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GMDSS Equipment Usage: Seafarers' Experience

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Abstract: Maritime non-commercial communications are performed using the equipment of Global Maritime Distress and Safety System (GMDSS), under the International Convention for the Safety of Life at Sea (SOLAS). This equipment includes numerous devices of different technologies, features and user interfaces, which every officer of the watch (OOW) must know how to use. Besides, the equipment, i.e., its technology has not changed significantly in the last 30 years. Therefore, the purpose of this research was to collect and analyze information on how often GMDSS devices are used and whether any modernization is needed. The main research method was a questionnaire survey intended for experienced officers. Each question, as well as the answers of the respondents, were analyzed in detail and presented graphically. The results of the survey analysis indicate that the VHF (Very High Frequency) radiotelephone, Navigational Telex (NAVTEX) receiver, and Enhanced Group Call (EGC) receiver are still very used, while Digital Selective Calling (DSC) devices and MF/HF (Medium Frequency/High Frequency) radios (telephone and telex) are almost unused onboard. Additionally, more than 80% of respondents believe that GMDSS needs modernization.

Keywords: GMDSS; frequency of use; electronic radio log; VDES; e-Navigation

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1. Introduction

The GMDSS, which was fully implemented on 1 February 1999, was expected to represent, at the time, a revolution in maritime communications. Its main purpose is to alert and warn coast centers and surrounding ships in cases of distress, urgency, and safety [1]. It can also be used for routine (commercial) communications. According to the GMDSS requirements, the amount of communication equipment on ships, depends on the area of navigation (A1–A4) and includes terrestrial and satellite devices. These devices are shown in Figure 1.

However, from the day of implementation until today, GMDSS technology has not changed significantly and some parts of it have become, at the very least, obsolete. Thus, the system as a whole has not reached its full potential. Therefore, the International Maritime Organization's (IMO) Maritime Safety Committee (MSC) in 2009 at its 86th session decided to initiate the modernization of the GMDSS, which is still in development phase [2,3]. As for the scientific literature review, there is a scarce research in general on the subject of the GMDSS.

Even before the IMO's decision on GMDSS modernization and shortly after its full implementation, a survey conducted on 100 respondents concluded that the design of the GMDSS and the increasing workload on the ship's bridge, constitute the main drawbacks to its operability [4]. In addition, based on another survey with the same number of respondents, the GMDSS was established to be operationally complex and its design was not satisfactory [5]. However, the same GMDSS devices are still used onboard SOLAS ships since then.

As for the use of GMDSS equipment, the authors found only two researches on that subject. The IMO's Sub-committee on Navigation, Communications and Search and Rescue (NCSR) presented analysis results of user survey on GMDSS modernization submitted

by the Republic of Korea [6]. On a sample of 129 respondents, it was found that MF/HF installation is the most unhelpful and underused GMDSS equipment, followed by NAVTEX and portable VHF radiotelephone. However, a questionnaire of 16 not very well-structured open-ended questions was used as a data collection method, on which only a qualitative analysis (which was not even described) could have been conducted. In addition, this study examined how often a respondent uses a DSC device in general. In other words, DSC devices were not separated by the frequency band (VHF, MF/HF). The same applies to the INMARSAT-C and the EGC receiver (which was not even mentioned in the paper). Furthermore, research on the use of GMDSS equipment and the Electronic Chart Display and Information System (ECDIS) on a sample of 260 seafarers on oceangoing vessels was also conducted [7]. It was concluded, based on the opinion of the respondents, that INMARSAT (telex) and MF/HF (telephone and telex) are the most unused devices in the GMDSS. However, the methodology of data collection was not described. It was only stated that a survey was conducted among seafarers on oceangoing vessels. In addition, this study did not examine the frequency of use of any DSC device. Thus, both of these studies have some drawbacks.

Figure 1. Typical Global Maritime Distress and Safety System (GMDSS) radio station and equipment for sea area A3.

Among other researches related to the modernization of maritime communications (including GMDSS), the authors highlight papers that have analyzed technological advancements and challenges in maritime communications and the integration of some GMDSS equipment with the Integrated Navigation System (INS) [8–11]. However, these researches did not investigate the frequency of use of GMDSS devices and the problem of GMDSS modernization among seafarers.

Prompted by the modernization of the GMDSS and drawbacks of the previous researches, the authors of this paper researched to investigate the extent to which every single existing GMDSS device is used (or not) on ships in international voyages (SOLAS ships), excluding locating devices (SART, AIS-SART, and EPIRB). Additionally, the authors wanted to examine the views of experienced seafarers on GMDSS modernization in the form of spatial equipment reduction, bridge integration, and radio log digitization and automation. Therefore, the main hypothesis of the conducted research, which sought to be confirmed, is that some GMDSS equipment is not practical and efficient for use in modern shipping and the modernization of the GMDSS is required. Furthermore, the main goal of the research is to get first-hand confirmation whether seafarers believe that GMDSS system or a part of it should be modernized or not. An additional goal is to prove that some GMDSS devices are still necessary and frequently used onboard ships.

2. Methodology

As a part of the GMDSS modernization evaluation and proposal, the authors developed an exploratory study to investigate the frequency of use of GMDSS equipment. The main method for data collection was a questionnaire survey conducted in an online environment (FreeOnlineSurveys.com, accessed on 15 October 2020). The questionnaire was anonymous and participation in it was on a voluntary basis. However, each respondent was asked to indicate age, rank, years of experience as an officer, and their nationality for the research purposes (this was indicated in the cover letter). The questionnaire consisted of only 10 questions (items), from which 8 were closed type and 2 were combined, offering closed answers (indicators) and providing an open section for comments. Such a simple questionnaire is not time consuming, and yet very valuable information about seafarers' personal experience can be obtained from it. Therefore, in order to prove the need for GMDSS modernization, the authors in the first 8 questions offered answers based on the 5-point Likert scale to indicate the average frequency of use of each GMDSS device (VHF radiotelephone, VHF DSC, MF/HF radiotelephone, MF/HF radio telex, MF/HF DSC, INMARSAT-C, NAVTEX receiver, and EGC receiver) during one watch. The following numerical answers were offered to the first six questions: "0 times", "1–2 times", "3–4 times", "5–10 times", and ">10 times", with the additional option "Equipment not installed", offered on questions 3., 4., 5., and 6., since not every ship needs to be equipped with all GMDSS devices. The following text-based answers were offered to the seventh and eighth question: "Upon message receipt", "Periodically during watch", "On daily basis", "On weekly basis", and "On monthly basis", with the option "Not reading". All of these answers were used for quantitative data analysis, which involves simple descriptive statistics in Microsoft Excel software. On the other hand, in the last 2 questions, the authors offered answers based on the 3-point Likert scale to examine whether respondents agree with the authors' suggestions regarding spatial reduction and integration of GMDSS equipment and radio log digitization. Those offered text-based answers were: "Completely agree", "Partially agree", and "Disagree at all". Additionally, in these questions, respondents were able to give their own opinions, which were used for qualitative data analysis shown in the Survey Analysis and Results section. The authors used the data triangulation method to better present the opinions of seafarers on the integration and reduction in GMDSS equipment and the digitization of the radio log, since the triangulation facilitates validation of quantitative data through cross-verification using qualitative data.

