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ENSURING ELECTROMAGNETIC COMPATIBILITY ON NEWLY BUILT VESSELS FOR THE POLISH NAVY

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ABSTRACT

The need to confirm compliance with the requirements of the Polish Defence Standards, STANAGs and shipping classification societies documents poses new challenges for manufacturers and suppliers of ship's equipment and systems. This is related to the continuous technical evolution of electronic and electrotechnical devices, especially in the field of wireless transmission and data exchange. These challenges also apply to research laboratories, which must keep up with both the technological changes of the examined objects and the updating of requirements and reference documents. It is connected with the necessity of constant development in the area of technical facilities and competences. This paper presents an overview of the currently binding requirements for devices and systems for newly built vessels, with particular regard on the area of electromagnetic compatibility. It indicates the planned trends of changes of these requirements in relation to the technical evolution of devices. Discussion with several examples of problems and challenges faced by both equipment suppliers and research laboratories engineers were presented.

Key words:
electromagnetic compatibility (EMC), research, requirements.

Research article

INTRODUCTION

New projects related to the construction of newly built vessels for the Polish Navy determine a lot of challenges for designers, constructors and suppliers of marine technology devices and subsystems. On the one hand this is an effect of very sophisticated and specialized requirements along with functionality and operational scenarios. On the second hand dynamic technology development brings the need to keep up with new, available and planned technical solutions and international standards.

One of the essential areas of designers work is to ensure electromagnetic compatibility (EMC) at each stage of the project. All of the electric or electronic ship devices or installations influence each other when interconnected or close to each another, for example as an effect of mutual interferences. The purpose of EMC is to keep control for all of those unwanted effects, without the disruption in its operation and functionality. Generally EMC applies for reducing disturbance and enhancing immunity to all the existing and future techniques and technologies. EMC ensures that electrical and electronic equipment does not generate, or is not affected by, electromagnetic disturbance. All devices which are implemented need to comply with EMC requirements.

REQUIREMENTS AND REGULATIONS

Selection of reference documents, such as international standards and EU directives, mainly depend on the purpose and classification of the object that has to comply them. Electromagnetic compatibility with regard to technologies used in the maritime industry is regulated by a set of civil standards and norms, as well as reference documents related to military use. In addition, there are also publications of classification societies containing a set of requirements for marine equipment.

The commercial market is primarily regulated by the electromagnetic compatibility directive EMC 2014/30/EU and the radio directive RED 2014/53/EU, which are sets of requirements selected for multi-purpose devices. Mentioned EU directives contain lists of applicable standards that are constantly updated due to continuous technological progress. For example, all devices included in ship systems can be qualified as multimedia devices (computers, monitors, network devices, etc.). Therefore, assembled on vessels should refer to the emission requirements regulated by the standard dedicated for such devices, i.e. PN-EN 55032:2015 [15]. However, the currently applicable requirements for marine systems do not apply this standard.

Another reference document in the maritime industry applicable in Poland is PN-IEC 60533 (Electrical and electronic installations on ships) issued in 2002 [16]. It is a translation of the official language version of the IEC 60533 international standard dated 1999. Currently valid international standard is dated 2015 and don't have obligatory polish version. So the difference between those requirements is over 15 years, which is a long very period for electronic equipment. The document was published in Poland was published in the years when wireless technologies began to develop, which is why the electromagnetic environment, as well as emission and immunity requirements were different.

Equipment intended for ships must also meet the requirements of classification societies. In the case of the civil market, one of the reference documents is Publication No. 11/P of the Polish Register of Shipping [13]. The Polish Register of Shipping is a classification society recognized by the European Commission for conducting inspections and surveys on marine and inland vessels. Publication No. 11/P specifies the scope and conditions of testing electrical, electronic and programmable equipment included control, monitoring and operational systems, as well as installations and security systems intended for installation on ships. The publication contains a description of the tests, most of which are based on commercial standards in the field of electromagnetic compatibility. The publication also contains descriptions of tests in the field of electrical energy quality tests, safety tests and environmental tests. Polish Register of Shipping has published also Publication No. 75/P relating to the navy vessels [14]. This publication is dated on 2006 and do not follow currently applicable military standards. It needs updating.

