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The Share of Data in Maritime Communications is Increasing

Deniz Haberleşmesinde Datanın Payı Artıyor

Türk Denizcilik ve Deniz Bilimleri Dergisi

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ABSTRACT

Communication is of great importance for the safe and delay-free navigation of ships. Especially life/property safety, navigational warnings, weather forecast reports, storm warnings, navigation maps, etc. Timely transmission of information to ships is only possible with effective maritime communications. In addition, communication is of great importance in making appropriate navigation plans based on the information received from the ships. In recent years, the share of data communication in individual and corporate communications has been increasing. In order to benefit from the great conveniences and opportunities provided by data communication in maritime communication systems, very radical decisions have recently been taken within IMO. These regulations made at the international level paved the way for data communication in close-range maritime communication systems. In line with these regulations, broadband data communication between the ship and the land will begin to be made via VHF devices in the next few years. Another development that will improve broadband data communication in maritime communication systems has been in Near Orbit Satellite systems. The technical features of these systems, the number of which has been increasing in recent years, are extremely suitable for data communication between ship and land. Among these, the Starlink system completes its network in space faster than other satellite systems. It is inevitable that the Starlink system, whose global satellite structure will be completed to a large extent by the end of 2025, will be used to a large extent in data communication between ships and land and between ships with each other. With the use of broadband data feature in the near future, it will be possible for ships to navigate much more safely, efficiently and with a reduced risk of accidents. For this purpose, maritime enterprises, ship personnel and land units must be informed about these developments and their communication infrastructure must be established by taking these systems into consideration.

Keywords: Maritime communications, Maritime businesses, Ship management, Broadband data communication, Maritime trade.

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ÖZET

Gemilerin emniyetli ve gecikmeksizin seyirleri için haberleşmenin önemi çok fazladır. Özellikle can/mal emniyeti, seyir uyarıları, hava tahmin raporları, fırtına ihbarları, seyir haritaları, vb. bilgilerin gemilere zamanında iletilmesi ancak etkin bir deniz haberleşmesi ile mümkündür. Ayrıca gemilerden alınacak bilgilere göre uygun seyir planlarının yapılmasında da haberleşmenin önemi çok fazladır. Son yıllarda bireysel ve kurumsal iletişimde data haberleşmesinin payı giderek artmaktadır. Veri iletişiminin temin ettiği büyük kolaylıklardan ve olanaklardan deniz haberleşme sistemlerinde de azami ölçüde yararlanılabilmesi için yakın süreçte IMO bünyesinde çok radikal kararlar alınmıştır. Uluslararası düzeyde yapılan bu düzenlemeler ile yakın mesafe deniz haberleşme sistemlerinde data iletişiminin önü açılmıştır. Söz konusu düzenlemeler doğrultusunda önümüzdeki birkaç yıl içinde VHF cihazları üzerinden gemi kara arasında genişband veri haberleşmesi yapılmaya başlanacaktır. Deniz haberleşme sistemlerinde genişband veri haberleşmesini geliştirecek diğer bir gelişme Yakın Yörünge Uydu sistemlerinde olmuştur. Son yıllarda sayıları giderek artan bu sistemlerin teknik özellikleri gemi kara arasındaki veri haberleşmesi için son derece uygundur. Bunlar içinde Starlink sistemi diğer uydu sistemlerine göre uzaydaki şebekesini daha hızla tamamlamaktadır. 2025 yılı sonunda çok büyük oranda global uydu yapısı tamamlanacak olan Starlink sisteminin gemi kara arasında ve gemilerin birbirleri ile yapacakları data iletişiminde çok büyük oranda kullanılması kaçınılmazdır. Önümüzdeki yakın süreçte genişband veri özelliğinin kullanılması ile birlikte gemilerin çok daha güvenli, verimli ve kaza riski azaltılarak seyir yapmaları mümkün olacaktır. Bunun için deniz işletmelerinin, gemi personelinin ve kara birimlerinin söz konusu gelişmeler konusunda bilgilendirilmeleri ve iletişim alt yapılarını bu sistemleri de dikkate alarak tesis etmeleri gerekmektedir.

Anahtar kelimeler: Deniz Haberleşmesi, Deniz İşletmeleri, Gemi Yönetimi, Geniş Bant Veri İletişimi, Deniz Ticareti

1. INTRODUCTION

New developments that emerge every day in the IT sector leads to serious changes in the maritime sector, as in many other sectors. The possibilities provided by new communication systems range from ship bridge navigation systems to ECDIS, AIS, VDR, RADAR, etc. (Kayisoglu *et al.*, 2023). It provides very positive capabilities in the capabilities of electronic navigation aids and communication systems. Major developments, especially in data communications, inevitably lead to major changes in maritime communication systems. Maritime communication, which was previously done manually with conventional systems, later started to be done through automatic systems (Ekinalan, 2020). But in recent years, in parallel with the great development in the IT sector, maritime communication systems have also undergone serious structural changes.

One of the most radical changes in this form of communication in recent years has been the emergence of a differentiation similar to the development in broadband data communication in the IT sector. While written communication, especially in the maritime communication sector, was previously carried out in Morse, later with the developing technology, written communication turned into telex communication. Then narrow band data communication began to be made for the first time using Inmarsat systems (Demir, 2009). Although such studies dealing with broadband data of ship systems have been missing in the literature in recent years, today the emergence of new technologies and devices working in these technologies has paved the way for broadband data communication in maritime communications (Kayisoğlu, 2024).

A series of regulations have recently been made by IMO (International Maritime Organization) in order to start broadband data communication between ships and ship/land via different communication systems and with different features (Acarer, 2023). In addition, different alternatives have emerged in this regard with some new technologies that have become operational recently, and especially with near-orbit satellite systems. It is of great importance for the relevant parties of the maritime industry that the said facilities/capabilities and the features of these systems are known by both maritime companies, ship employees and port/cargo officials, and that these opportunities are utilized to the maximum extent.

In addition, in the article, the broadband data communication in question is used for ships' reporting, meteorological data, navigation maps, etc. It was emphasized that the speed and convenience it will provide for many important types of communication will make a very positive contribution to the safety of life and property in addition to the safe navigation of ships.

The remainder of this article is structured as follows. In Chapter 2, the materials and methods of the research are given. In Chapter 3, the findings obtained in this research are presented. In Chapter 4, the effects of new technologies on data communication at sea are discussed, according to the findings obtained in the research. In Chapter 5, the research in the article is concluded.