The authors used the so-called snowball sampling: the link to the online questionnaire was sent via e-mail to the Faculties of Maritime Studies of the Republic of Croatia, selected crewing agencies and seafarers' companies in order to be distributed among experienced OOW's. Therefore, the target group, i.e., the sample frame of this research was the OOW's on SOLAS ships holding a Certificate of Competence for ships of 3000 GT or more (this was also indicated in the cover letter). The questionnaire was available from 4 April 2020, to 4 October 2020. In that period, the answers were collected, exported to the Microsoft Excel software, and analyzed on a sample of 112 respondents. Data on the respondents were derived using descriptive statistics in Microsoft Excel software (Figure 2).

Regarding the limitations of the survey, it is important to note that the use of GMDSS equipment also depends on the navigation area, which was not considered in this survey, i.e., not every ship needs to be equipped with all GMDSS devices. However, it was indicated in the questionnaire that the participants should answer according to their personal experience. Furthermore, it should be emphasized that the survey was conducted anonymously and is based on the subjective responses of the respondents. Therefore, the results should be used with caution. However, the results coincide to a good extent with the already mentioned previous researches (regardless of different sample of the respondents), as will be shown hereinafter.

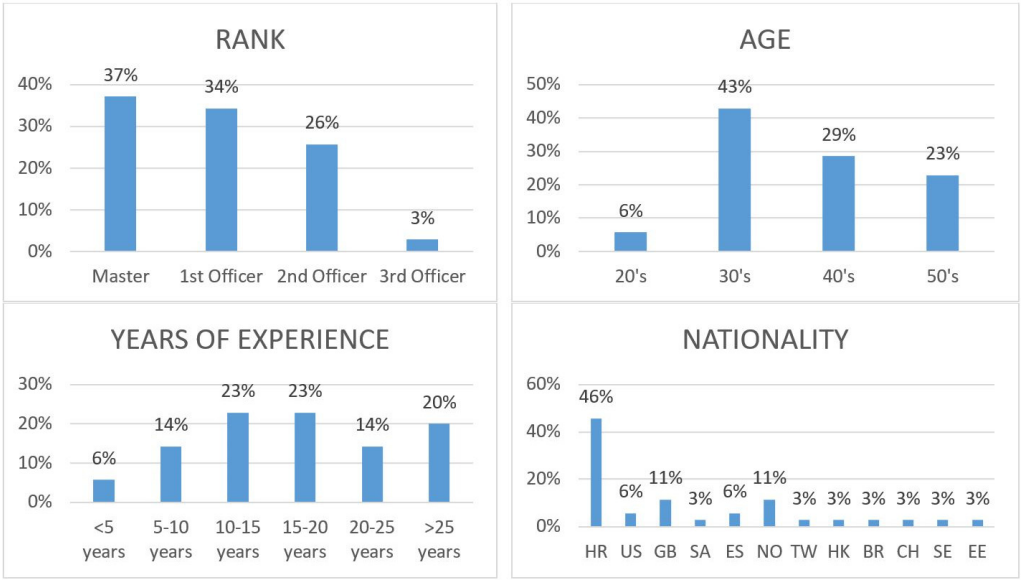

Figure 2. Rank, age, years of experience, and nationality of respondents.

3. Survey Analysis and Results

In this section, each question of the survey is presented, followed by the results and analysis. In the last subsection, the reliability and correlation analyses of the survey are presented.

3.1. On Average, How Often Do You Use a VHF Radiotelephone for any Type of Communication, during One Watch?

The authors are convinced that the VHF radiotelephone is still one of the most used methods of terrestrial radiocommunications in the maritime world, which is confirmed by the respondents' answers (Figure 3).

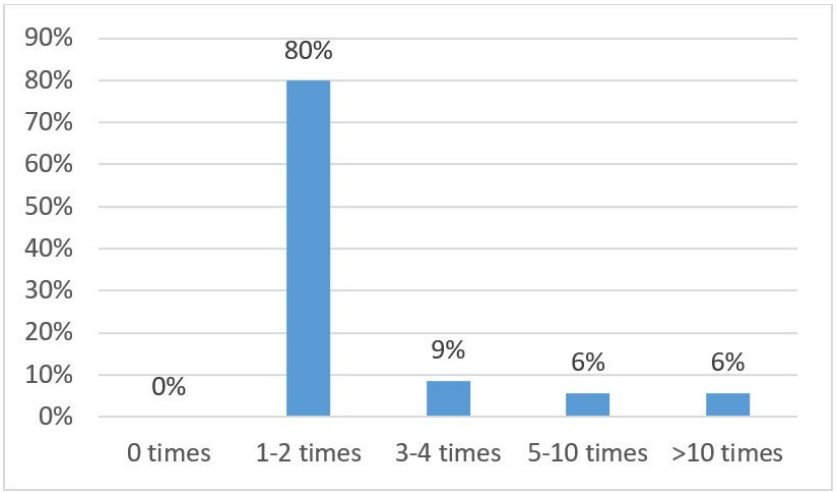

Figure 3. Frequency of use of the VHF radiotelephone.