Reference document prepared by the Det Norske Veritas (DNV) is Class Guideline DNVGL-CG-0339 (Environmental test specification for electrical, electronic and programmable equipment and systems) issued in November 2015, specifies the requirements of electromagnetic compatibility tests, electrical tests and environmental devices intended for vessels [1]. It refers to instrumentation and automation devices, such as: hydraulic, pneumatic, electric, electromechanical and electronic equipment, including computers and peripherals.

The next reference document is the Lloyd's Register Classification and Regulations for the Classification of Naval Ships [4]. The document was released in January 2017, therefore it refers to new technological solutions, at the same time taking into account the management of electromagnetic compatibility on ships.

Requirements in the field of electromagnetic compatibility in the military industry are regulated by a set of defense standards. In Poland the most commonly used are NO-06-A200:2012 [6] and NO-06-A500:2012 [7], which are the equivalent of the American MIL-STD 461F standard [5]. The latest version of MIL-STD 461 is the G version and the changes compared to the previous version mainly consist in corrections resulting from the update of standards and test stands for new technologies needed. So NO-06-A200 and NO-06-A500 standards also need to update.

The next military reference document is the NO-06-A511 (Part 1-5) dated 2013 [8 –12], which was developed on the basis of the international document Defense Standard 59-411 from 2007. The standard contains product guidelines and EMC requirements specifications for military equipment and systems as well as guidelines for purchasing commercial products.

The intention of this article is the presentation of results of analysis and review of a wide range of requirements, regarding the compliance of electromagnetic compatibility on naval vessels. The intention of the article is also to signaling the problem of the lack of coherence in the existing reference documents and the resulting problems and challenges faced by designers, producers and suppliers of military equipment. This problem also applies to research laboratories that provide services for the assessment of product conformity. The examples of those challenges have been presented in the paper.

Due to the wide range of various test procedures and test methods based on applicable standards, there is no database of results that would allow to show the problem in an analytical way. The intention of this article is not to show the analysis of research results, because their database is very limited. Moreover, these are mostly restricted data that should not be explicitly presented in scientific publications.

CHALLENGES

The procedures and requirements described in the standards relating to the commercial market for equipment intended for vessels and industrial equipment mostly overlap. But lot of updating work has to be performed. With regard to defense standards, differences can be noticed both in the scope of tests and technical parameters. Moreover, the ranges of tests may be divergent within defense standards — for example the measurement of emissions of electromagnetic disturbances conducted according to the norm NO-06-A500 [7] is carried out in the frequency range 10 kHz–10 MHz, while a similar test according to the norm NO-06-A511 [10] is carried out in the frequency range of 500 Hz–100 MHz. So one of the challenges is proper choice of requirements set which should be provided to the EMC lab before starting test procedures. The full set of tests should be agreed by provider of onboard equipment with end user representatives.

All procedures contained in reference documents should be performed in accredited and competent research laboratories, which are scarce in Poland, and each has a narrow specialization that does not often cover the whole scope of required research. Hence the need to perform tests in various laboratories, and this translates into lot of complications, including logistics, time and cost of testing.

Another challenge is related to meeting the requirements is access to appropriate standards, which may be restricted documents. Therefore, to store and circulate such a document, it is required to have a special procedures and infrastructure for work with classified documents [3].

GOOD LABORATORY PRACTICE

Good laboratory practice recommends starting EMC-related activities from the very beginning of the project.

Ensuring compliance with a number of standards related to electromagnetic compatibility should be preceded by a correct EMC management plan. This plan should take into account the requirements that a given system or device should meet. This plan should be created at the stage of developing technical assumptions. At the first stage of the project — beginning of the technical design, the technical assumptions of a given system or device should start with the analysis of the set of standards. As it was presented earlier these standards have large discrepancies regarding the requirements for emission compliance and electromagnetic immunity. The frequency ranges as well as the level of electromagnetic disturbances should be analyzed here. Pay attention not only to the requirements, but also to the test method. Requirements standards often refer to other standards related to test methods. The fulfillment of requirements and the test method must be closely related [8].