2. MATERIALS AND METHODS

In this study, first of all, it is emphasized that the share of data communication in the activities of both individual and corporate users is increasing and today, the transmission method of many correspondences, meetings and reports is explained as data communication.

In particular, the contribution of the convenience and benefits provided by this form of communication to the development of data communication is discussed. Then, the devices that must be kept on ships in different voyage zones by the GMDSS (Global Maritime Distress and Safety System) legislation, which determines maritime communication obligations, are presented as a table, and the systems in this table that can be used in data communication are evaluated separately. After explaining the features of the existing devices in the table in question, which are also defined as conventional systems, and the possibility of their use in data communication, information about new systems that can provide broadband data communication is given. The ability of these systems to be used in high-speed data communication in maritime systems was examined, especially considering their bandwidth and speed.

In this study, it is explained that sending large amounts of data with minimum delay is impossible with current maritime communication systems and that this will only be possible with broadband data communication. For this purpose, the decisions taken in the recent past within the IMO to enable ships to communicate with broadband data are explained and the importance of this issue in international maritime transportation is emphasized.

In addition, recent decisions taken by IMO for broadband data communication of ships were announced and the importance of this issue regarding international maritime transportation was drawn. The fact that the first regulation made by IMO on this subject was made on VHF, the most commonly used communication system on ships, was evaluated as an indication of the importance IMO attaches to this issue. Meanwhile, since Near Orbit Satellite systems are seen as the most suitable among the developing technologies related to broadband data communication in recent years, this issue has been discussed separately and the contribution of these systems to broadband data communication has been examined in detail. It is pointed out that the initial installation and communication costs of these systems are very low compared to existing systems, and the contribution that advances in this field will provide the communication environment of ships is explained in detail.

3. FINDINGS

Although many systems are used in maritime communication today, they generally have different structures from each other. All of these systems, which have different features, work in the form of radio communication and have two main structures: terrestrial and satellite systems. Marine communication devices, defined as Terrestrial systems, operate either as direct communication between ship-land or ships (such as VHF systems) or as electromagnetic waves reflected from the ionosphere (as in HF systems). In medium distance systems (Medium Frequency- Medium Wave), communication is carried out as Ground Waves.

In satellite systems, which is another type of maritime communication, communication between ship to ship and ship to land is provided through satellites. These non-terrestial systems should be considered differently from terrestrial systems (Gul *et al.*, 2024). Inmarsat and Cospas Sarsat satellite systems are used in this form of communication (Demir, 2009). Today, while commercial communication and danger/safety type communications are generally established through the Inmarsat system, only life/property safety and distress communications are provided through the Cospas Sarsat satellite system. While Inmarsat communication is commercial and requires a fee, distress communication using the Cospas Sarsat system is free.

It is not possible to transmit broadband data with minimum delay with these systems.

3.1. Terrestrial Marine Communication Systems

VHF system is the most intensive way of Terrestrial Marine Communication. The most important feature of this is that it is the most used system in voice communication between ship to ship and ship to land. The VHF system works on the principle that the antennas of these devices see each other directly. The frequency band used n VHF communication has been determined as 156-174 MHz by the International Maritime Organization (ITU) (Korkmaz, 2002).

The other terrestrial maritime communication system is Medium Wave devices (MF), and these devices have a medium distance (approximately 150-200 nautical miles) coverage area. In this system, a form of communication called Ground wave is used.

In Long Distance (High Frequency) radio systems, which is another type of Terrestrial Marine Communication system, communication between devices is carried out through waves reflected from the ionosphere. Since the ionosphere is naturally reflective, this type of communication is considered a very safe form of communication in strategic terms. In the HF system, different frequency bands are used between communicating devices according to day/night hours (Ekinalan T., 2020). In accordance with the GMDSS obligation, DSC terminals used with HF devices can also provide automatic communication to Long Distance systems.

3.1.1. Very High Frequency (VHF) System

Very High Frequency (VHF) System, communication is made on the principle that the antennas of VHF devices see each other optically, so this form of communication between ships is free. DSC (Digital Selective Calling) terminals working with VHF devices provide these devices with automatic calling capability for both routine communication and distress/safety calls.

Max. power 25 W, min. Its power is 1 W (Atmaca, 2009). Since VHF devices in Coastal Radio stations are generally installed in high places such as hills and mountains on the coastline, the coverage area of these stations is much greater than the VHF communication established between two ships, depending on the height at which they are installed. This distance is determined by the formula below.

The figure below shows graphically the VHF short distance maritime communication between ship-ship and ship-shore stations and the distance of this communication in nautical miles. This distance is determined by the formula below.

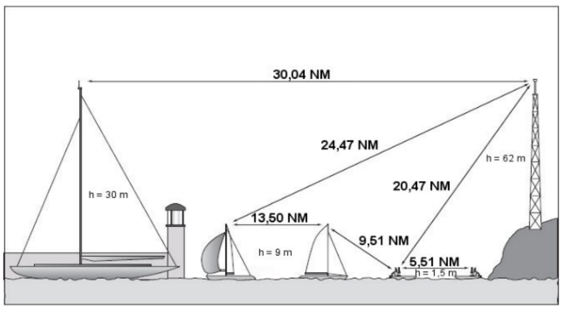

Figure 1. Distances between VHF devices (Ekinalan, 2020).

In the figure above, "h_1" and "h_2" show the heights above sea level of the antennas of VHF devices on ships.

"l" is the distance between the antennas of VHF devices on ships in nautical miles (nm).

$$l = 4.1 \times \left[\sqrt{h_1} + \sqrt{h_2} \right] (m) \quad \text{or}$$
$$l = 4.1 \times \left[\sqrt{h_1} + \sqrt{h_2} \right] (nautical\, mile) \qquad (1)$$

In this formula;
l: communication distance
h_1 and h_2; These are the heights of the antennas on VHF devices (two different VHF Devices) above sea level in meters. (1 nautical mile=1852 m)
According to this formula, the coverage area of VHF communication between two ships is calculated as approximately 25 nautical miles (Demir, 2009).
Accordingly; the communication distance between a marine vessel with a VHF antenna 30 m above sea level and a VHF system (for example, a device in a coastal radio station) on the shore with an altitude of 62 m above sea level is;

l = 2,21 x [$\sqrt{h_1}$ + $\sqrt{h_2}$]
l = 2,21 x [$\sqrt{30}$ + $\sqrt{62}$]
= 2,21 x [5,477 + 7,84]
= 2,21 x 13,317 nM
l = 29,43 nM ~ 30 nM'dir. (2)