It can be seen that 80% of the respondents answered that they use a VHF radiotelephone at least once during the watch. However, such result is expected, as it is generally known that the radiotelephone in question is, due to the principle of operation, the most reliable and fastest way to establish a contact with surrounding ships or coast facilities. Additionally, ships subject to the SOLAS Convention must maintain a continuous watch on the VHF channel 16 [12]. The obtained results also correlate with the results of researches conducted in [6] (96% of the respondents answered that they often use the equipment and

91% of the respondents answered that the equipment is absolutely necessary) and [7] (the first most used GMDSS device).

3.2. On Average, How Often Do You Use a VHF DSC for Calling (Excluding Test Calls), during One Watch?

VHF DSC, as a special feature of VHF radio station, is extremely rarely used for sending ship-to-shore and/or ship-to-ship calls, excluding safety test calls.

Figure 4 shows that 82% of respondents mainly do not use the DSC functionality of a VHF radio station to send a call, while the remaining 18% of respondents answered that on average, they use VHF DSC only 1–2 times during a single watch. The survey did not ask to specify the reasons for the minimal use of this functionality, but it can be assumed that some of the main reasons are: very low data rate (1200 bps), compared to modern technologies such as Telenor Maritime Radio (133 kbps) or WiMAX in sub-GHz frequencies (over 20 Mbps) [8,9]; very limited range (line of sight), compared to satellite coverage; not very user-friendly interface—in terms of a small display with complex menu trees [13]; and in general, sending a DSC call is a time demanding task compared to a voice call. It should also be noted that the survey conducted in [6] examined how often respondents use DSC in general (either VHF or MF/HF), while the authors of this paper wanted to separate the frequency bands. On the other hand, the survey conducted in [7] did not consider DSC devices at all.

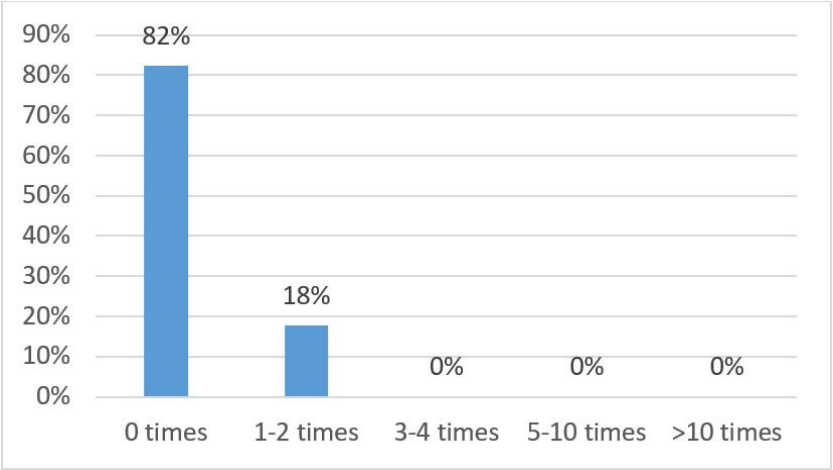

Figure 4. Frequency of use of the VHF Digital Selective Calling (DSC).

3.3. On Average, How Often Do You Use MF/HF Radiotelephone for any Type of Communication, during One Watch?

The MF/HF radiotelephone is certainly a communication system that is no longer recognized among seafarers as useful, either because of its complexity of use (ionospheric effects on ground and sky waves) or because of outdated analogue technology (SSB modulation).

Figure 5 shows that almost 90% of respondents never use an MF/HF radiotelephone during one watch, while others possibly use it once or twice. Furthermore, none of the respondents answered that they did not have this device installed onboard, although it is not mandatory in the GMDSS sea area A1. The obtained results on the frequency of use of this device do not correlate with the results of researches conducted in [6] (53% of the respondents answered that they often use the equipment) and [7] (the third most frequently used device). However, respondents in these researches largely agree that the MF/HF installation is unhelpful, difficult to operate, and requires functional improvement.

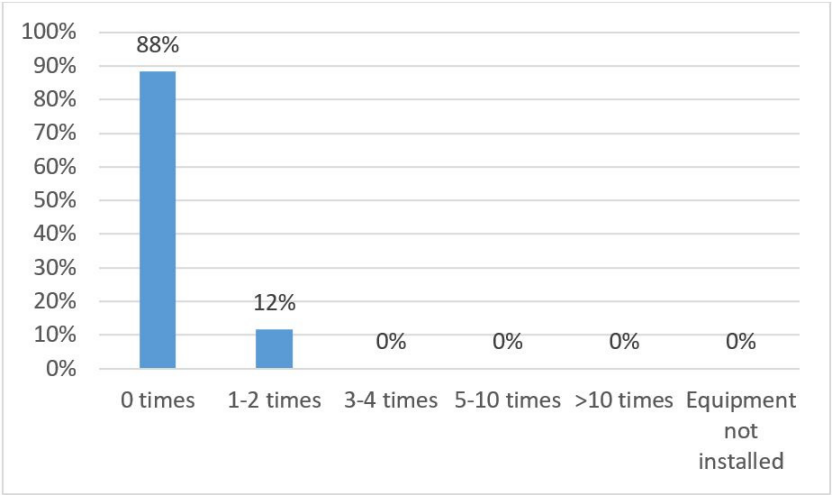

Figure 5. Frequency of use of the MF/HF radiotelephone.

3.4. On Average, How Often Do You Use MF/HF Radio Telex for Calling, during One Watch?

The radio telex as an optional device for SOLAS ships navigating in the GMDSS sea area A3 and mandatory for SOLAS ships navigating in the GMDSS sea area A4 is also rarely used or not used at all, especially among the younger generations of seafarers. The reason is that radio telex requires a complex procedure for today's seafarers, providing slow data transmission (100 bps) and it is generally known that more and more ships use the Internet protocol, i.e., e-mail to send information. In terms of Internet/e-mail availability in the polar (A4) areas, more and more ships are using different terrestrial and/or satellite telecommunications systems that provide these features, among others. This further pushes radio telex to the margins of maritime long-range communications systems, although it is still mandatory for ships in the A3 (if there is no INMARSAT equipment) or A4 sea area.

