime community and the protection of the environment.

IALA's vision for achieving this is that:

- Marine Aids to Navigation are developed and harmonised through international cooperation and the provision of standards, and that
- All coastal states contribute to a sustainable and efficient global network of Marine Aids to Navigation through capacity building and the sharing of expertise.

1.2 Scope and Objectives

The objective of the Maritime Radio Communications Manual (MARCOM) is to provide an overview of the use of radio communication to support the operational needs of IALA members, with a focus on Marine Aids to Navigation (AtoN) including Vessel Traffic Services (VTS). This includes the need for infrastructure to support communications between ships and shore considering current, developing, and future systems.

2 Background

The digitalisation of the maritime environment depends upon efficient, reliable and robust ship-ship, ship-shore or shore-ship electronic data transfer including terrestrial and satellite systems. Noting the different requirements for communications ship to ship; ship to/from shore and shore to shore, it is important to facilitate and monitor the development of digital communications solutions. Studies provide a basis for analysis of candidate technologies and the opportunity to provide strategic guidance on implementation of various applicable technologies.

2.1 General

The challenge facing radio communication in the maritime sector is the need for greater data bandwidth and lower latency as the communications services migrate from analogue to digital systems. This includes a number of points:

- Spectrum, as a finite resource, is under increasing demand from all users globally and national licensing and regulatory authorities have been to use pricing and cost to drive efficiency improvements.
- Co-operation and coordination between International, Intergovernmental, and other organizations including International Maritime Organisation (IMO), International Telecommunication Union (ITU), International Civil Aviation Organization (ICAO), World Meteorological Organisation (WMO), International Hydrographic Organisation (IHO), IALA, International Standardisation Organisation (ISO), International Electrotechnical Commission (IEC), International Maritime Electronics Alliance (IMEA), Comite International Radio Maritime (CIRM), and Radio Technical Commission for Maritime Services (RTCM) is necessary to ensure an effective approach to maritime communications.
- Co-ordination with ITU is required to secure access to radio spectrum to support maritime communications technology.

IALA national administrations are encouraged to ask their national representatives at ITU to raise awareness of the MARCOM manual.

2.2 Regulatory

Radio spectrum is regulated by the ITU, which includes not only the frequencies but the technologies and standards for the systems employed. The carriage requirement for radio communications equipment on SOLAS convention vessels is identified by the IMO including Automatic Identification System (AIS), Digital Selective Call (DSC), voice communications and radar equipment and communications equipment to support Global Maritime Distress Safety System (GMDSS) and Long-range identification and tracking (LRIT).

IALA has highlighted the requirement to provide an optimum mix of Aids to Navigation for the users, which includes SOLAS convention vessels; domestic commercial vessels; and recreational craft.

IALA Recommendation *R1001 IALA Maritime Buoyage System*. Recommends authorities providing marine aids to navigation comply with the IALA Maritime Buoyage System. It can be found at https://www.iala.int/product/r1001/

This MARCOM manual reflects the requirements for effective and secure communications identified by IMO, in addressing the needs of the maritime industry, including domestic commercial vessels and recreational craft.

2.3 Commercial

Growth of the world fleet requires that both commerce and public correspondence communications systems to cope with the load on AIS exceeding the optimal 50% traffic load in some areas.

Analogue communications can be viewed as a suboptimal means of relaying information. Developments in digital data transfer, including digital voice, can enhance efficiency of spectrum use and provide additional capability to meet increased demands for communications and data transfer. The option of more spectrum in the maritime mobile service is not readily available, so alternatives must be found to support future growth. Existing spectrum allocated to maritime use will need to be fully utilized.

2.4 Operational

Operational aspects include the development and implementation of digital services, the widespread reliance on Global Navigation Satellite Systems (GNSS) and its role in underpinning positioning, navigation and timing and the growing deployment of local and specific traffic monitoring schemes and VTS. This requires that traditional navigation skills are augmented with the understanding of digital data and maritime informatics. Challenges are raised as the role of the human element within technological advances such as Electronic Chart Display Information System (ECDIS) and Integrated Bridge Systems (IBS) are recognised and addressed. Training and competence with the changing technologies are included within the operational aspect.

Before adopting any technology, human factors must be addressed (safety, liability, on-board training and duty of care). Digital service implementation requires the active participation of international bodies such as IMO, ITU, IHO, IALA, ISO, World Association for Waterborne Transport Infrastructure (PIANC), IEC, WMO, RTCM, European Telecommunications Standards Institute (ETSI) and CIRM.

The Maritime Safety Committee, at its ninety-fifth session (3 to 12 June 2015) approved the MSC.1/Circ.1512 Guideline on Software Quality Assurance and Human-Centred Design for e-navigation, as set out in the annex of the Circular.

2.5 Technical

Significant changes underpinning services and systems are expected over the next decade being precipitated by the rapid deployment of satellite systems, the rapid growth of high bandwidth, low latency radio data communication systems and the merging of data and voice services.

Technical developments in digital data exchange and communications environment include the ITU work on:

- International Mobile Telecommunications 2020 (IMT-2020).
- International Mobile Telecommunications IMT-2030 (IMT-2030).
- The development of the VHF Data Exchange System (VDES).
- The development of the digital Navigational Data System (NAVDAT).

- The development of maritime VHF digital voice communications.

3 Developments in Maritime Communications

The maritime domain uses radio communication to support safe navigation, efficient operations, and commercial aspects (commerce and public correspondence). Because many of these technologies have been developed with a single application in mind, vessels need to carry many different types of communications equipment, to be able to receive relevant data.

Developments in the maritime environment, including digital services and Maritime Autonomous Surface Ships (MASS) require an assessment of the communications needs as well as an understanding of the radio spectrum available to the community.

3.1 Maritime Communication Requirements

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

Current and future needs (Figure 1) require the design of the communications architecture to be flexible with the ability grow to encompass other applications and technologies.

Safety		Operational		Commercial
▪ AIS position reports ▪ AIS AtoN ▪ DSC ▪ LRIT ▪ Differential GNSS ▪ Navigational Telex (NAVTEX) /Enhanced Group Calling (EGC) ▪ VTS coordination ▪ Search and Rescue (SAR) ▪ Distress and Urgency alerting/calling		▪ Weather data ▪ Ship reporting ▪ Notifications to coastal States ▪ Port arrival notification ▪ Maritime Information Overlays ▪ Port & VTS surveillance feeds ▪ Electronic chart updates ▪ Access to vessel and equipment manuals ▪ Remote maintenance and service ▪ Telemedical Assistance Service (TMAS)		▪ Voyage orders ▪ Commercial port services ▪ Operational reports ▪ Cargo telemetry ▪ Point of Sale ▪ Crew personal communications ▪ Passenger Internet access ▪ Crew training ▪ Infotainment

Figure 1 Overview of the use cases requiring maritime communication

3.2 General Overview of Existing Communication System Technologies

This section details the technologies used for maritime communications by frequency band. Table 2 – Overview of Communications Technologies presents the overview of communication technologies. Maritime spectrum allocations can be found in the Radio Regulations. This table will continue to evolve as information is used.

The Radio Regulations, Edition of 2024, contains the complete texts of the Radio Regulations adopted by the World Radiocommunication Conference of 1995 (WRC-95) and reviewed by the subsequent WRC until WRC-23. It is posted at https://www.itu.int/hub/publication/r-reg-rr-2024/. The list of ITU recommendations on maritime and technical characteristics can be found at https://www.itu.int/rec/R-REC-M/en .