Again, if the antenna heights of the VHF systems of the two marine vessels are shown in the figure above and are quite low at sea level (the height of the antennas of the VHF systems of both vessels is "9 m" above sea level), the communication distance of these two VHF devices is;

l = 2,21 x [$\sqrt{h_1}$ + $\sqrt{h_2}$]
l = 2,21 x [$\sqrt{9}$ + $\sqrt{9}$] = 2,21 x [3 + 3]
= 2,21 x 6 nM
l = 13,26 nM ~ 13,5 nM'dir. (3)

With the regulations made within IMO in recent years, it is aimed to provide data communication in VHF devices. For this purpose, duplex channels (channels with different receiving and sending frequencies) in the VHF system are allocated for data communication (ITU, Final Acts., 2019). These regulations aim to ensure data transmission in close-range wireless maritime communication and to provide this written communication free of charge or at a very low cost.
Another VHF system used under GMDSS legislation is Handheld VHF. (Portable VHF) Since the coverage area of handheld VHFs is less than 1 km, these devices are mostly used for in-ship voice communication and during cargo handling in ports (Acarer, 2018). Currently, Portable VHF devices cannot communicate with data.

3.1.2. MF and HF Systems

Another device that is compulsorily installed on ships due to GMDSS obligations is MF. In addition to voice communication through these devices, automatic communication between DSC terminals and ships and between ship and land is also possible. Although DSC technology provides automatic data communication to VHF, MF and HF devices, mutual broadband data and internet communication cannot be made between these devices.
In addition, since the width of the channels used in medium distance systems is 3 KHz (Ekinalan, 2020) more than one MF channel must be combined to enable data communication through this system. Since there is still no regulation made by IMO on this issue, there is no possibility of data communication in the MF band in the near future.
In long distance wireless systems, transmission is made between the receiver and transmitter units through waves reflected from the ionosphere. Since there are no satellites etc. and completely natural reflectors are used, this system is extremely safe from a strategic point of view. Since different bands are used in the long-distance system, the distance to the communicating units also includes different distances depending on these band values and day/night hours.

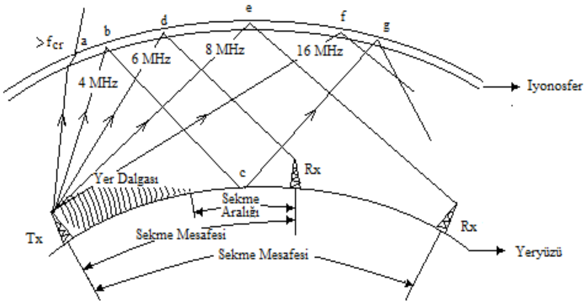

Figure 2. Different Frequency Bands Used in HF System (Ekinalan, 2020).

Again, IMO has not allocated channels for data communication in HF systems, as in MF. There is still no regulation or planning in the short term on this issue. Again, since the channel width in the HF band is determined as 3 KHz, it will be necessary to bring together many more channels than VHF for broadband data communication to reach the required channel width for broadband. (Carrier Aggregation)

Although this process is theoretically possible, it is impossible to implement in practice because dozens of HF channels would need to be combined to achieve the required channel width for wideband.

3.1.3. Navtex System

Navtex is a device that is mandatory on all ships related to the Terrestrial Marine Communication System. This device is a receiver only on ships and is a device where one-way broadcasts made by Coastal Radio stations are received and automatically recorded. Since this system, which operates in the medium wave band, contains extremely important information for the safe navigation of ships, Navtex devices are mandatory on all ships. Since this system involves broadcasting from land to ships, there is no possibility of mutual communication between ship/land units.

For this reason, it is not possible to benefit from broadband data communication from Navtex devices on ships.

3.2. Satellite Systems

Other wireless communication systems that, must be kept on ships in accordance with GMDSS rules are Satellite equipment. Some of these are required to be installed on ships only for distress and safety purposes, while some (such as the Cospas Sarsat satellite system) are devices capable of voice and internet communication. Although there are terminal devices with many different features in the Inmarsat satellite system (such as the Inmarsat satellite system), the only devices that can perform distress communication and therefore fulfill GMDSS obligations are the Inmarsat C and Inmarsat F77 satellite terminals.

Although voice communication is still not possible with Inmarsat C, written communication and long-distance navigation safety broadcasts (Enhanced Group Call-EGC) are possible. With Inmarsat F77, both voice and low-speed data communication can be provided (Ekinalan, 2020).

3.2.1. Inmarsat System

Designed as the International Maritime Satellite system and briefly defined as Inmarsat, the establishment target of the satellite system is maritime communication services. In the following years, land and air satellite communication services began to be provided through this system. Inmarsat satellites were designed as Geostationary Earth Orbit (GEO) satellites and launched into orbit at an altitude of 36,000 km. Figure 3 shows the names of long-distance Inmarsat satellites and areas they cover (INMARSAT, 2012).

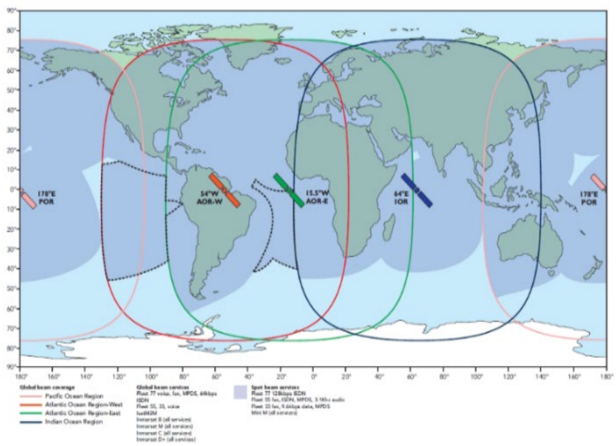

Figure 3. Inmarsat Satellites (INMARSAT, 2012).

There are 4 Geostationary Inmarsat satellites these are.