Figure 6 shows the frequency of use of radio telex, where it can be seen that 88% of respondents never use this device, 9% of respondents use it once or twice during one watch, while only 3% of respondents stated that they did not have this device installed on a ship. The obtained results also correlate with the results of researches conducted in [6] (75.2% of the respondents answered that they do not use the equipment) and [7] (the first most useless device).

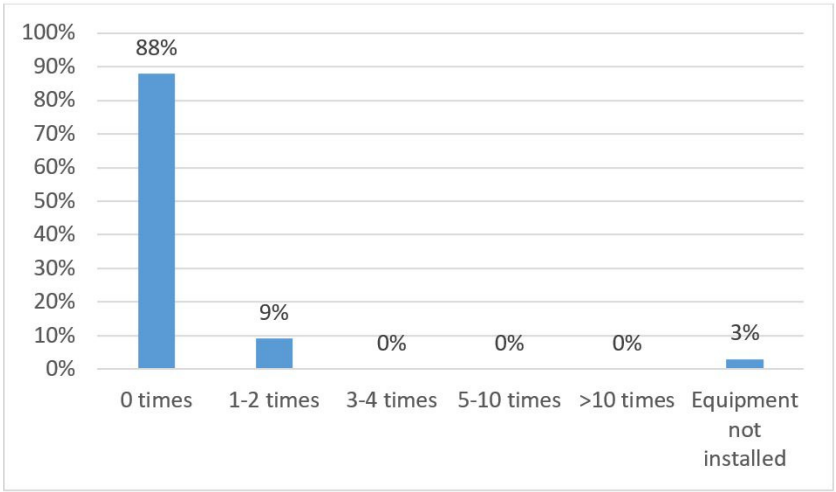

Figure 6. Frequency of use of the MF/HF radio telex.

3.5. On Average, How Often Do You Use MF/HF DSC for Calling (Excluding Test Calls), during One Watch?

The MF/HF DSC as a special possibility of transmitting a digital selective call on MF/HF frequencies also confirms the research hypothesis that MF/HF radio installation as a whole is almost not used in today's maritime radiocommunications, which is confirmed by the survey results shown on Figure 7.

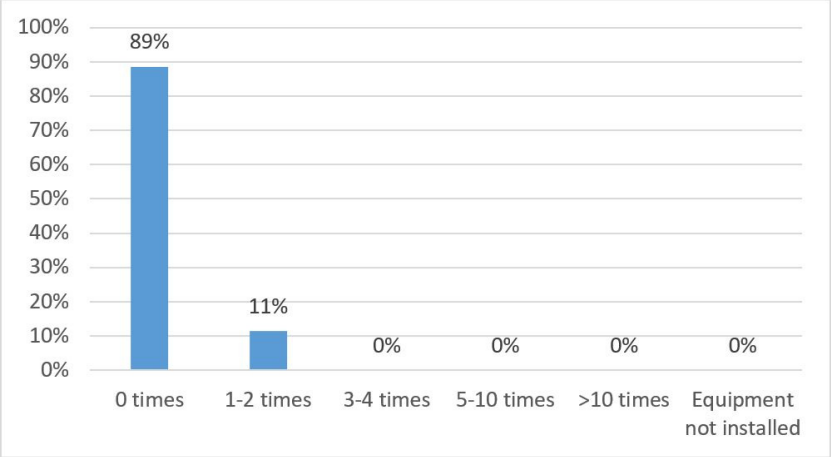

Figure 7. Frequency of use of the MF/HF DSC.

As can be seen, as many as 89% of respondents do not use the MF/HF DSC for calling at all, although no one answered that the device was not installed on the ships on which they navigated. The reasons for this are the same as already stated for VHF DSC with the emphasis that the data rate of MF/HF DSC is 12 times less than the data rate of VHF DSC.

3.6. On Average, How Often Do You Use INMARSAT-C Ship Earth Station (Excluding EGC Receiver) for Any Type of Communication, during One Watch?

The INMARSAT-C ship Earth station (SES) has remained on ships to these days as the only satellite communication device to provide GMDSS communication functions (excluding the COSPAS-SARSAT EPIRB, which is intended for ship-to-shore alerting and locating). Until recently (December 2020), INMARSAT Fleet 77 also existed, but like its predecessors, INMARSAT-A and INMARSAT-B, it was discontinued due to new satellite communications systems and services within GMDSS, which provide more features compared to it (Iridium, Inmarsat Fleet Safety) [14]. Given the poor capabilities of the INMARSAT-C device in terms of data rate (600 bps) and store and forward messaging (when high-speed Internet on board is often available), the device is still used on ships, but to a lesser extent. Its biggest advantage over modern satellite communication devices is its small omnidirectional antenna and economic cost-effectiveness. Besides, INMARSAT-C can be effectively used for Long Range Identification and Tracking (LRIT) and Ship Security Alert System (SSAS) [15].

As can be seen from Figure 8, 55% of respondents stated that they did not use INMARSAT-C, 36% of them answered that they used the device up to 2 times during one watch, 6% of them answered that they used it up to 4 times, while only 3% of respondents stated that they did not have it installed onboard. If these results are compared with the results of researches conducted in [6] (71% of the respondents answered that they often use the equipment) and [7] (the third most frequently used device), a correlation can be seen regarding its use. Namely, this device is still used onboard ships, but the authors in those researches concluded that it requires functional improvement.

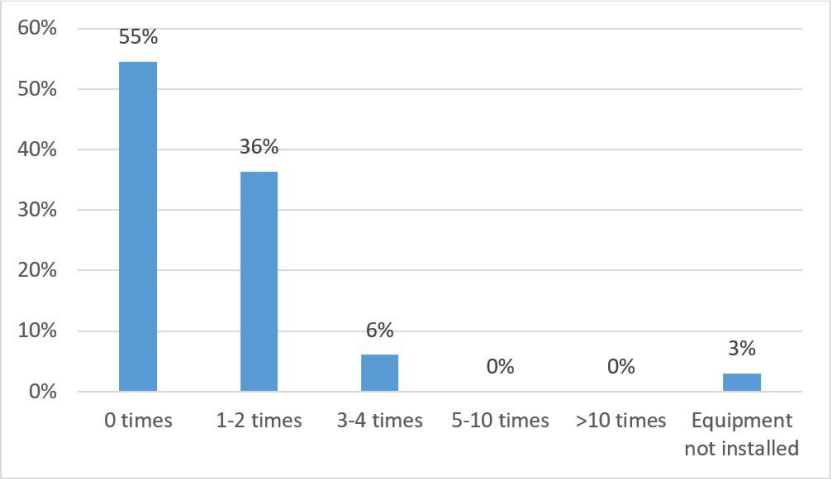

Figure 8. Frequency of use of the INMARSAT-C ship Earth station (SES).