3.2.1 Low Frequency Band (LF)

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

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

The MF/HF radio spectrum is used by the maritime community for communication of voice and data. MF/HF transmissions support both general, Maritime Safety Information (MSI) and distress related communications using DSC, Narrowband Direct Printing (NBDP) (also known as Radio Telex), voice and data.

These communications take place across the maritime mobile service bands within 0.3-26.5 MHz as defined in Articles 5, 33, 52, Appendix 15 and Appendix 17 to the ITU Radio Regulations. Distress, urgency and safety communications are consigned to a small set of specific channels as indicated in Article 33 and Appendix 15 to the ITU Radio Regulations. Article 52 describes special rules relating to the use of frequencies, including some frequencies arrangements in the MF and HF band. Appendix 17 of RR identifies frequencies and channelling arrangements in the HF bands for the maritime mobile service (MMS). Channel bandwidths are typically 0.5 kHz (DSC and NBDP) and 3 kHz (voice and data).

3.2.2.1 Digital Selective Calling

DSC is an element of the GMDSS and 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 using a unique Maritime Mobile Service Identity (MMSI) (refer to Recommendation ITU-R M.585). 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.

DSC distress alerts 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 DSC distress and safety communications, one in each communication sub-band up to 16 MHz band. There are a number of developments in DSC:

- Automatic connection system (ACS) is an automatic connection function using DSC for shore-to-ship, ship-to-shore or ship-to-ship communication. ACS can judge the most appropriate frequency band for MF/HF communication from which an available working channel is selected.
- WRC-23 approved the introduction of ACS and allocate frequencies 2 174.5 kHz, 4 177.5 kHz, 6 268 kHz, 8 376.5 kHz, 12 520 kHz and 16 695 kHz to it, all of which are withdrawn from NBDP distress communication.
- Operational procedures for both ship and coast stations for automatic connection system using DSC communications in MF and HF bands are detailed in Report ITU-R M.2531.
- Operational procedures for the use of DSC equipment in the maritime mobile service are detailed in recommendation ITU-R M.541.
- DSC system for use in the maritime mobile service are detailed in recommendation ITU-R M.493.

3.2.2.2 Voice Communication

The MF/HF radio spectrum is used by the maritime community for communication of voice in ship-to-ship, shore-to-ship, and ship-to-shore modes of operation. General voice communication takes place across the band 1.6-26.5 MHz using single sideband (SSB). Channel bandwidths are typically 3 kHz. The following ITU Recommendations are referred:

- Recommendation *ITU-R M.1171 Radiotelephony procedures for routine calls in the maritime mobile service* describes the radiotelephony procedures for routine calls within the maritime mobile service.
- Recommendation *ITU-R M.1173 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* provides the technical characteristics for single sideband transmitters used in the MF/HF maritime mobile service bands.

3.2.2.3 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.1798-2, published in February 2021, includes four 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 Quadrature Phase Shift Keying (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 quadrature amplitude modulation (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.

System 4 is a wideband HF data system for Point-To-Point (PTP) communication for shore-to-ship, ship-to-shore, and ship-to-ship for exchanging digital data. The system operates on the HF maritime bands of 4-27.5 MHz in a radio communication channel with a 10 kHz bandwidth, providing data rate up to 51 kbit/s. The system establishes a communication link using Frequency ShiftKeying (FSK) and then exchanges data using OFDM.

3.2.2.4 Narrowband Direct Printing

NBDP uses HF channels of 0.5 kHz using FSK modulation and supports low speed data transmissions (100 bps) in the maritime mobile service bands within 1.6-26.5 MHz. NBDP can be used as the text-based general communications between ship-to-ship, ship-to-shore and shore-to-ship.

NBDP has been removed from SOLAS IV Regulation 10 in January 2024 as part of the modernisation of GMDSS. NBDP is no longer used for distress follow-up communications but can still be used for MSI transmission.

The characteristics of the NBDP equipment are described in Recommendations ITU-R M.476, ITU-R M.625 and ITU-R M.627. Operational procedures for the use of direct-printing telegraph equipment in the maritime mobile service are described in Recommendations ITU-R M.492.

Technical characteristics for a HF NBDP system for promulgation of high seas maritime safety information are described in Recommendation *ITU-R M.688 Technical characteristics for a high frequency direct-printing telegraph system for promulgation of high seas and NAVTEX-type maritime safety information*.

3.2.2.5 Navigational Telex

NAVTEX is an international automated system for distributing MSI such as maritime navigational warnings, weather forecasts and warnings, and SAR related information from shore to ship by means of narrow-band direct-printing telegraphy.

A NAVTEX receiver is installed on the ship's bridge. NAVTEX messages are broadcast in English on the international frequency 518 kHz, with national broadcasts on frequency 490 kHz and 4209.5 kHz in the local language. The messages are coded with the transmitting stations, type of messages, and the serial number of the message. The time of broadcasts are internationally co-ordinated by Navigation Area (NAVAREA) & Meteorological Area (METAREA) Coordinators.

Operational and technical characteristics for MF NAVTEX are described in Recommendation *ITU-R M.540 Operational and technical characteristics for an automated direct-printing telegraph system for promulgation of navigational and meteorological warnings and urgent information to ships*. Technical characteristics for HF NAVTEX are described in Recommendation ITU-R M.688.

3.2.2.6 Navigational Data (NAVDAT)

NAVDAT is an MF and HF radio system, for broadcast and automatic reception of MSI and SAR related information from shore-to-ship by means of digital modulation. Channel bandwidths can be 1, 3, 5, or 10kHz.WRC-12 approved the worldwide exclusive usage of the frequency band 495 - 505 kHz for the maritime mobile service. The NAVDAT system uses an OFDM modulation in this 10 kHz bandwidth which provides a flow rate of up to 30 kbits/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; and
- possibility to use Single Frequency Network (SFN) technology, with no need for time slot allocation on the same frequency.

WRC-19 added a footnote to the 495-505 kHz frequency band in the frequency allocation table of Article 5 of RR and specified its use as NAVDAT. In addition, NAVDAT was added to the footnote at 415-495 kHz and 505-526.5 kHz in addition to radiotelegraphy (NAVTEX).

WRC-19 also lists the NAVDAT frequency bands in the Maritime HF Band Frequency Table in RR Appendix 17.

WRC-23 lists the detailed NAVDAT frequencies in Articles 5 and 33 and Appendix 15 of RR. *Resolution 364 (WRC-23) Coordination of services provided by the NAVDAT system* has been published.

The MF NAVDAT system is described in the Recommendation *ITU-R M.2010 Characteristics of a digital system, referred to as Navigational Data for broadcasting maritime safety and security related information from shore-to-ship in the 500 kHz band*.

The HF NAVDAT system is described in the Recommendation *ITU-R M.2058 Characteristics of a digital system, referred to as navigational data for broadcasting maritime safety and security related information from shore-to-ship in the maritime HF frequency band*.

3.2.2.7 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. IALA maintains a list of active stations.