- AOR - E (Atlantic Ocean Region East)
- AOR - W (Atlantic Ocean Region West) is the satellite of the Atlantic Ocean Region West.
- IOR (Indian Ocean Region)
- POR (Pacific Ocean Region)

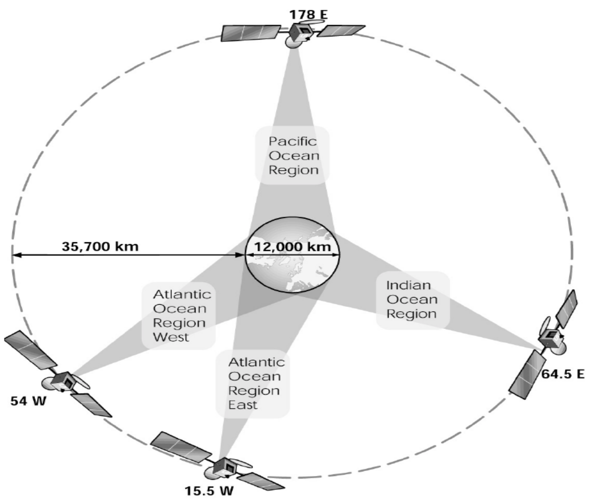

Figure 4. Locations of satellites& the distance from Earth (Yılmaz, 2014).

The main forms of communication using the Inmarsat system are;
- Voice,
- Emergency communication,
- Narrowband data communication and
- M2M (Machine to Machine) access.

Many different terminals are used on ships in M2M communication and narrowband data communication. Although there are many Inmarsat terminals, only Inmarsat C and Fleet 77 are compatible with GMDSS. Among these, data communication can be made especially through Inmarsat C and Fleet 77 terminals. Among these, Inmarsat C has a speed of 600 Bits and is quite slow. Data communication up to 64 kbps is possible via Inmarsat Fleet (ITU, 2013).
These terminals are;
- BGAN M2M
- BGAN Broadband Global Area Network
- IsatData Pro Terminal (ISATM2M)
- Isatdata Pro
- Inmarsat Fleet Services

Since the channel width allocated to this device is small, only narrowband data communication is possible. Therefore, it is not possible to perform wideband data communication with Inmarsat C and other Inmarsat devices.

3.2.2. Cospas Sarsat System

Cospas-Sarsat satellite system is an international organization with members of 45 countries, including Turkey. The purpose of this organization is to detect the position and identity of the marine vessel through radio transmitters (EPIRB - Emergency Position Identification Radio Beacon) activated in distress situations of the ships and to inform the relevant units in different countries. In such a danger situation, after the distress signal sent from EPIRB devices on ships, search and rescue units in the nearest country are notified and search and rescue process is initiated.
These orbits are mainly**.**
- Low-altitude Earth Orbit-LEO,
- Medium orbit (Medium-Altitude Earth Orbit-MEO),
- It is a fixed distant orbit. (Geostationary Earth Orbit-GEO)

Figure 5. Cospas Sarsat Satellite System (Participants shown in green) (Cospas-Sarsat., 2023)**.**

In the Cospas-Sarsat satellite system, the signal sent from the EPIRB devices for the ship in distress is first sent to the satellite and from there to Satellite Ground stations in different countries called LUT (Local User Terminal). This information coming to the LUT is then sent to the unit defined as the Mission Control Center (MCC), and from there to the Search and Rescue Center (RCC) of the country closest to the EPIRB where the distress broadcast is broadcast. RCCs, who are informed of the distress, initiate the rescue function by notifying the Search and Rescue (SAR) units as soon as possible. Cospas-Sarsat satellite orbits in different orbits are shown below.

Figure 6. LEOSAR and GEOSAR Orbits (International Civil Aviation Organization, 2023)

In the Cospas-Sarsat system, only EPIRB devices are used on ships. Since the channel range used in this system is very narrow, it is not possible to establish wideband data communication with EPIRB devices on ships.

3.3. Mandatory Devices on Ships According to International Legislation

Decisions regarding inter-ship and ship/land communications are taken at regular meetings under the coordination of the International Maritime Organization. From time to time, these decisions are collected under different headings and turned into a set of rules. The most important and well-known set of decisions regarding maritime communications is "SOLAS" (Safety Of Life At Sea Convention) and GMDSS, which is a part of it. (Global Maritime Distress and Safety System) With these and similar regulations, which devices will be installed on ships depending on the regions they sail to and their tonnage, the qualifications of the personnel who will use them, the types of licenses, the features of the devices in question, how many of them will be kept on the ship, etc. obligations have been introduced. As long as developments in technology continue, it will be inevitable for these regulations to continue.

The most important body of legislation that still maintains its validity regarding maritime communications and determines the obligations of ships regarding maritime communications is GMDSS. The authorization of marine vessels, their inspections in ports, the types of licenses of the personnel who will use the communication devices, the maintenance/handling obligations that these personnel have to carry out regarding the devices, their testing and control processes, and the procedures and principles regarding communication are explained in detail in these regulations.

The table below shows the communication devices and their features that must be available on ships operating in different voyage zones according to IMO regulations, depending on tonnage (Ekinalan, 2020). All member countries of IMO must fulfil their obligations in this legislation and equip their ships accordingly.

Table 1. GMDSS Regions and Mandatory Equipment (Ekinalan, 2020).

	A1	**A2**	**A3 (INM)**	**A3 (HF)**	**A4**
VHF DSC	X	X	X	X	X
POR. VHF	X	X	X	X	X
EPIRB	X	X	X	X	X
SART	X	X	X	X	X
NAVTEX (RX)	X	X	X	X	X
MF DSC (TLF/DSC)	X	X	-	-	-
HF DSC (TLF/DSC/TLX)	-	-	-	X	X
EGC	-	-	X	X	-
INM (C/77)	-	-	X	-	-

As can be seen from the table above, some of the devices in different voyage areas are Terrestrial, as explained in the previous articles, and some are Satellite systems. While some of the devices in question are used only for distress/safety communication, some are installed on ships for both distress and commercial/routine communication purposes. Again, it is not possible to establish broadband data communication with the devices listed in this table and kept on ships as required by legislation.

3.4. New Generation Low Orbiting Satellite Systems

Until recently, communication satellites were designed as Very High Geostationary Orbit satellite systems. (Geostationary Earth Orbit-GEO) On the other hand, observation, meteorology, scientific, etc. The architectural structure was dominant for satellites to be low-altitude Earth Orbit (LEO) satellites. However, in recent years this structure has changed greatly. Especially after broadband data communication became widespread, communication satellites began to be used in Very Low Orbits. The goal of minimizing the delay time in broadband data communication also plays a major role in this change. Because as the distance between the satellite and the earth increases, the delay time inevitably increases.
This delay time is minimum for a satellite at 36,000 km;
72,000/300,000 seconds = 0.24x2=0.48 seconds is happening. (The distance is doubled, taking into account the signal's travel to/from the satellite)
This is especially the case in new generation communication systems, autonomous technologies, online transactions, etc. It contains very serious negative aspects. For this reason, new generation satellites for communication purposes are inevitably placed in close-range orbits, thus minimizing this time. In addition, it is possible to conduct broadband data communication with all of these systems.
It is possible to group these satellite systems, the number of which has been increasing in recent years, under the following headings.