3.7. How Often Do You Read Received NAVTEX Messages?

The NAVTEX system and its receiver on ships, as part of GMDSS terrestrial communications for receiving Maritime Safety Information (MSI), are still very used onboard ships, as shown by the results of the survey (Figure 9).

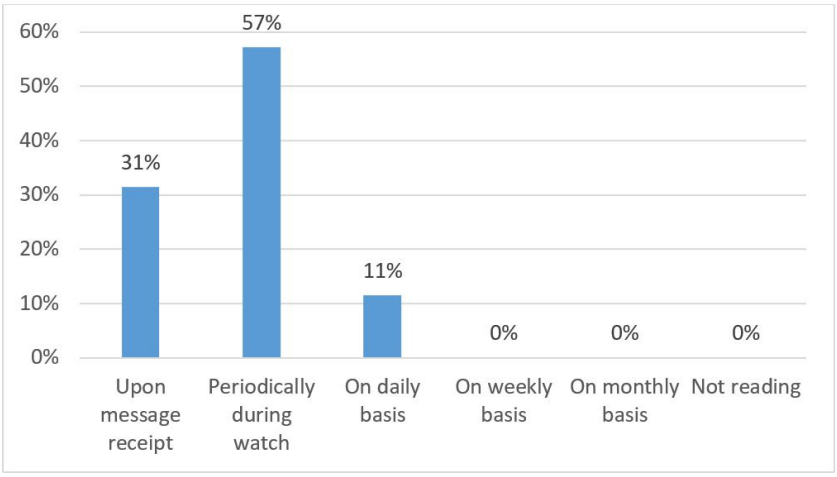

Figure 9. Frequency of use of the Navigational Telex (NAVTEX) receiver.

The authors wanted to examine and show how often respondents read NAVTEX messages received on a NAVTEX receiver, and it can be seen that 31% of respondents read messages immediately upon receipt, 57% read them periodically during one watch, while the remaining 11% read messages daily. As it is known, the device as such has not undergone some serious modernization from the time of the official introduction, but it is also a known fact that a certain degree of integration with other systems, such as ECDIS, has been achieved [16]. In addition, that is the main reason why this GMDSS device is used more when compared to other GMDSS devices. Thus, it can be said that the survey results confirm the justification of the existence and future use of this system.

3.8. How Often Do You Read Received EGC Messages?

When it comes to the INMARSAT, i.e., EGC system, it has to be emphasized that it has the universality in informing ships in the form of weather forecasts, notifications for sailors, fleet or single ship, etc. (SafetyNET and FleetNET). Typically, an EGC receiver is integrated into an INMARSAT-C SES, but it has different functionality, and therefore, the authors wanted to specifically examine the use of both devices.

If the survey responses shown in Figure 10 are compared with the survey responses to the previous question, a correlation can be observed in the use of these two systems, emphasizing that the EGC system is not integrated into any type of navigation system, such as ECDIS. It can be concluded that the system is still used onboard ships because 97% of the respondents answered that they read received messages, while only 3% of respondents do not read them at all.

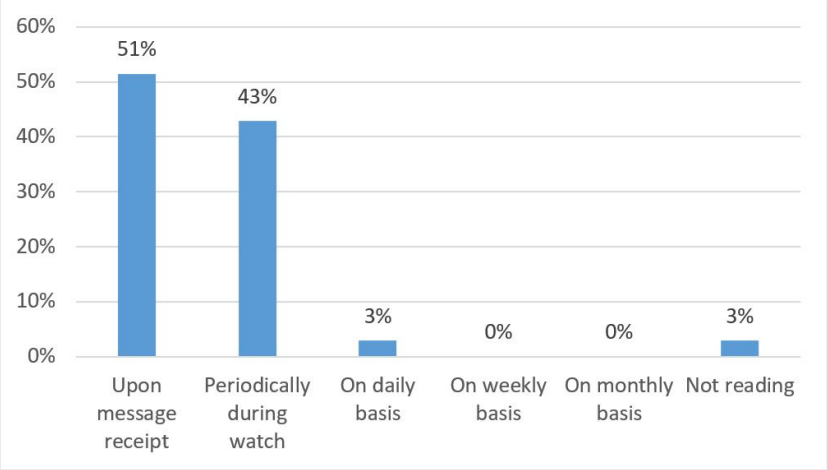

Figure 10. Frequency of use of the Enhanced Group Call (EGC) receiver.

3.9. According to You, Should GMDSS Equipment Be Dimensionally Reduced and Integrated on the Ship's Bridge, Which Would Then Have a Unique Communication Interface and Thus Serve to Store and Automate the Communication Process?

After examining the frequency of use of individual GMDSS equipment, the authors wanted to examine the opinions of respondents on the spatial reduction in GMDSS equipment and its integration on a ship's bridge. The answers to this question indicate that modernization in general is necessary, in order to increase the efficiency and ease the information collection and logging process (Figure 11).

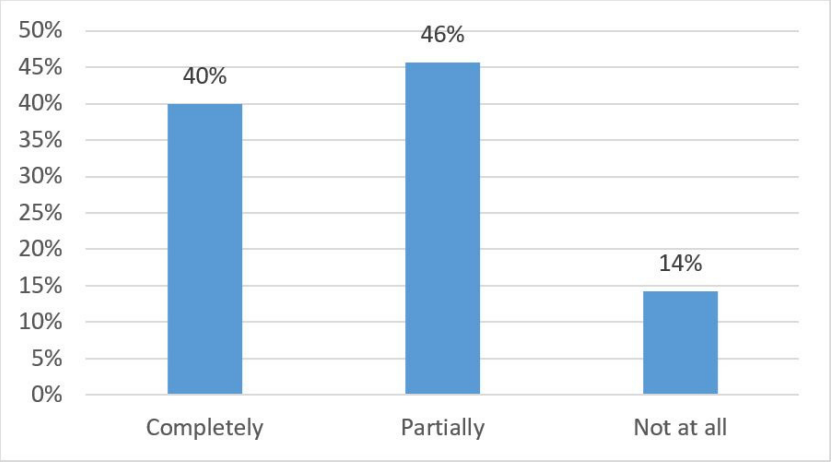

Figure 11. Respondents' compliance with space reduction and integration of GMDSS equipment.