IALA Differential GNSS list of active stations can be consult at https://www.iala.int/technical/positioning-navigation-and-timing/world-dgnss-stations-list/

3.2.3 Very High Frequency Band

Voice communication uses the maritime VHF band (156.025-162.025 MHz) as the primary means of ship-to-shore, shore-to-ship, and ship-to-ship communication system. It is used for distress, urgency and safety information and general communications. Maritime VHF channel arrangement is detailed in Appendix 18 of the RR. Channel spacing is currently 25 kHz although the use of 12.5 kHz channels on an interleaved basis is allowed as described in accordance with Recommendation *ITU-R M.1084 Interim solutions for improved efficiency in the use of the band 156-174 MHz by stations in the maritime mobile service* to improve spectrum efficiency.

Digital Selective Calling (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, urgency and safety calling including general communications using channel 70 (156.525 MHz). DSC is an element of the GMDSS. Additionally, DSC may be used for AIS channel management in specific geographic areas by VTS. DSC distress alerts, which consist of a preformatted distress message, are used to initiate emergency communications with ships and Rescue Coordination Centres (RCCs).

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 are assigned a unique 9-digit MMSI (Referred in Recommendation *ITU-R M.585 Assignment and use of identities in the maritime mobile service*).

3.2.3.1 Voice Communication

Voice communication in VHF is currently analogue and uses the maritime mobile band (156.025 to 162.025 MHz). It is used for distress, urgency, safety and general communications. Hand-held units are generally utilized for on-board communications. Channel 06 (156.3MHz) may be used for communication between ship stations and aircraft stations engaged in coordinated search and rescue operations. It may also be used by aircraft stations to communicate with ship stations for other safety purposes. Channel 13 (156.650 MHz) is used for ship-to-ship communications relating to the safety of navigation. Channel 16 (156.8 MHz) is used for distress and safety communications by radiotelephony.

Additionally, the frequency 156.8 MHz may be used by aircraft stations for safety purposes only. Aircraft stations use aeronautical frequencies 121.5 MHz and 123.1 MHz to communicate with ship stations for on-scene SAR communications.

The use of other channels is designated in Appendix 18 to the ITU RR.

Report *ITU-R M.2530 Digital voice communication in the VHF maritime frequency band* gives the requirements for voice and digital communication in the VHF band and describes possible ways to address coexistence with existing analogue and digital voice channels. The report investigates an approach for the possible expansion of the number of VHF maritime voice channels based on the implementation of digital technology.

3.2.3.2 121.5 MHz Locating Beacon

The frequency 121.5 MHz is an emergency frequency used for the locating function of GMDSS. 121.5 MHz radio beacons were developed in the mid-seventies for installation on aircraft, as Emergency Locator Transmitters (ELTs). However, they can also be used on board ship as part of Emergency Position-Indicating Radio Beacons (EPIRBs) or in Personal Locator Beacons (PLBs). 121.5 MHz is no longer used for ELTs or EPIRBs.

3.2.3.3 VHF Data Exchange System

ITU introduced a standard with options for 25 kHz, 50 kHz, and 100 kHz channels at an on air (not throughput) data rates up to 307.2 kbps to improve spectrum efficiency in 2012. 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. ITU Recommendation *ITU-R M.2092 Technical characteristics for a VHF data exchange system in the VHF maritime mobile band* provides the technical characteristics of ASM and VDE. ITU Recommendation *ITU-R M.1371 Technical characteristics for an automatic identification system using time division multiple access in the VHF maritime mobile frequency band* provides the technical characteristics of AIS.

Development of the VDES, the concepts of VDES, the role within the e-Navigation concept of IMO and the potential of VDES in the maritime environment and the use cases supported by VDES are described in IALA Guideline *G1117 VHF Data Exchange System (VDES) Overview*.

The ASM uses π/4 Quadrature Phase Shift Keying (π/4-QPSK) modulation and the VDE uses a range of different modulation methods dependent on the Radio Frequency environment. VDES has both a bi-directional Terrestrial and a Satellite component. A VDES transceiver can communicate with AIS, ASM and VDE Terrestrial and Satellite systems.

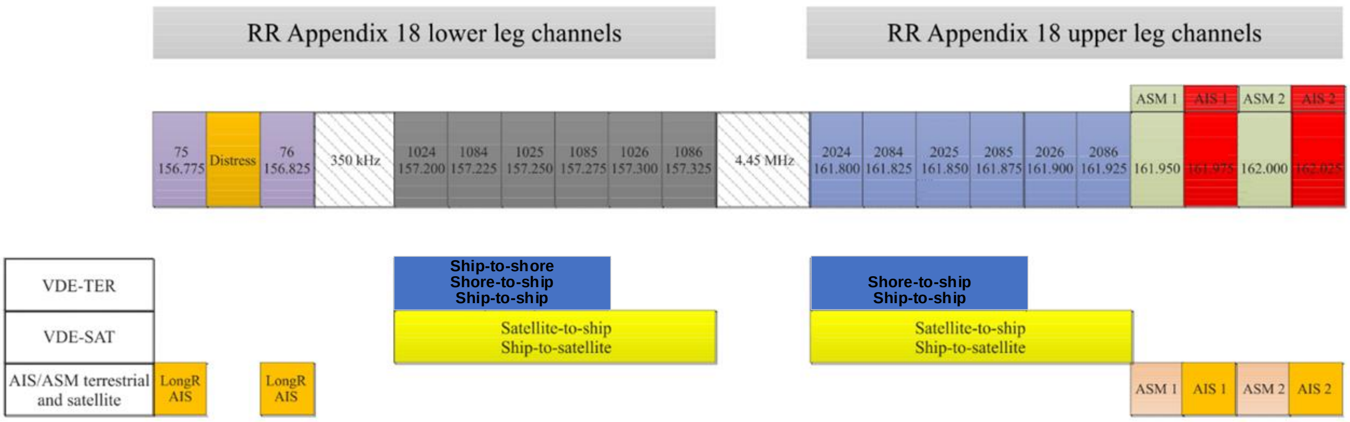

Figure 2 Overview of VDES Frequencies

IALA Guideline *G1117 VHF Data Exchange System (VDES) Overview* provides insights into the VDES. It gives information about the development of the VDES, the concepts of VDES, the role within the e-Navigation concept of IMO and the potential of VDES in the maritime environment and the use cases supported by VDES. It can be found at https://www.iala.int/product/g1117/

The Recommendation *ITU-R M.2092 Technical characteristics for a VHF data exchange system in the VHF maritime mobile band* provides the technical characteristics of VDES which integrates the functions of VDE comprising both terrestrial and satellite components, ASM and the AIS operating in the frequency bands listed in Appendix 18 of the RR.

VDES consists of four components: AIS + ASM + VDE-TER + VDE-SAT

- AIS uses channels AIS 1, AIS 2, 75 and 76, for terrestrial communications (AIS 1 and AIS 2) and satellite uplinks (AIS 1, AIS 2, 75 and 76);
- ASM uses channels ASM 1 and ASM 2, for both terrestrial communications and satellite uplinks;
- VDE-TER uses channels 24, 84, 25, 85, 1024, 1084, 1025, 1085, 2024, 2084, 2025 and 2085 for terrestrial communications; and
- VDE-SAT uses channels 1024, 1084, 1025, 1085,1026, 1086, 2024, 2084, 2025, 2085, 2026 and 2086, for both satellite uplink and downlink communications.