3.4.1. Starlink Satellite System

It is a satellite system developed by SpaceX company. This company was founded by Elon Musk in 2002 and is an American organization that aims to provide aviation/space transportation services. "Reducing space transportation costs and colonizing Mars" are among the main goals of the company in question.
SpaceX company became the first private company to successfully send a spacecraft into space and return it from the ground. The company's “Falcon 9” rockets have landed and flown again more than 200 times. This company has created an internet network around the world by placing more than 4,500 small satellites in low orbit from January 2020 until the end of 2023 (Space.com, 2023). The height of these satellites above the ground is 360-400 km. between. The architectural structure of Starlink and similar satellite systems is shown Starlink Architecture.

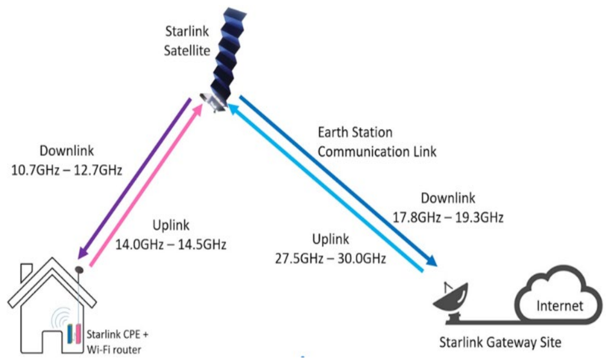

Figure 7. Starlink Architecture (Learning, 2022).

The antenna of the system in question must be installed in individual or corporate buildings that constitute the user side of the Starlink architecture. It is sufficient to install this antenna on the roof of the building or in a location that will not obstruct the view of the satellites. Although a single satellite configuration is shown in the figure above, there are thousands of satellites in the architectural structure. It is aimed to have a total of 42,000 SpaceX satellites in the architectural structure of the Starlink satellite system in the future.
The Starlink satellite system, many satellites are used effectively during a user's communication, and the smart satellite receiver on the user's side is automatically positioned by the system according to the satellites in low orbit.

Figure 8. Starlink Smart Satellite Receiver (Starlink Mag, 2023).

In the Starlink system, there is a need for a bridge between the satellite placed in low orbit and the fiber internet network on the ground. These bridges are called gateways. In the Starlink system, these crossings are made through ground stations. With these ground stations, communication is provided between the internet network on earth and satellite systems in low orbit. In this way, it is possible to manage the satellite fleet and the network in question. As of the end of 2023, Starlink has approximately 160 active ground stations and gateways in the world. Below is an image of Starlink's ground stations.

Figure 9. Starlink Ground Station (Starlink, 2023).

From time to time in our country, as in various parts of the world, Starlink satellites become visible at night and are followed with interest by people.

Figure 10. Starlink Satellite Constellation Migration (Starlink, medium.com, 2023).

In the Starlink Satellite system, Mobile Fixed Broadband Access allows mobile devices such as smartphones or tablets to be directly connected to the Starlink system without a smart satellite receiver. In this way, it is aimed to provide high-speed internet access to mobile devices located in remote or rural areas outside the limited coverage area of mobile cellular networks. In the coming period, on this system; SMS in 2024, data and voice in 2025, and internet of things (IOT) communication in 2026 will also be possible through this system. The general operating structure of the system is as follows.

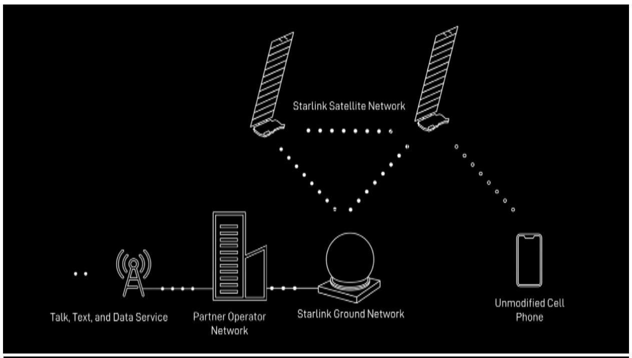

Figure 11. Mobile Fixed Broadband Access (Starlink, pocket-lint, 2023).

In this architectural structure, mobile devices are connected to Starlink satellites and the data transmitted in this way reaches Starlink's ground station. This access is then connected to the mobile operator's network, thus establishing a convergence of the classical telecommunication system and the Starlink satellite system. In this regard, the FCC aims to allocate a part of the US Frequency Plan to these functions and to

implement other regulations on the subject in the near future (FCC, 2023).
Due to the features of the Starlink system, it is inevitable that it will be the system that will use the most broadband data communication on ships in the future.

3.4.2. Amazon Kuiper Satellite System

The project called "Kuiper", which aims to place 3,236 satellites in low orbit to provide global broadband internet service, was announced to the public by the US e-commerce company Amazon in 2019. In this way, it is aimed to establish a satellite constellation within 10 years.
Users of this system include users on sea and air vehicles, especially passengers on ships and yachts, oil refineries on land and at sea, buoys on the high seas, etc. Amazon company has received the necessary permission from the FCC in this regard and aims to complete half of the satellite architecture in question by 2026. The remaining half of this project is expected to be completed by the end of 2029.
Due to the features of the Amazon Kuiper Satellite system, it is inevitable that it will be one of the systems that will provide the most broadband data communication on ships in the future.

Figure 12. Kuiper Smart Satellite Receiver (Amazon, 2023).

3.4.3. Eutelsat-OneWeb Satellite System

Bharti, an Indian company with a similar architectural structure to the Starlink and Kuiper satellites, and "OneWeb", jointly owned by the United Kingdom, were established as low-orbit satellite internet service providers. This system is approximately 1200 km. It aims to launch 7000 satellites into high orbits and thus establish a satellite constellation. This system aims to provide data access and emergency communication to areas where there is no internet or broadband is insufficient. Eutelsat-OneWeb's smart satellite receiver systems are shown below.

Figure 13. Oneweb Smart Satellite Receiver (Chandaphan, 2022).

Due to the features described in the Eutelsat-OneWeb Satellite system, it is inevitable that it will be one of the systems that will provide the most broadband data communication on ships in the future.