The proposed GMDSS integration aims to reduce the administrative effort of OOW's. Figure 11 shows that 46% of respondents partially agree that integration and reduction in GMDSS equipment dimensions would be good to some extent, while 40% of respondents fully agree with the authors' proposal. However, it is important to note that there is a certain amount of caution (14% of respondents) among seafarers when it comes to further integration. Not only were quantitative answers offered to this question but respondents

were also able to write their own opinion. Quantitative and qualitative analysis found that only 40% of the respondents wrote their additional opinion. Qualitative analysis implied content analysis. After all additional answers, i.e., opinions of the respondents were collected, their coding was performed in order to create meaningful categories for easier analysis. Respondents' opinions and comments were coded using 8 codes: NAVTEX integration, VHF DSC integration, EGC integration, Overall simplification, Overall space reduction, Overall integration, Overall modernization, and Changeless. After coding the qualitative data, a triangulation with quantitative data was performed, in order to verify the additional comments of the respondents. Namely, the answers offered to this question quantified the extent to which the respondents agree with the authors' proposal on the reduction and integration of GMDSS equipment: "Completely", "Partially", and "Not at all" (Figure 11). Using the triangulation method, the authors concluded that additional comments (qualitative data) can be compared with the offered answers (quantitative data). The codes NAVTEX integration, VHF DSC integration and EGC integration support the quantitative answer "Partially", since some of the respondents stated that they would only like to integrate some of devices on the ship's bridge. The codes Overall simplification, Overall space reduction, Overall integration, and Overall modernization support the quantitative answer "Completely", since some of the respondents stated that they would like to completely simplify, modernize, reduce, and/or integrate all of the GMDSS devices. Finally, the code Changeless supports the quantitative answer "Not at all", since some of the respondents stated that they would not like to change anything in the GMDSS equipment. The triangulation method proved that some GMDSS equipment is not practical and efficient for use in modern shipping and that partial or complete modernization of GMDSS is required, which was the basic hypothesis of this research.

It is interesting to note that among the respondents who provided their additional opinion, 21% would not change anything regarding GMDSS equipment. What is important to emphasize is that such an opinion cannot be correlated with the age of the respondents, because within that 21% of respondents who believe that nothing should be changed, there are seafarers of all ages (20–50 years). The same applies to respondents who provided comments in the form of changing, integrating, or reducing GMDSS equipment.

Some of the additional comments, which the authors found significant, are "Definitely GMDSS equipment needs to be reduced and integrated into an information system, like ECDIS with a unique communication interface"—56 years; "DSC is unnecessary equipment that distracts the watch with a large number of messages, rather than contributes"—53 years; "It is time for this system to be modernized and adapted to the times in which we live"—35 years; and "It would be good to integrate VHF DSC to send reports automatically"—31 years.

3.10. Do You Agree That the Radio Log Should Be Automated and Exclusively Stored in Electronic form, i.e., in a Form Filled on ECDIS?

This question aimed to prove that a certain type of information centralization is needed, which could be obtained by automated and electronic GMDSS radio log.

As can be seen in Figure 12, 88% of respondents partially or completely agree with the proposed change in this particular example, while as in the previous question, there is a certain caution towards changes (12% of respondents). As with the previous question, the respondents were able to give their own opinion regarding the proposed automated electronic radio log. After all the additional comments of the respondents were collected, the authors performed their coding with the following codes: Digitalization, Automation, Data oversight, and Changeless. Again, a triangulation with quantitative data was performed, in order to verify the additional comments of the respondents. Namely, the answers offered to this question quantified the extent to which the respondents agree with the authors' proposal on electronic and automated radio log: "Fully agree", "Partially agree", and "Disagree at all" (Figure 12). The code Automation matches the quantitative answer "Fully agree", since some of the respondents wrote that they would like complete automation of the radio logging process. The codes Digitalization and Data oversight

match the quantitative answer "Partially agree", since some of the respondents wrote that they would like an electronic form of the radio log, but believe that its full automation would lead to data oversight. Again, the code Changeless matches the quantitative answer "Disagree at all", since some of the respondents stated that they would not like to change anything regarding the radio log.

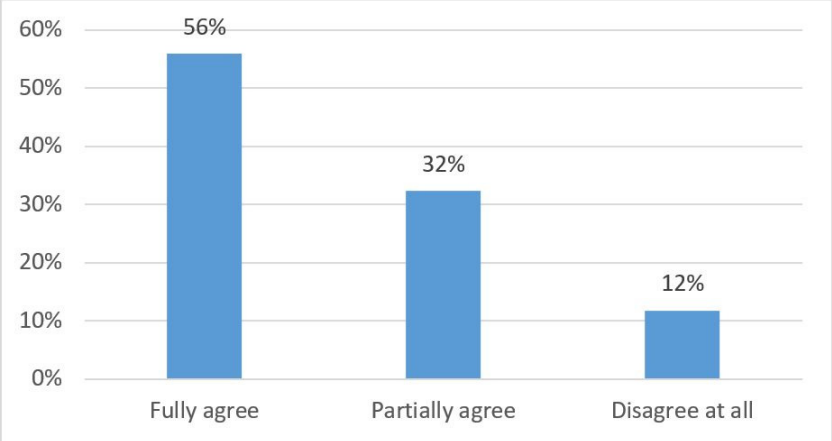

Figure 12. Respondents' compliance with automated electronic radio log.