The directives contain requirements that a given system should meet and the test method, recalling the relevant standard. But in a given directive there are often additional information that is not present in the test method, such as the frequency of power supply or the grounding method of the device.

The next stage of the project in which EMC issues should be taken into account is the stage of construction and factory testing (FAT — factory acceptance tests) of the subsystem components. It is then necessary to check all devices that were built individually or that were purchased as ready-made (commercial off the shelf — COTS) ones that meet, for example, only civil standards.

Standards for defense-related devices contain much more stringent requirements. Compliance with civil norms does not guarantee compliance with the Defense standards. For example, radiated immunity test for industrial devices is performed for a sinusoidal modulation signal at 10 V/m in the frequency range from 80.0 MHz to 2.7 GHz [15]. For devices complying the defense standard for land forces equipment radiated immunity test is performed for modulation of a rectangular signal at the signal level of 50 V/m in the range frequencies from 2.0 MHz to 18.0 GHz [7]. The full set of EMC requirement should be selected by system provider. For effective research schedule in EMC lab provider of vessel equipment should prepare test program and send it along with tested equipment.

The third stage in project, in EMC ensuring aspect, are tests for fully operational subsystem. At this stage, all devices of the subsystem should be connected and integrated and its functional operation should be checked along with preparation and for whole subsystem EMC testing. It is very important that during the laboratory tests the configuration and functional features of the subsystem reflect as accurately as possible the situation on the ship [11]. This is particularly difficult when the subject of the research is a system dispersed across the entire ship and it is hard to perform even a model that ensures the performance of research of real system model. Often, systems consist of many devices, e.g. a fire protection system. There are a lot of different sensors mounted around the ship. The ship is divided into several EMC zones with different disturbance conditions, e.g. from radars, radio-communication, navigation, etc. Devices mounted under the deck acc. NO-06-A500 standards meet more stringent criteria than onboard devices. Therefore, for such a system it would be necessary to accept the worst conditions. Sensors that are mounted on the deck should meet higher requirements from sensors mounted under the deck and from the control center which is also below the deck [7].

The selection of subsystem equipment and full configuration of devices with the system, as well as any type of data transmission that will be on the ship should be tested in electromagnetic compatibility laboratories. Preparation of test equipment is as important as laboratory testing. There are systems on ships that require a high level of power to run and operate. In this case, the laboratory may have problems in providing the required conditions powered by the needs of tests. The only solution in this case will be, where possible, testing in the place of installation or in a place where the laboratory client will provide the right conditions for testing.

The next stage is EMC ensuring is verification through the tests on the vessel. Such tests require a very detailed analysis in terms of their ability to perform them on the ship in reference to labs technical capabilities. After installing the devices, there is often no access to power cables that are very important during conducted immunity and emissions measurement. Even if there is an access to cables but it is not possible to distribute/separate them for measuring conducted emissions, it cannot be separated and determined whether the source of high conducted emission is the tested device (or system) or high level of conducted emission is from other devices. During exposures of conductive immunity acc. the defensive standard should also be separated from the power supply with the line impedance stabilization network (LISN) in which the device is separated from the mains. Performing immunity without such separation results in the fact that the exposure goes to the supply network which can lead to damage to other devices that are not test object.

Another challenge with onboard EMC test is number of equipment and subsystem's elements on the vessel. When there is a limited time in project schedule provider or end user/the owner of the vessel should choose the most critical subsystems with the highest priority for EMC testing.

Another problem that can be encountered during shipboard research is limited space. To make radiated immunity and radiated emission tests, it is necessary to use a large antennas, which must be placed one meter from the device under test. Often the devices are mounted in such places where it is impossible to provide conditions to bring or set the antenna according to the standard requirements. The implementation of radiated immunity test on the ship is also connected with the fact that all devices installed next to the tested device are exposed, there are not always possible to turn them off or to secure them.