3.5. Arrangements Made on VHF Channels

3.5.1. Available VHF Channels

Currently, channels between "01-28 and 60-88" are actively used in marine VHF systems in Europe and the MENA (Middle East and North Africa) region, including Turkey (Atmaca, 2009) Accordingly, channels "28 and 60" are not used in marine VHF systems. Some of the VHF channels in question are allocated as duplex (receiving and transmitting frequencies are different from each other), while others are allocated as simplex channels (receiving and transmitting frequencies are the same).
The reception/transmission frequencies and usage purposes of these channels are shown in detail in the Radio Regulations. The most functionally important of these simplex channels and their intended use in maritime communications are listed below.

Table 2. VHF Channels "01-28 and 60-88" (Ekinalan, 2020).

Channels	Allocation
01-05	(included)
07	X
06-17	(included, 07 excluded)
18-28	"
60-66	"
67-77	"
78-86	Duplex channels
87-88	Simplex channels

The diagram below shows the configuration of VHF channels in RR Annex 18 (Radio Regulation 18) and the output frequencies according to the use of Ship and Shore Radio stations

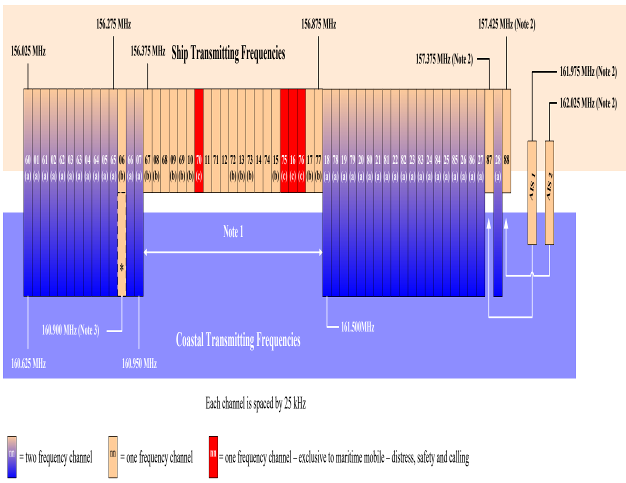

Figure 14. VHF marine channels (ITU, Manuel, 2009).

3.5.2. VHF Channels Allocated to Data Communication

As can be seen from the graph below, data communication has increased significantly in recent years, and it is calculated that this rate of increase will continue soon. Today, the communication of many services is done in the form of data, and this form of broadcasting is technically necessary for digital technology.

The most important factor in choosing the data communication method is that it is possible to transmit large amounts of data quickly and securely. The most important of these methods is combining adjacent channels and thus increasing the channel spacing (carrier aggregation). Since the more channels are combined in this way, the channel spacing will increase, the speed of data communication will be equally high.

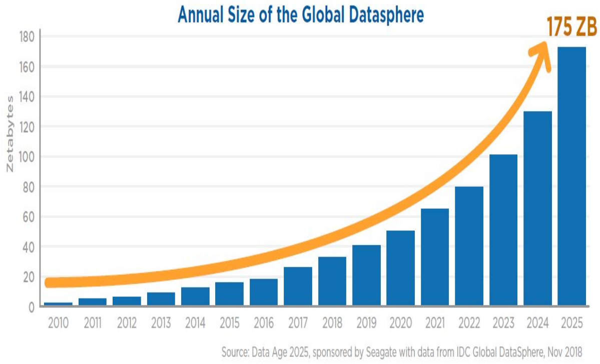

Figure 15. Increase in Data Traffic by Year (IDC, Data Age 2025 Report, 2021).

Increasing the channel width by combining adjacent channels is a suitable method for VHF maritime communication. Because the VHF maritime communication band determined by ITU is the standard and this range is 156-174 MHz (Acarer, 2014). In addition to maritime communications in the 30-300 MHz VHF band in electronics, television, radio, security, air traffic, etc. Since many different communication services are provided, it is not possible to further expand the 156-174 MHz band range allocated for VHF maritime communication.

In addition, since all existing VHF devices on ships operate in this band, it will be inevitable for millions of devices to remain idle and unusable if the marine VHF band changes. For this reason, combining adjacent existing VHF marine channels and thus obtaining wider channel spacing is technically the most realistic method. For this purpose, as a result of the decision taken at the World Radiocommunication Conference (WRC-19) held in November 2019 within the ITU, it was decided to combine adjacent duplex channels and convert them into simplex channels (ITU, Final Acts, 2019). It was decided that the channels combined in this way would be allocated to data communication and for this purpose, the maritime authorities of the countries would carry out the necessary tests and share them with the International Telecommunications

Organization (ITU).

3.6. Communication Facilities Provided by Data Channels in the VHF System

The regulations regarding VHF channels described in the regulation manuel (ITU, Manuel, 2009) are the most serious regulations made in the field of maritime communications in the recent past. These regulations aim to provide channels of the required width for broadband data transmission by combining existing duplex channels. In this way, it will be possible to communicate at high speeds in close-range maritime communications. It is possible to define this regulation as the most important changes in maritime communications after GMDSS to date. Because today, fixed and mobile communications are increasingly shifting to Internet Protocol. This form of communication, also briefly defined as IP, will soon be the only form of communication both corporate and individual. Because soon, communication methods such as voice, SMS and video will begin to be carried out entirely over the Internet Protocol.

The above-mentioned regulations regarding VHF channels are extremely important to ensure that similar developments in our daily lives can be made in close-range maritime communications. As a result of these changes, it will be possible to send files, maps, pictures, meteorological maps and written documents of different sizes in the form of data in close-range maritime communication. In addition, with this infrastructure, mutual internet communication will be possible between the ship and the land. Another important advantage of wireless data communication via VHF systems will be the reduction in communication costs. Since the communication medium in the VHF system is direct transmission between antennas, there is no charge for the establishment and operation of this medium. After the expansion of the band and therefore the communication channels, the communication cost for big data transmission through these channels will be almost free, and this will provide a very significant cost advantage for ships. In this way, ships will have the opportunity to communicate quickly and cheaply with the data facility brought to VHF systems in their communications with agencies, cargo persons, port authorities, companies and support units.

Again, it is inevitable that the regulations regarding VHF channels will contribute significantly to the navigational safety of ships. Because many marine vessels serve for different purposes in close-range sea areas. With data communication via VHF systems, it will be possible to transmit information in a very short time and in very wide content to the marine vessels in this area. Any information regarding navigational safety is of great importance for the safe navigation of ships.