Of the respondents who gave their additional opinion (29% of respondents), 40% would not want an automated electronic radio log. Again, such an opinion cannot be correlated with the age of the respondents, because within this 40% of the respondents there are seafarers of all ages (20 years–50 years). The same is true for respondents who gave positive comments in terms of paperwork reduction. Some of the additional comments, which the authors found significant are "All ISM should be paperless and electronically filled"—56 years; "The Deck Logbook already exists in electronic form and is used, so in that case, it only needs to be upgraded to contain the radio log in it"—53 years; "I completely agree, for the reason of reducing paperwork and unnecessarily filling in a large number of logs, and devoting more time to navigation"—35 years; and "Given that today more and more navigation is going in the digital direction, communication and 'record-keeping' should be integrated and developed in that direction"—32 years.

3.11. Reliability and Correlation Analyses of the Survey Questions and Answers

Regarding the reliability analysis of the survey, the authors used XLSTAT statistical software for Microsoft Excel. As the questions have different answers, reliability analysis could not be done on the whole dataset. Therefore, first the reliability analysis was done on the first six questions, where the offered answers "0 times", "1–2 times", "3–4 times", "5–10 times", and ">10 times" were numbered from 1 to 5, respectively. The obtained value of Cronbach's alpha was 0.494, which was not acceptable. However, after analyzing the results of the survey, it can be concluded that unlike other devices, the VHF radiotelephone is often used and therefore, the answers to the first question are not consistent with the answers to the other questions. After removing the answer to the first question (for VHF radiotelephone) the value of Cronbach's alpha was 0.751, which indicates a very good reliability of the survey questions.

After that, the reliability analysis was performed on the next two questions, where the answers "Upon message receipt", "Periodically during watch", "On daily basis", "On weekly basis", and "On monthly basis" were also numbered from 1 to 5, respectively. The obtained value of Cronbach's alpha was 0.628, which also indicates a very good reliability of these survey questions.

Finally, the reliability analysis was performed on the last two questions, where the offered answers "Completely agree", "Partially agree", and "Disagree at all" were numbered

from 1 to 3, respectively. The obtained value of Cronbach's alpha was 0.758, which also indicates a very good reliability of the survey questions.

Figure 13 represents the Pearson correlation matrix between respondents' answers to every question, including their age. The variable representing the age of the respondents was categorized and numbered (Figure 2), in order to be able to calculate the Pearson correlation coefficients. The values in bold in Figure 13 indicate the significance of the correlation coefficients at a 0.05 significance level.

Correlation matrix (Pearson):

Variables	AGE	VHF RT	VHF DSC	MF/HF RT	MF/HF TLX	MF/HF DSC	INMARSAT-C	NAVTEX	EGC	REDUCTION AND INTEGRATION	ELECTRONIC RADIO LOG
AGE	**1**	0.018	−0.066	−0.101	−0.025	−0.101	**0.428**	−0.101	−0.031	0.179	0.065
VHF RT	0.018	**1**	0.107	−0.057	−0.018	−0.057	−0.144	0.314	**0.409**	−0.278	−0.185
VHF DSC	−0.066	0.107	**1**	**0.622**	**0.456**	**0.622**	0.205	−0.128	−0.075	0.276	**0.488**
MF/HF RT	−0.101	−0.057	**0.622**	**1**	**0.852**	**0.717**	0.301	−0.026	0.164	0.138	0.218
MF/HF TLX	−0.025	−0.018	**0.456**	**0.852**	**1**	**0.530**	0.257	0.101	0.280	0.266	0.185
MF/HF DSC	−0.101	−0.057	**0.622**	**0.717**	**0.530**	**1**	**0.452**	−0.170	−0.164	0.138	**0.350**
INMARSAT-C	**0.428**	−0.144	0.205	0.301	0.257	**0.452**	**1**	−0.115	−0.044	**0.451**	**0.421**
NAVTEX	−0.101	0.314	−0.128	−0.026	0.101	−0.170	−0.115	**1**	**0.461**	0.143	−0.059
EGC	−0.031	**0.409**	−0.075	0.164	0.280	−0.164	−0.044	**0.461**	**1**	−0.114	−0.077
REDUCTION AND INTEGRATION	0.179	−0.278	0.276	0.138	0.266	0.138	**0.451**	0.143	−0.114	**1**	**0.627**
ELECTRONIC RADIO LOG	0.065	−0.185	**0.488**	0.218	0.185	**0.350**	**0.421**	−0.059	−0.077	**0.627**	**1**

Values in bold are different from 0 with a significance level alpha = 0.05

Figure 13. Pearson correlation matrix of the respondents' answers.

To begin with, the low correlation coefficients between the age of the respondents and reduction and integration of GMDSS equipment as well as the electronic radio log confirm the conclusions of the analysis conducted in Sections 3.9 and 3.10—there is no correlation between the age of the respondents and their desire for GMDSS modernization. In addition, according to the coefficients in bold, it is evident that there is a positive correlation in the answers to the last two questions on the reduction and integration of the equipment and electronic radio log, i.e., on the modernization of the GMDSS.

Furthermore, according to the coefficients in bold, a positive correlation can be seen in the responses on the use of VHF DSC, MF/HF radiotelephone, MF/HF radio telex, and MF/HF DSC, which supports the analysis results on the use of these devices in Sections 3.2–3.6, i.e., they are very rarely used during a single watch.

Finally, it can be seen that there is a positive correlation in the answers to the questions on the use of NAVTEX and EGC receivers, i.e., on reading the received safety messages. Again, this correlation supports the results of the analysis in Sections 3.7 and 3.8.

4. Discussion

The main findings of the conducted research are:

1. The VHF radiotelephone, NAVTEX receiver and EGC receiver are often used and therefore still necessary on SOLAS ships;
2. The DSC, in general, as well as MF/HF installation (telephone and telex), are almost unused on SOLAS ships;
3. More than 80% of respondents expect modernization of GMDSS in terms of integration with existing bridge systems and changes to the existing GMDSS technical platform.

Due to its simplicity and efficiency, the VHF radiotelephone is the most widely and frequently used GMDSS communication equipment. Although it uses analogue open VHF channels, it can very easily be used for almost all GMDSS communication functions: alerting (distress call), SAR coordinating communications, on-scene communications, transmission (and reception) of MSI, general communications, and bridge-to-bridge communications. This was confirmed by the analysis of the survey results. Namely, none of the respondents answered that they do not use a VHF radiotelephone, while 6% of them stated that they use it more than 10 times during a single watch. Furthermore, the analysis of the

survey results showed that MSI receiving devices (NAVTEX and EGC receiver) are used daily for reading messages related to the safety of navigation either immediately upon receipt or periodically during a single watch.