Table 1 – VHF Data Exchange System Overview (VDES)

	VHF Data Exchange System (Recommendation ITU-R M.2092-1)		VHF Data Exchange System (AIS elements) (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; 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	▪ Space detection of AIS ▪
Message types	▪ 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
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

3.2.3.3.1 VDES - AIS

AIS is a Self-Organised Time Division Multiple Access (SOTDMA) data exchange system used by ships and shore authorities to improve the safety of navigation by assisting in the efficient navigation of ships, protection of the environment, and operation of VTS. AIS data includes identification, position, course, and speed. AIS assists VTS and the vessel's watch keeping officers and allow maritime authorities to track and monitor vessel movements. The AIS technical specification is Recommendation ITU-R M.1371.

AIS uses VHF Channels AIS 1 (161.975 MHz) and AIS 2 (162.025 MHz), 75 (156.775MHz) and 76 (156.825MHz). Channels 75 and 76 are designated for long-range AIS. 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.

There are various types of AIS and used for different purposes and include:

- AIS base stations
- AIS repeaters
- AIS AtoN types 1, 2 and 3
- Class A AIS used on SOLAS vessels
- Class B Carrier Sense
- Class B SOTDMA
- AIS SART (see section 3.2.3.5)

Guidance on the use of AIS ASMs is provided in IMO SN.1/Circ. 289, and guidance for the presentation and display of AIS ASM information is provided in IMO SN.1/Circ. 290. Regionally, ASMs are managed by IALA, through the IALA e-Navigation Portal[1]

3.2.3.3.2 VDES - Application Specific Messages

ASM channels of VDES are the channels ASM1(161.950MHz, 2027) and ASM2(162.000MHz, 2028), which are available for satellite uplink [refer to figure 2] as well as terrestrial use.

3.2.3.3.3 VDES - VHF Data Exchange

These are the channels provided for VDE.

- Channels 1024-1085 are used for ship-to-shore shore to ship and ship to ship communication, also used for satellite to ship and ship to satellite communication on a global basis.
- Channels 2024-2085 are identified for shore-to-ship and ship-to-ship global communication, also used for satellite to ship and ship to satellite communication.
- Channels 1026-1086 are available for satellite to ship and ship to satellite communication.
- Channels 2026-2086 are identified for satellite to ship and ship to satellite communication.

3.2.3.4 Man Overboard Device

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. Autonomous Maritime Radio Devices (AMRD) Group A MOB device operates on VHF channel 70 for alerting using VHF DSC and on automatic identification system frequencies (AIS1 and AIS2) for tracking. The devices are fitted with a VHF DSC and an AIS transmitter. MOB devices should operate in accordance with Recommendations ITU-R M.493, ITU-R M.541, ITU-R M.1371 and ITU-R M.2135.

3.2.3.5 AIS SART

AIS SART is a locating device (alternative to radar SART). As an element of the 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. The AIS SART station should transmit AIS Message 1 and Message 14 using the burst transmissions according to Recommendation ITU-R M.1371.

3.2.3.6 Autonomous Maritime Radio Devices

WRC-19 agreed introduction of AMRD Group A, which enhance the safety of navigation, and Group B, which do not enhance the safety of navigation.

[1] http://www.iala.int/asm/

A modification was developed to a footnote in Appendix 18 to allow the use of AMRD Group A on channel 70 and AIS 1 and AIS 2 using DSC and/or AIS technology. A new footnote designates 160.9 MHz (channel 2006) to AMRD Group B using AIS technology. The Recommendation ITU-R M.2135-1 Guidelines for evaluation of radio interface technologies for IMT-Advanced is referred to AMRD.

3.2.3.7 Two-way VHF Radiotelephone Apparatus

Two-way VHF radiotelephone apparatus is defined in SOLAS Chapter IV Regulation 7. 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 Channel 16 (156.8 MHz) and at least one other simplex channel.

3.2.3.8 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.

3.2.3.9 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. Satellite to ship communications in the maritime VHF band is under development (refer to Section 3.2.3). Services are available for SMS, weather, and tracking, and these can be used for maritime purposes.

3.2.4 Ultra-High Frequency Band (UHF) and Super High Frequency Band (SHF)

3.2.4.1 Emergency Position Indicating Radio Beacon

Emergency radio beacons transmit a distress signal on 406MHz and a homing signal on 121.5MHz which aid in the detection and location of ships in distress. The radio beacons are part of the COSPAS/SARSAT[2] system, an international satellite system used for SAR. When activated, the beacon transmits a distress alert signal that, can be detected by Geostationary Orbit (GEO), Low-Earth Orbit (LEO) and Medium Earth Orbit (MEO) satellites.

The distress alerts received by the satellite system are forwarded to a Mission Control Centre (MCC) for onward coordination by an appropriate SAR organization. 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 assets, modulated with a swept audio tone and may also have an incorporated AIS SART based transmitter (EPIRB AIS).

Some EPIRBs may be provided with the Return Link Service capability to give EPRIB user a confirmation that the distress alert message has been received. Documents about COSPAS/SARSAT system and EPIRB can be found at https://www.cospas-sarsat.int/en/documents-pro/system-documents/system-documents.

3.2.4.2 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.

Recommendation *ITU-R M.1174 Technical characteristics of equipment used for on-board vessel communications in the bands between 450 and 470 MHz* describes the technical characteristics for equipment operating in the maritime mobile services in accordance with the provisions of No. 5.287 of the RR for on-board vessel communications. Provision is made for 25 kHz or 12.5 kHz channel spacing for analogue and digital technologies. In addition, 6.25 kHz channel spacing may also be used for digital technology.

[2] COSPAS is an acronym for the Russian words "Cosmicheskaya Sistema Poiska Avariynyh Sudov" and SARSAT is an acronym for Search And Rescue Satellite-Aided Tracking

3.2.4.3 Satellite Voice and Data Communication

Satellite communications in the UHF band is commonly deployed on vessels to fulfil several distress, safety and general communications purposes:

- Satellite communication links can support 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. Non-geostationary systems are often in LEO or MEO.
- Inmarsat[3] ,Iridium and BDMSS[4] are elements of the GMDSS for distress alerting, urgency, and safety communication.
- Other Geostationary systems include Thuraya.
- Non-geostationary satellite systems include Globalstar, SpaceX, OneWeb and Orbcomm.

3.2.4.4 Enhanced Group Call (EGC)

Enhanced Group Calling (EGC) allows messages to be broadcast to ship stations located in a circular area, a rectangular area, a coastal warning area or a NAVAREA/METAREA within satellite coverage. The EGC service is part of the GMDSS for the transmission of MSI and SAR related information for areas where there is no coverage by NAVTEX. The messages broadcast includes Navigational Warnings, Meteorological forecasts and warnings and SAR related information. The information broadcast over NAVTEX and EGC are not mutually exclusive.

3.2.4.5 Long Range Identification and Tracking

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.

3.2.4.6 Global Navigation Satellite System

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.

The accuracy of the GNSS systems is augmented by a variety of systems including terrestrial (DGNSS among others) and satellite services (Satellite Based Augmentation Systems (SBAS) among others). GNSS features are supported by IMT2020 and expected to be supported by IMT2030 and beyond technologies.

3.2.4.7 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 SART both create identifiable patterns when interrogated by vessel radars. Racons are used to highlight the location of a visual 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.

[3] Inmarsat B, C, Fleet 77 and Fleet Safety are elements of GMDSS. Inmarsat C is currently in operation. Fleet Safety is expected to provide GMDSS service in mid-2025.