4. DISCUSSION

First, the increasing possibility of using these new technologies in marine communication and the changes they have brought about are examined. Afterwards, the installation and operating costs of existing communication devices on ships and new generation communication devices are compared. Finally, the need for evaluation and regulation regarding this situation is highlighted.

4.1. Factors Causing the Increased Need for Broadband Data Communication on Ships

Today, data communication has been increasingly used in social and business life in recent years and provides great convenience in terms of communication. For this purpose, in recent years, the communication traffic between ship and land has increased due to many issues such as the delivery of the cargo to be carried in maritime transportation to the recipient in the shortest time, its damage-free transportation, safe navigation, insurance rules, ISM, etc. This form of communication is very important in terms of meeting the information needs of both ships and all parties related to maritime trade. In particular, the goal of reducing transportation time and increasing efficiency naturally causes the amount of information and reports sent from ships to land to increase. The same applies to information transmitted from land to ships. It has become almost impossible to transmit the increasing data traffic manually and without interruption. In order to meet this need, the International

Maritime Organization (IMO) has initiated a study using both existing systems and new generation communication systems.
The effective use of new systems will not only affect the commercial activities of ships but will also make a very positive contribution to the safe navigation of ships.

4.2. Increasing Usage Opportunities of New Generation Systems in Maritime Communications and the Emerging Changes

It is technically very natural to start the arrangements in question from VHF systems. Because VHF systems are the most used system in ships and in communication between ships and land, it will be a very serious example for the arrangements to be made from now on. It is inevitable that similar arrangements will be made in MF and HF systems in the future. Therefore, it is possible to say that the arrangements made regarding VHF channels will continue in other terrestrial maritime communication systems.
Although data exchange/transmission is not needed as much as close distance for ships in medium and long-distance navigation, many reports and information are sent/received regularly with land in ships at these distances.
Today, the most important development in broadband data communication between ships and land at medium and long distances has been in short-range satellite systems. Among these systems, the Starlink system in particular is developing faster than other short-range satellite systems. This system has also started to be used on ships in a short period of time. The installation and call costs of these systems, which are extremely easy to install, are extremely low compared to the current systems within the scope of GMDSS.
In the Starlink system, the download network speed (download) reaches 220 Mbps, and the upload network speed (upload) reaches 25 Mbps. It is possible for this speed to increase even more in the future. The invoices issued to ships are flexible and can be paused when desired.

Table 3. Data fee according to the currently valid tariff

Data Usage	Data Fee
50 GB	250 Euro/Month
1 TByte	1000 Euro/Month
5 TByte	5000 Euros/Month

To observe the trend in Table 3 better, we provide the following figure. For less data usage like 50 GB, data fee becomes 250 Euro/Month which is equivalent to a tariff with 1000 GB usage with 5000 Euros/Month. However, we observe that 1000 GB data usage and 5000 GB data usage are provided with data tariffs with 1000 Euros/Month and 5000 Euros/Month, respectively, which are just 20% of the data tariff for 50 GB usage. Hence, it can be observed that high data usage can be provided with 5 times cheaper data tariffs.

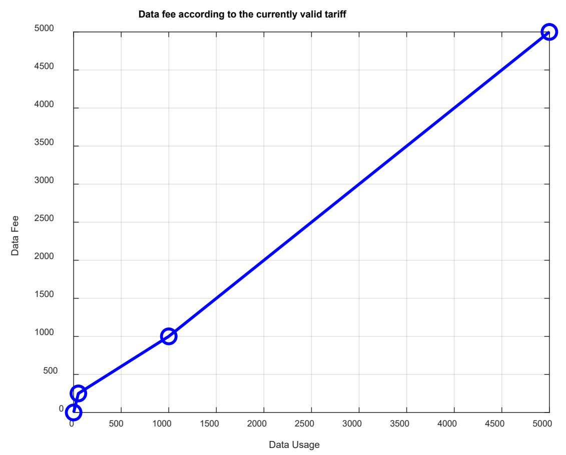

Figure 16. Data fee trend vs. Data Usage

In existing conventional systems, especially the Inmarsat satellite system, which currently provides maritime communication services, the installation fee of the terminals on the ship and the call fees over these systems vary depending on the Earth stations used and the tariffs determined by the countries where these Earth stations are located. The usage fee is determined as approximately 4,000 Euro/Month. Considering this price is relatively proportional, it is possible to say that the speeds achieved in the Starlink system, where broadband data service is provided, are 10 times higher than the existing data communication systems in the

GMDSS system, and the data cost per Gbyte is at least 10 times lower than the existing systems. Due to these features, the Starlink system will inevitably contribute greatly to data communication between ship and land. Because, inevitably, this system will greatly increase both the speed and bandwidth of data communication on ships.

4.3. Comparison of GMDSS Required Systems on Ships and New Generation Communication Systems in Terms of Installation and Operational Features

In the previously explained article titled "Devices Mandatory on Ships Due to International Legislation", the devices that must be installed as required by international legislation called GMDSS are explained in detail. Depending on the sea region they sail in, some or all of these devices are installed on ships. Some of the communication devices on ships are used only for distress/safety communication, and some are used for both commercial and distress/safety communication. Which devices will be used in different voyage regions are collected in international legislation under the name GMDSS, in line with the decisions taken at IMO.

The devices that must be installed on marine vessels are generally equipment with distress/safety communication capabilities. On the other hand, different systems are used on ships, especially for commercial communication purposes, in addition to the devices required in GMDSS. The most important of these is the Inmarsat terminals described above, which are not in the category of mandatory devices. However, the majority of these devices either only can communicate with voice or can communicate with data at very low speed. Low-speed data communication includes navigational and meteorological maps, observation reports, etc. It causes major problems in the transmission of files requiring large data to ships.

Commercial maritime communications can be made between ships and ship/land by using VHF, MF and HF systems and Inmarsat C and F77 devices, which are required to be installed on marine vessels in accordance with the GMDSS obligation. However, the desired speeds cannot be reached, especially since Inmarsat communication is at least 10 times more expensive than Starlink and the bandwidth for data transmission is insufficient. For this reason, maritime companies use Starlink for data communication that requires high speed and bandwidth. It will be a natural process for them to turn to new generation systems.

On the other hand, the fact that in practice only manual communication can be made via the VHF, MF and HF systems explained in the "Terrestrial Marine Communication Systems" article as a terrestrial system and that the cost of this communication is higher than automatic communication will naturally increase the interest in the Starlink satellite system in the near future.