The DSC (VHF and MF/HF) proved to be a missed modernization concept of the communications at the time of its introduction, because, in addition to not being used for calling, as shown by the survey results, it may act as a distraction during demanding navigational situations [17]. As its name suggests, the device is intended only for calling, not communication. However, it is easier for seafarers to establish a contact by telephone (either satellite or terrestrial) rather than browse and type the necessary data to make a DSC call (MMSI, working channel, etc.). Besides, the analysis of the survey results showed that MF/HF installation (telephone and telex) are seldom used during a single watch on SOLAS ships (almost 90% of respondents are not using that equipment). Although still mandatory in some GMDSS sea areas, outdated technology and the cessation of mandatory watchkeeping have caused their seldom or no use by seafarers.

In addition to examining the frequency of use of GMDSS devices, the authors wanted to examine respondents' opinions on the possible reduction and integration of GMDSS equipment within information systems. The authors believe that the modernization of GMDSS should include the spatial organization of the system (deployment of GMDSS units) to facilitate radiocommunications, both emergency and general. As can be seen from Figure 1, the compact GMDSS console consists of multiple devices, which have different interfaces taking a lot of space. Thus, the authors suggest that the ship's bridge should have a unique interface of GMDSS equipment which could be on the conning display, ECDIS, or some new integrated GMDSS management system. Among all the respondents, only 14% disagree with this authors' proposal. Besides, the authors also suggested the use of an automated electronic radio log, and only 12% of the respondents disagree with that proposal.

It should be emphasized that the modernization of GMDSS has already begun. For example, the NAVTEX receiver can optionally be integrated within the ECDIS for displaying MSI. In terms of its modernization, its successor Navigational Data (NAVDAT), is in the development and testing phase, which will provide additional possibilities for displaying MSI [18]. Besides, the satellite system for receiving MSI, i.e., INMARSAT's EGC SafetyNET, also got its successor EGC SafetyNET II as part of INMARSAT's modernization of GMDSS services [14].

One of the systems that can serve to modernize GMDSS, if included in its infrastructure, is the VHF Data Exchange System (VDES), which was developed as a direct response to congestion of Automatic Identification System (AIS) [19–22]. Namely, a study conducted in 2013 by the International Telecommunication Union (ITU) has proved that in some parts of the world with dense maritime traffic, a limit of 50% of the data link capacity, which represents the critical level of the ship's AIS station, has been reached [23]. The causes of reaching 50% of AIS channel capacity are dense maritime traffic, use of Application Specific Messages (ASM), additional AIS stations such as AIS Aids to Navigation (AtoN), too much coastal AIS station information, as well as atmospheric effects [24]. It can be concluded that the AIS in some areas is at the edge of its capacity, while some GMDSS devices are not used, but must be installed on ships concerning the area of navigation. Therefore, the VDES can be seen as a successor to AIS (AIS represents only one of the VDES possibilities for data exchange) and its capabilities could improve certain services of today's GMDSS. As an example, the survey has shown that the INMARSAT-C SES is used almost exclusively when receiving EGC messages (Figures 10 and 12). According to its features, the VDES could support the reception of EGC messages with the additional possibility of global coverage (VDES will also have a LEO satellite component), which INMARSAT-C cannot satisfy (due to GEO satellites). If the modernization of GMDSS is considered in the function of improving the safety of navigation and information exchange with land services related to port operations and safety of navigation, VDES could serve as a communication platform that ensures the automatic exchange of information between ship and coastal stations [25].

In addition to contributing to the acceleration of the communication process with the ship's environment, it can also serve as a single data platform in achieving e-Navigation, as a given development goal [26,27].

5. Conclusions

We live in the 21st century where technology is advancing day by day making life easier. However, the GMDSS has not changed significantly in technological terms since its introduction (back in 1999). The authors believe that the time has come for GMDSS modernization, not only on a technological level but also on a conceptual level. Therefore, the items in the questionnaire survey were very precisely structured, indicating in each question for what purpose and how often each device was used during one watch. The research revealed the extent to which experienced seafarers use each individual GMDSS device during one of their watches. Thus, unlike other researches on the topic of GMDSS modernization, quantitative answers were obtained on the frequency of use of each individual device during a single watch. The survey results showed that some GMDSS devices are hardly used during the watch on the ship's bridge (MF/HF radio station and DSC in general). In addition, a qualitative analysis of respondents' opinions revealed that experienced seafarers want the GMDSS modernization in terms of spatial equipment reduction and integration on a ship's bridge, as well as in terms of paperwork reduction and process automation, which has not been presented in previous researches.

However, it should be noted that GMDSS is primarily designed for emergencies, which occur extremely rarely. So, the fact that the survey results showed that it is not used a lot does not mean that it is not necessary and useful in distress situations. Thus, the aim of the survey was not to prove that GMDSS equipment is not needed, but that its modernization is needed. The spatial reduction, functional improvement, and integration of GMDSS equipment on the ship's bridge would certainly modernize communications of all priorities (distress, urgency, safety, and routine) and also facilitate OOW's daily navigation. Of course, each change (improvement) of the equipment also requires a certain type of familiarization and training that takes time. However, it should be emphasized that according to the current IMO's Model Course 1.25, the training for the General Operator's Certificate (GOC) for the GMDSS suggests a total of 108 h for lectures, practice, and examination.

One of the systems mentioned in the maritime community in the context of GMDSS modernization is certainly the VDES, which represents the future of maritime communications, both distress/safety and general/commercial. In addition, new maritime terrestrial (NAVDAT) and satellite communication systems (Iridium) and services (INMARSAT Fleet Safety, SafetyNET II) have already started to be used (tested) in some areas.

Therefore, more similar research, in terms of precisely structured survey items, is needed to gather important information from practice (from seafarers) in order to develop and standardize guidelines for future change and upgrade of the GMDSS system. Additional research that will continue in this direction could include a correlation analysis between accidents at sea and the use of GMDSS equipment to report them, to show whether this equipment is really necessary onboard ships.

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