[4] See paragraph 13.24 of MSC 106/19 "Report Of The Maritime Safety Committee On Its 106Th Session"

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

3.2.4.8 International Mobile Telecommunications-2020

The IMT 2020 (5G) enables voice, data, and Internet of Things (IoT) communications to be provided in areas where the previous IMT systems such as IMT-Advanced, long term evolution (LTE) are unable to provide the required communication coverage. The IMT-Advanced (LTE) system whose communication coverage is generally limited in range, is mainly deployed in the littoral state, port, or harbour environment. On the other hand, the IMT-2020 system supports diverse deployment scenarios to be implementable in maritime domain by providing more enhanced communication coverage at sea and indoor in a vessel etc. because of new features such as the satellite component which is one of the 5G New Radio (NR) access technologies, and the 5G Standalone Non-Public Network (5G SNPN) (also called as 5G private network or 5G local network on market) which provides the 5G mobile communication services with the data rate exceeding 1 Gbps under ideal circumstances in a dedicated zone such as outdoor at a harbour or indoor of a large ship such as a cargo ship.

The 5G SNPN being established within various ports are being used for both the delivery of maritime focused services (e.g. connecting Closed-circuit television (CCTV) and high-speed data links to shore and providing data connections to ships in the coverage area) and the provision of services to users who have the authorization of accessing the 5G SNPN within the port environment.

Some IMT 2020 network and service providers can offer GNSS independent positioning services within the port and port approach environments dependent on the coverage of the IMT 2020 systems.

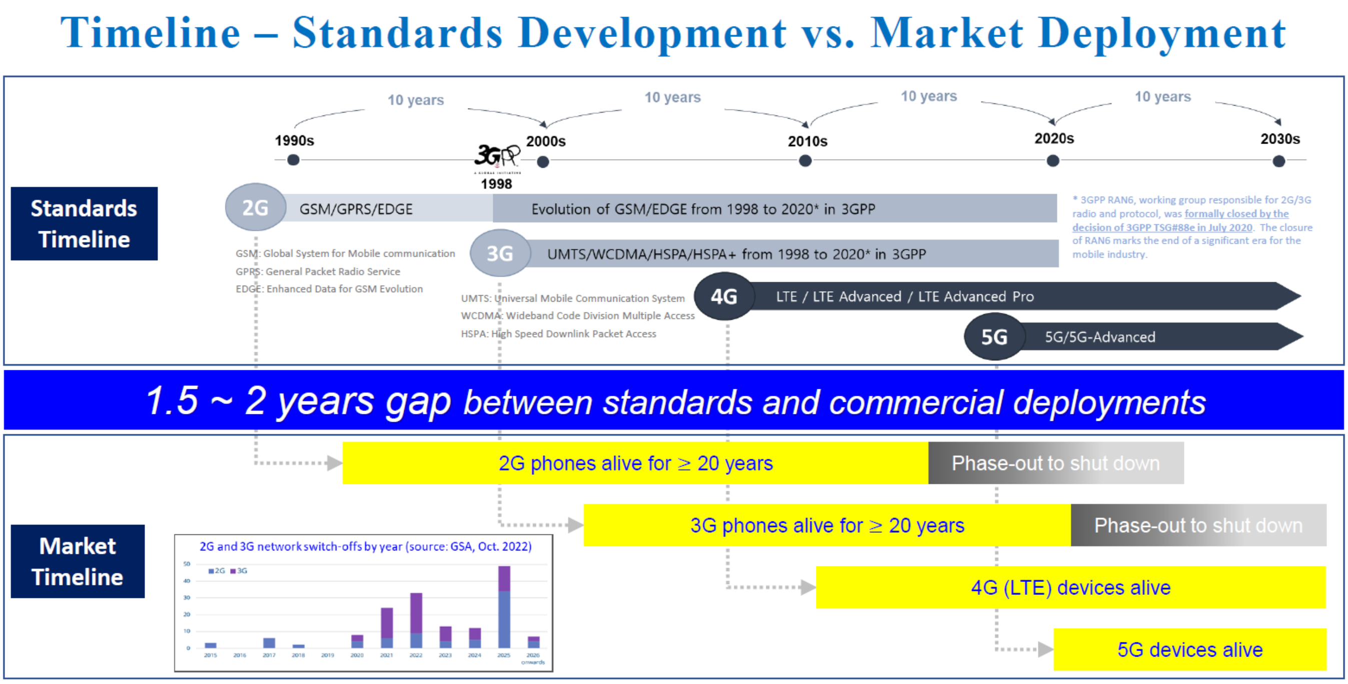

Figure 3 Timeline – Standards Development vs Market Deployment

3.2.4.9 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 Wi-Fi, WiMax, and short-range devices like ZigBee and Bluetooth links. These offer the possibility of high-speed data transfer.

3.2.4.10 GNSS augmentation systems

GNSS augmentation systems are designed to supplement and enhance the accuracy, integrity, and availability of GNSS. Through a network of fixed ground-based reference stations that measure the variation of satellite signals and then send correction messages via ground based differential radio beacons (i.e., DGPS) or space-based services (i.e. SBAS) which augmentation- enabled GNSS receivers can use to improve its position computation.

3.3 Future Development

This section details future technologies or existing technologies not widely used for maritime radio communications or positioning by frequency band.

3.3.1 Low Frequency Band (LF)

3.3.1.1 Enhanced Long Range Navigation (eLORAN)

The enhanced Loran (eLoran) system is a 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.

3.3.2 Medium Frequency / High Frequency Band

WRC-31 preliminary agenda item 2.8 is to consider improving the use and channelization of maritime radiocommunication in the MF and HF bands, including potential revisions of Article 52 and Appendix 17, in accordance with *Resolution 366 (WRC-23) Improving the utilization and channelization of maritime radiocommunication in the MF and HF bands, including potential revisions to Article 52 and Appendix 17*.

Resolution 366 (WRC-23) invites ITU-R to complete in time for WRC-31 studies on possible revisions to the Article 52 and Appendix 17 channel plans to identify additional working channels on an international basis to improve the use of maritime radiocommunication in the MF and HF bands.

Resolution 366 (WRC-23) invites WRC-31 to consider, based on the results of studies, possible revisions to the Article 52 and Appendix 17 channel plans in the maritime mobile MF and HF bands to improve use and efficiency.

3.3.2.1 Digital Data Communication Using MF/HF Band

The likely increase in ship traffic in Polar regions, because 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.1798-2. Appendix 17 to the RR was revised at the WRC-12. The revision of Appendix 17 implements new digital bands for 3 kHz systems as well as wideband systems. WRC-19 has also approved use of band 495-505 kHz, 4221-4231 kHz, 6332.5-6342.5 kHz, 8438-8448 kHz, 12658.5-12668.5 kHz, 16904.5-16914.5 kHz and 22445.5-22455.5 kHz for use of high-speed NAVDAT.

WRC-23 lists the detailed NAVDAT frequencies in Articles 5 and 33 and Appendix 15 of RR. And Resolution 364 (WRC-23) Coordination of services provided by the NAVDAT system has been published. Draft performance standard for NAVDAT is pending adoption at IMO MSC 109. Draft NAVDAT manual is in preparation.

3.3.3 Very High Frequency Band

3.3.3.1 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.

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; and
- 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; and
- 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.