For this reason, even though the installation of Starlink devices is not mandatory according to GMDSS rules, especially on marine vessels where official and private meetings are frequently held, it will be the most important factor in the rapid increase in the use of these devices on ships due to the advantages listed above.

4.4. Need for Evaluation and New Regulation

Although terrestrial and satellite systems, which are currently defined as conventional maritime communication systems, have taken on a digital structure with GMDSS, the general form of communication between ships and ship/land is manual. However, the recent regulations made within the IMO have paved the way for serious changes in the structure of existing maritime communications.

In recent years, data communication has become increasingly widespread in both corporate and individual communication and the use of Voice, SMS, Video, etc. As communication methods began to be made via data, the structure of communication began to change significantly. The confidentiality, speed and ability to transmit large amounts of data very quickly and securely provided by data communication, etc. Factors increasingly bring this form of communication to the fore. Again, the fact that data is much cheaper than other forms of communication and that it enables written and visual communication (maps, figures, graphics, etc.) are other important

factors in the spread of this form of communication.
For this reason, to benefit from these developments in communication between companies and individuals to the maximum extent in maritime communication between ships and ship/land, it has become necessary to make these regulations. In parallel with these developments, the most important technical developments regarding maritime communications in the near future are Starlink etc. low orbit satellites were used and marine VHF channels were allocated to digital communications. The common point of the arrangements made in both systems is that they enable broadband data communication. Since in the VHF system, communication is provided between ships and ship/land on the basis that the antennas are visible to each other, the transmission medium between them is free.
This feature is extremely important for the development of data communication over the VHF system. When this regulation, made by IMO and accepted by all member countries, is put into practice, the necessary data communication will be possible for the safe navigation and more effective activities of ships in close proximity.
In addition, great conveniences and opportunities in broadband data communication have been provided through the communication via the SpaceX satellite system via Starlink satellite terminals, which have recently started operating. Since both the initial installation cost and the communication cost of this system are quite low, it is inevitable that this system will contribute greatly to the broadband data communications of ships. For this reason, if the system in question begins to be used both in long-distance vessels and in the large number of yachts and cruise ships, there will be significant changes in the communication capabilities of marine vessels. The biggest disadvantage of the Starlink system is that it is not on the list of devices that must be kept on ships in different sea regions in accordance with GMDSS obligations. In other words, this system is not required to be installed on large tonnage ships, nor on yachts, cruise ships and offshore fishing vessels, in accordance with international rules. For this reason, installing Starlink devices on marine vessels is not mandatory, but optional.

5. CONCLUSIONS

Currently, many communication systems are used in maritime communications in accordance with GMDSS obligations. Although the number and types of these devices vary depending on the tonnage of the ships and the sea region they sail in, as per the GMDSS legislation, their common feature is the ability to make automatic danger/safety communication. The term GMDSS stands for maritime distress and safety communications.
Today, as a result of developing technology and the increasing need for communication, the need for uninterrupted communication from anywhere and at any time is increasing. In particular, the safe navigation of ships, the increase in reports coming to and from the ship, the change in the structure of ships, the documents required by maritime and port authorities, etc. As a result of these reasons, voyage processes are getting faster and faster. In addition, the increasing need for information and document requirements in the inspection legislation greatly increases the communication needs of ships.
These developments also necessitate regulations for data communication in terrestrial and satellite systems (Inmarsat and Cospas Sarsat satellites), which we define as conventional systems in maritime communications. For this reason, IMO has recently allocated duplex channels used in VHF systems, where maritime communications are most intensive, to data communication. For this purpose, adjacent duplex channels in the VHF system have been combined, increasing the channel width and paving the way for broadband data communication to be used in ships navigating at close distances. However, since the possibility of using the regulations regarding VHF systems in long-distance vessels is limited, new generation satellite systems have emerged as a serious alternative to meet the need for broadband data communication.
There have been very important technological developments in this regard in recent years. There are serious developments especially in new generation satellite systems operating as

global networks. In particular, the technical capabilities of these systems will be able to easily provide a solution to the broadband data communication needs of ships. Meanwhile, the satellite capacities of many Low Orbit satellite systems, whose development continues rapidly, are rapidly increasing on the space side.

The technical capabilities and especially the broadband data capabilities provided by these systems have emerged as a very important solution for ships. These systems have more bandwidth and latency than High Orbit Satellites. *Because High Orbit Satellite Systems are generally 36,000 km above the earth, and Low Orbit Satellite Systems are 400 km above the earth, the delay in these is 180 times [(36.00/400)x2)] less than High Orbit systems.*

This feature is extremely important for broadband maritime communications. This reduction in latency will contribute greatly to both the transmission of large amounts of data with minimal delay and the development of autonomous ships, whose trial runs have started in the near future. Because even in semi-autonomous systems, the delay time in communication between relevant units and central control elements must be minimized. Otherwise, it is inevitable to encounter serious accidents and disruptions. For this reason, it is imperative that the data rate of the systems used in the communication infrastructure of autonomous systems is high and the delay time is minimum.

As explained today, although there are many Low Orbit Satellite systems, the most advanced among them is Starlink, which became operational a few years ago. The architectural structure of this system, its low orbit (below 400 km) and its focus on broadband data communication have made these devices a very important alternative system, especially in commercial maritime communications. In addition, since both the facility costs and communication costs of the Starlink terminals to be installed on ships are quite cheap compared to other maritime communication systems, this system will provide a serious solution to the ever-increasing broadband data communication for ships. Another important advantage of this system over the existing satellite systems on ships is that the terminals are small in size and extremely easy to install.

Nowadays, in the communication sector, where all forms of communication are provided via data, it is inevitable that a similar process will occur in maritime communication between ships and ship/land. In parallel, both the regulations regarding VHF devices and the opportunities provided by Starlink satellite terminals regarding broadband data communication will inevitably lead to major changes in the use of existing marine communication systems.

Even though it is still mandatory to have different maritime communication systems in use on ships by the GMDSS provisions, their high communication costs and the fact that they do not allow broadband data communication will cause these systems to function only as distress/safety communication after a few years. On the other hand, routine maritime communication will shift to new generation satellite systems where broadband data communication can be made.

In addition, with new regulations to be made within the International Maritime Organization in the future, Starlink and similar Low Orbit Satellite systems may also be given the ability to make automatic distress/safety broadcasts. In this way, it is possible to say that the use of many existing marine radio communication systems on ships will be eliminated and they will be replaced by new generation communication systems.

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The author declares that for this article they have no actual, potential or perceived conflict of interests.

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