WRC-19 VHF Data Results:

- WRC-19 made new secondary allocations in the bands 157.1875-157.3375 MHz and 161.7875-161.9375 MHz for the maritime mobile-satellite service in the uplink/downlink and amended the channelling arrangement for VHF maritime frequencies contained in ITU RR Appendix 18;
- the frequency bands 157.1875 157.3375 MHz and 161.7875-161.9375 MHz (corresponding to channels: 24, 84, 25, 85, 26, 86, 1024, 1084, 1025, 1085, 1026, 1086, 2024, 2084, 2025, 2085, 2026 and 2086) are identified for the utilization of the VHF Data Exchange System (VDES). The VDES terrestrial and satellite components are described in the most recent version of Recommendation ITU R M.2092. These channels shall not be used for feeder links. The channels may be merged using multiple 25 kHz contiguous channels to form channel bandwidths of 50, 100 or 150 kHz;
- the channels 1024, 1084, 1025 and 1085 are identified for ship-to-shore, shore-to-ship and ship-to-ship communications, but ship-to-satellite and satellite-to-ship communications may be possible without imposing constraints on ship-to-shore, shore-to-ship and ship-to-ship communications;
- the channels 2024, 2084, 2025 and 2085 are identified for shore-to-ship and ship-to-ship communications, but ship-to-satellite and satellite-to-ship communications may be possible without imposing constraints on shore-to-ship and ship-to-ship communications;

- the channels 1026, 1086, 2026 and 2086 are identified for ship-to-satellite and satellite-to-ship communications and are not used by the terrestrial component of VDES; and
- the channels 24, 84, 25 and 85 are identified for ship-to-shore and shore-to-ship communications.

IMO NCSR is considering amending SOLAS chapter V to incorporate VDES. Guidelines for the operational use of VDES and draft VDES performance standard are being development in IMO NCSR. IEC is drafting test standard for VDES.

3.3.3.2 IMT-2020 based IoT communication

There are many wireless technologies that enable IoT (e.g., sensors, machines, smart buoys, robots, etc.) to be connected to the internet, and the communication coverage for IoT communication depends on the extent of the mobility supported from those technologies. IMT-2020 based technologies supporting IoT communication can support much wider communication coverage, and the global interoperability compared to other technologies (e.g., ZigBee, Bluetooth, WiFi, LoRa).

Following technologies standardized in 3GPP are the example of IMT-2020 based technologies dedicated for the support of IoT communication applicable to the usage related to AtoN on board ship or between ships and shore or at sea.

- LTE-Machine Type Communication (LTE-M) technology that allows the reuse of an LTE base station with extended coverage and offers a data rate of 1Mbps for Release 13, up to 4Mbps for Release 14.
- Narrowband IoT (NB-IoT) technology with a single narrowband of 200 kHz over LTE or 5G New Radio (NR) systems that is especially suitable for indoor coverage (e.g. inside a big ship) and enables a wide range of IoT devices and services with the improvement of the power consumption of IoT devices (e.g., supporting more than 10 year battery life) as well as with 26 kbps for Release 13 and 127 kbps for Release 14.
- Massive IoT (also known as massive Machine-Type Communications (mMTC)) technologies based on further enhancements of NB-IoT and LTE-M technologies over 5G system (3GPP Release 15 onwards) that enable massive number of low-complexity and low-cost devices with long battery life and low throughput to be connected for the exchange of the information.
- Industrial IoT (IIoT) technologies over 5G NR system for supporting diverse industrial requirements including industry 4.0 and industrial automation from Release 16 onwards.
- NB-IoT technology over 5G satellite access that enables the communication for IoT devices to be provided via 5G satellite access integrated to 5G system from Release 17 onwards.

3.3.3.3 IoT dedicated communication

A number of Internet of Things (IoT) communication systems are available for use with AtoN and on board ship and for ship to shore and shore to ship depending on application.

IALA Guideline *G1179 An introduction to the Internet of Things (IoT) from an IALA Perspective*. It provides guidance those who may be undertaking testing, trials and/or deployment of IoT systems in the scope of IALA. This Guideline also provides guidance for organizations implementing technical solutions to support the introduction of IoT. The Guideline can be found at https://www.iala.int/product/g1179/

3.3.3.4 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.

WRC-31 preliminary agenda item 2.7 is to consider improving the utilization of VHF maritime radiocommunication, in accordance with Resolution 363 (Rev.WRC-23) *Improving the utilization of the VHF maritime mobile band*.

Resolution 363 (Rev.WRC-23) invites ITU Radiocommunication Sector to complete in time for WRC-31 studies on sharing and compatibility with incumbent services that are allocated on a primary basis in the same and adjacent frequency bands and studies on spectrum needs, transitional arrangements and possible changes to the VHF maritime mobile band, in order to advance digital voice and data technologies in the MMS.

Resolution 363 (Rev.WRC-23) invites WRC-31 to consider, based on the results of studies, and within the Radio Regulations, excluding new allocations under Article 5, possible regulatory changes to advance digital voice and data technologies in the MMS within the VHF maritime mobile band.

3.3.3.5 R-Mode

Ranging mode (R-Mode) is a terrestrial positioning system which is under development. It uses the frequency bands of the existing maritime radio infrastructure for the provision of timing signals that enables GNSS-independent position and time estimation. At present, the MF band of the IALA radio beacon system and the VHF bands utilized for AIS, ASM and VDE-TER of the VDES are being used in R-Mode testbeds in Europe, Asia and North America.

IALA Guideline *G1158 VDES R-Mode*. It provides guidance for authorities to setup VDES R-Mode and developers to design a VDES R-Mode receiver or transmitter. The Guideline can be found at https://www.iala.int/product/g1158/

WRC-31 preliminary agenda item 2.7 is to consider improving the utilization of VHF maritime radiocommunication, in accordance with Resolution 363 (Rev.WRC-23).

Resolution 363 (Rev.WRC-23) invites ITU Radiocommunication Sector to complete in time for WRC-31 compatibility studies, limited to frequencies identified in Appendix 18 for VDES, for a new allocation of the maritime radio navigation service under Article 5 and within the existing MMS to implement R-Mode.

Resolution 363 (Rev.WRC-23) invites WRC-31 to consider, based on the results of studies, possible revisions to the Radio Regulations, including new allocations under Article 5, limited to frequencies identified in Appendix 18 for VDES, for implementation of R-Mode as a new maritime radionavigation service.

3.3.4 Ultra High Frequency Band / Super High Frequency Band

3.3.4.1 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, Russian Global NAvigation Satellite System (GLONASS) and BeiDou Navigation Satellite System (BDS)).

Resolution 365 (WRC-23) may affect maritime spectrum use. It concerns provisional application of the Radio Regulations for the introduction of new geostationary satellite networks into the global maritime distress and safety system.

The frequency band 1 645.5-1 646.5 MHz was once used for EPIRB. However, the 1.6 GHz EPIRB service has been withdrawn from GMDSS by the IMO and this band has remained unused for many years[5]. Consequentially at WRC-23, limit of this band use to EPIRB was removed from the RR Appendix 15, but the band was retained for GMDSS. Furthermore WRC-23 adopted Resolution 252 (WRC-23), which may affect future use of this band. See more information in section 4.2.

3.3.4.2 Public Mobile Wireless Communications

Public mobile wireless communications (public correspondence) such as IMT-2020 technologies are being used by mariners and ports / port authorities in coastal waters and could be further developed to support evolving maritime communication needs. In addition, 5G coverage is expanding and several satellite service providers have announced that they are working to deploy satellite based 5G services that would be available to the maritime sector.

[5] See MSC 80/24(paragraph 13.7), MSC/Circ.1171 and MSC.201(81).

3.3.4.3 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.

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

Radio communication technologies are characterized by performance parameters that include range, bandwidth, latency, and the need for infrastructure. Available Data Rate means available at maximum and in good conditions to a single user of the system. Depending on the system, Latency could either mean round trip delay or single trip delay.

Table 2 – Overview of Communications Technologies

Note – this table will be under continual review and updated as more information becomes available

Communication Technology	On air data rate	Frequencies	Latency	Available data rate	Primary constraints	Infrastructure	Coverage	Transmission	Maritime / public	Notes
NAVDAT	Up to 30 kbps	Can operate in both MF (500kHz) and HF (6 bands from 4.226kHz to 22.455,5kHz)	0.4 sec	Up to 18 kbps	To increase amount of data, another form of modulation is used (4-QAM ,16-QAM and 64-QAM), which means the transmitter output power needs to be larger to obtain the same coverage (compared to NAVTEX). Existing NAVTEX Receivers (vessels) will have to be replaced or supplemented.	Based on NAVTEX infrastructure	250/300 NM for MF NAVDAT. Global coverage for HF NAVDAT	Broadcast Terrestrial	Maritime	
NAVTEX	100bps	490kHz, 518kHz and 4209.5kHz	To be provided	50bps	To be provided	Shore to ship, coast NAVTEX station	To be provided	Broadcast Terrestrial	Maritime	
AIS	9.6 kbps	AIS 1 (161.975 MHz), AIS 2 (162.025 MHz), 75(156.775MHz) and 76(156.825MHz)	4 sec	100bps	No available capacity for ASM transmission in congested areas	Ship-ship: direct, ship-shore/shore-ship via Base stations, Ship-satellite (receive only)	15 NM – 65 NM, global reception via satellite	Addressed / Broadcast	Maritime	

Communication Technology	On air data rate	Frequencies	Latency	Available data rate	Primary constraints	Infrastructure	Coverage	Transmission	Maritime / public	Notes
VDES VDE - Terrestrial	up to 307 kbps	Channels 1024-1085; Channels 2024-2085 See figure 2.	4 sec	48 kbps	Coexists with prioritized AIS reception and VDE-ASM transmissions. VDE-terrestrial coexists with VDE-satellite.	Ship-ship: no shore based infrastructure required Shore-ship: Base stations Sat-ship: Satellite	Terrestrial: 15 NM-65 NM	Addressed / Broadcast	Maritime	
VDES VDE - Satellite		Channels 1024-1086 Channels 2024-2086 See figure 2.	20 sec	0.8 to 16 kbps			Satellite component provides further coverage	Terrestrial / Satellite		
VDE-ASM	19.2 kbps	Channels ASM1 and ASM2. See figure 2.	4 sec	19 kbps	ASM coexists with AIS. ASM offers transmission with and without forward error correction.	Shore-ship: Base stations Ship-to-sat: Satellite (reception only)	Approx. 15 NM-65 NM	Addressed / Broadcast	Maritime	
							Satellite component provides further coverage	Terrestrial / Satellite		
Wi-Fi 5 (IEEE 802.11ac)	866 - 1730 Mbps (theoretical max)	2.4/5 MHz	To be provided	~1 Gbps	Congested frequency bands	Routers / Access points	50m Up to several km with directional antennas	Addressed	Public	2.4/5 MHz
Wi-Fi 6 (IEEE 802.11ax)	2400 Mbps (theoretical max)	5 MHz	To be provided	~1.5 Gbps				Addressed	Public	5 MHz
Wi-Fi 6E (IEEE 802.11ax)	5400 Mbps (theoretical max)	5/6 MHz	To be provided	~2.5 Gbps	Not available worldwide (yet)			Addressed	Public	5/6 MHz
WiMax	*75 Mbps*					*Routers / Access points*	*2-5 km*	*Addressed*	*Public*	*Not used anymore*
Analog VHF Voice	Not Applicable	---	Not Applicable	Not Applicable	To be provided	To be provided	To be provided	To be provided	To be provided	

Communication Technology	On air data rate	Frequencies	Latency	Available data rate	Primary constraints	Infrastructure	Coverage	Transmission	Maritime / public	Notes
Analog MF Voice	Not Applicable	---	Not Applicable	Not Applicable	To be provided	To be provided	To be provided	To be provided	To be provided	
Analog HF Voice	Not Applicable	---	Not Applicable	Not Applicable	To be provided	To be provided	To be provided	To be provided	To be provided	
Digital VHF Voice	4.8 kbps in 6,25 kHz	To be provided	To be provided	2.4 kbps in 6.25 kHz with FEC	Co-exists with current 25 kHz analogue channels	Base station / mobile / hand portable radios	Approx. 15-65 NM	Broadcast, Group, Addressed	Maritime	
Digital MF Voice	To be provided	To be provided	To be provided	To be provided	To be provided	To be provided	To be provided	To be provided	To be provided	
Digital HF	19.2 kbps	3–30 MHz		up to 9.6 kbps	With HF-radio, data rate and connectivity is highly dependent on many factors like propagation conditions, antenna structures, polarization and location on of transmitters and transceivers. Frequences must be coordinated globally including the reference receiver stations to optimize the connectivity. In order to HF for data transfer there has to be commonly agreed and defined link-establishment protocol in place. Transmit power is also a key factor and the	Base station / mobile radios	Global	Addressed / Broadcast	Maritime	

Communication Technology	On air data rate	Frequencies	Latency	Available data rate	Primary constraints	Infrastructure	Coverage	Transmission	Maritime / public	Notes
IMT Families										
IMT-Advanced (4G / LTE)	600 Mbps (up to 1 Gbps downlink and 100 Mbps uplink)	Dependent on locality	To be provided	To be provided	Cell coverage - high cost of deployment and maintenance	4G Base stations	Depending on deployment scenario for use (i.e. 5-30 km (3-16 NM))	Addressed	Public	
IMT-2020 (5G)	1,200 Mbps (up to 20 Gbps downlink and 10 Gbps uplink)	Dependent on locality	To be provided	To be provided	Cell coverage - high cost of deployment and maintenance	5G base stations	Depending on deployment scenario for use (i.e. 5-30 km (3-16 NM)) Satellite coverage	Addressed	Public	Maritime use cases available
IMT-2030 (6G)	Unknown	Dependent on locality	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Public	Developing technology
GEO Satellite										
Inmarsat-B	128 kbs					Satellite functioning on L-band	-82° to 82°, spot beams	Addressed / broadcast	Maritime	No longer in use
Inmarsat C	600 bps	To be provided	To be provided	600 bps	To be provided	Satellite functioning on L-band	-82° to 82°, spot beams	Addressed / broadcast	Maritime	
Inmarsat GX	50 Mbps	To be provided	To be provided	To be provided	To be provided	Satellite functioning on Ka-band	-82° to 82°, spot beams, polar coverage by 2023	Addressed / broadcast	Cross Industry	
LEO Satellite										

Communication Technology	On air data rate	Frequencies	Latency	Available data rate	Primary constraints	Infrastructure	Coverage	Transmission	Maritime / public	Notes
Iridium	Up to 134 kbps	To be provided	To be provided	2.4 kbps	To be provided	Satellite functioning on L-band	Global, dependent on constellation size	Addressed / broadcast	Cross Industry (Iridium Pilot Maritime)	IMO Approved
Iridium Next	Up to 1.5 Mbps	To be provided	To be provided	500 kbps	To be provided	Satellite functioning on L-band	Global, dependent on constellation size	Addressed / broadcast	Cross Industry (Iridium Pilot Maritime)	
OneWeb	200 Mbps	To be provided	To be provided	To be provided	To be provided	Satellite functioning on Ku-band	Global, dependent on constellation size	Addressed	Cross Industry	
Starlink	350 Mbps	To be provided	20-50 ms	10-40 Mbps UL; 100-300 Mbps DL	To be provided	Satellite functioning on Ka/Ku/V-band	Global, dependent on constellation size	Addressed	Cross Industry	
IoT										
Sigfox										Purchased by UnaBiz
LoRaWAN	0.3 kbps - 27 kbps	To be provided	To be provided	To be provided	To be provided	To be provided	~10 NM	Addressed / broadcast	To be provided	Information to be provided
NB-IoT										Information to be provided
LTE-M										Information to be provided

3.5 Future Vision: Automated Selection Process of Available Communication Technologies

The Table 2 identifies 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 VDES (including 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.

3.6 Modernisation of GMDSS

The current GMDSS system was designed over 25 years ago and has recently been reviewed and updated 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 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).

This was followed by the development of legal instruments, revision/development of relevant performance standards and an implementation period. This followed the modification work to chapters III and IV of the International Convention for the SOLAS and consequential amendments to IMO instruments other than the SOLAS Convention.

IMO finalized the work for GMDSS modernization at NCSR 8 (April 2021. MSC 104 (October 2021) approved draft amendments to SOLAS Chapters II-1, III, IV and V, and the appendix (Certificates) and relative MSC resolutions. MSC 105 (April 2022) adopted a set of amendments to complete the work on modernization of the GMDSS and to enable the future use of modern communication systems in the GMDSS whilst removing obsolete requirements. The amendments entered into force on 1 January 2024.

MSC.1/Circ.1676 declares delays affecting the availability of new GMDSS equipment compliant with the revised performance standards set out in resolutions MSC.511(105), MSC.512(105) and MSC.513(105). MSC.1/Circ.1676 invites Member States to consider permitting until 1 January 2028 the continued installation of:

- Shipborne VHF radio installations conforming to performance standards not inferior to those specified in the annex to resolution A.803(19), as amended;
- shipborne MF and MF/HF radio installations conforming to performance standards not inferior to those specified in the annex to resolutions A.804(19), as amended and A.806(19), as amended; and
- Inmarsat-C ship earth stations conforming to performance standards not inferior to those specified in the annex to resolution A.807(19), as amended.

WRC-23 has approved the possible regulatory actions of Radio Regulations to support the modernization of the GMDSS. RR of 2024 edition has been published, which reflects the ITU study results of GMDSS modernization from the view of frequency spectrum usage.

4 Allocation of Spectrum

4.1 Situation with Respect to Existing Spectrum Usage

The Section 3.2 describes the existing maritime technologies, which use the radio spectrum and indicates 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.

4.2 Agenda Item for WRC-27

Three agenda items will directly impact maritime spectrum usage.

- Agenda item 1.2 to consider possible revisions of sharing conditions in the frequency band 13.75-14 GHz to allow the use of uplink fixed-satellite service earth stations with smaller antenna sizes, in accordance with Resolution 129 (WRC-23).

Note: Some administrations use this frequency band for VTS radar.

- Agenda item 1.11 to consider the technical and operational issues, and regulatory provisions, for space-to-space links among non-geostationary and geostationary satellites in the frequency bands 1 518-1 544 MHz, 1 545-1 559 MHz, 1 610-1 645.5 MHz, 1 646.5-1 660 MHz, 1 670-1 675 MHz and 2 483.5-2 500 MHz allocated to the mobile-satellite service, in accordance with Resolution 249 (Rev.WRC-23).

Note: Some frequency bands are used in GMDSS distress and safety operations.

- Agenda item 1.12 to consider, based on the results of studies, possible allocations to the mobile satellite service and possible regulatory actions in the frequency bands 1 427-1 432 MHz (space-to-Earth), 1 645.5-1 646.5 MHz (space-to-Earth) (Earth-to-space), 1 880-1 920 MHz (space-to-Earth) (Earth-to-space) and 2 010-2 025 MHz (space-to-Earth) (Earth-to-space) required for the future development of low-data-rate non-geostationary mobile satellite systems, in accordance with Resolution 252 (WRC-23).

Note: The use of the frequency band 1 645.5-1 646.5 MHz by the mobile-satellite service (Earth-to-space) and for inter-satellite links is limited to distress, urgency and safety communications.

4.3 Preliminary Agenda Item for WRC-31

The Preliminary agenda items 2.7 and 2.8 in Resolution 814 (WRC-23) may affect for maritime spectrum use.

Preliminary agenda item 2.7:

- To consider improving the utilization of VHF maritime radiocommunication, in accordance with Resolution 363 (Rev.WRC-23).

Preliminary agenda items 2.8:

- To consider improving the utilization and channelization of maritime radiocommunication in the MF and HF bands, including potential revisions of Article 52 and Appendix 17, in accordance with Resolution 366 (WRC-23).

Note: Preliminary agenda item for WRC-31 will not necessarily become the final agenda for WRC-31. The final agenda of WRC-31 needs to be considered by WRC-27.

5 Summary

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. Some driving factors for development in technology include:

- Modern services on land require continuous connectivity on the vessel which is being addressed by current maritime communications and technology developments.
- Enhanced connectivity will enable improved service provision for the maritime community.
- 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, IMT, broadband maritime and satellite communications.

The digitalisation of maritime communications enhances 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 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 technology develops the IALA MARCOM will continue 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
BDMSS	BeiDou Message Service System
CDMA	Code Division Multiple Access
DGNSS	Differential Global Navigation Satellite System
DGPS	Differential Global Positioning System
ECDIS	Electronic Chart Display Information System
EGC	Enhanced Group Call
eLoran	Enhanced Loran
ELT	Emergency Locator Transmitters
EPIRB	Emergency Position-Indicating Radio Beacon
EPIRB AIS	Emergency Position-Indicating Radio Beacon with AIS
ETSI	European Telecommunications Standards Institute
FDD	Frequency Division Duplex
GAGAN	GPS-Aided Geo Augmented Navigation (System) (India)
GALILEO	European GNSS (not an acronym)
GEO	Geostationary Orbit
GMDSS	Global Maritime Distress and Safety System
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 Organization of Marine Aids to Navigation
IBS	Integrated Bridge System
ICAO	International Civil Aviation Organization
IEC	International Electrotechnical Commission
IHO	International Hydrographic Organization
IMO	International Maritime Organization
IMEA	International Maritime Electronics Alliance
INS	Integrated Navigation System
IP	Internet Protocol

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)
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
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
RACON	RAdar BeaCON
RCC	Rescue Coordination Center
RAIM	Receiver Autonomous Integrity Monitoring
RR	Radio Regulations
SBAS	Satellite Based Augmentation System
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
Wi-Fi	Wireless Fidelity
WiMax	Worldwide Interoperability for Microwave Access