During the EMC tests, it is necessary to ensure the safety of the testing personnel as well as ship crew which should not be exposed. Therefore, despite performing the test at the place of installation, we must configure the device so that it can be monitored in a different place or assisted with such devices as, for example, high-speed cameras to monitor the operation of the system. Therefore, despite performing the test at the place of installation, the device must be configured in such a way that its operation can be monitored in a place that is safe for the testing personnel or supported by devices such as high speed cameras for system monitoring.

EMC equipment is very sensitive and sophisticated and must work in appropriate environmental/weather conditions. This is the manufacturer's requirement to ensure correct measurements and ensure that the equipment wouldn't be damaged.

Therefore, during the research planning, environmental conditions and time of the year should be taken into account. Possibility of changing weather conditions should be taken as one of the risk management element.

PRACTICLE EXAMPLES

The device submitted for testing should be safe for the operator and laboratory staff. The lab customer should pay attention to such elements as:
- insulated connectors and live wires;
- protected moving parts of the device;
- protection against harmful agents (e.g. ozone);
- protection against high or low temperatures (e.g. heaters);
- sharp edges of devices.

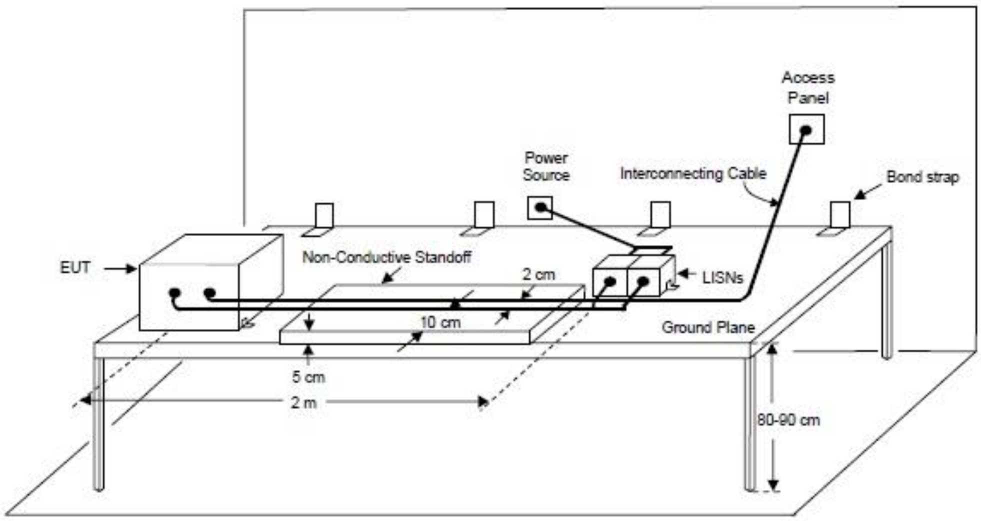

Fig. 1. Test set-up for conductive surface mounted EUT according to NO-06-A500:2012 [7]

During testing, the device should work in accordance with its functional and operational application and mode. If the device has different modes of operation, test should be perform in these modes or choose one of the most critical in which it has the highest emission level or is the least resistant to the exposure. Devices which under normal conditions are loaded and this cannot be done in laboratory conditions should be charged with a substitute loading method.

Fig. 2. Test set-up for conductive surface mounted EUT

The test object whose housing will ultimately be grounded should be adequately grounded during EMC tests. For example, as required, the earth resistance between the earthing pin and the farthest metal element of the device should be less than 2 mΩ. Grounding the device should have such features:

– sufficiently large wire cross-section;
– durable, solid connection;
– connecting structural elements (e.g. door);
– proper earthing contact (no paint between pin and housing).

During radiated emission test, the outgoing wires from the test device act as antennas. To suppress and reduce this radiation, ferrites are often used. However, it is important to choose them sensibly and basing on its parameters. Thanks to data sheets and pre-compliance measurements in the laboratory, the ferrite can be precisely selected to the appropriate frequency range. Ferrites allow to reduce emissions by several decibels.

Fig. 3. Test set-up for free standing EUT, in situ test

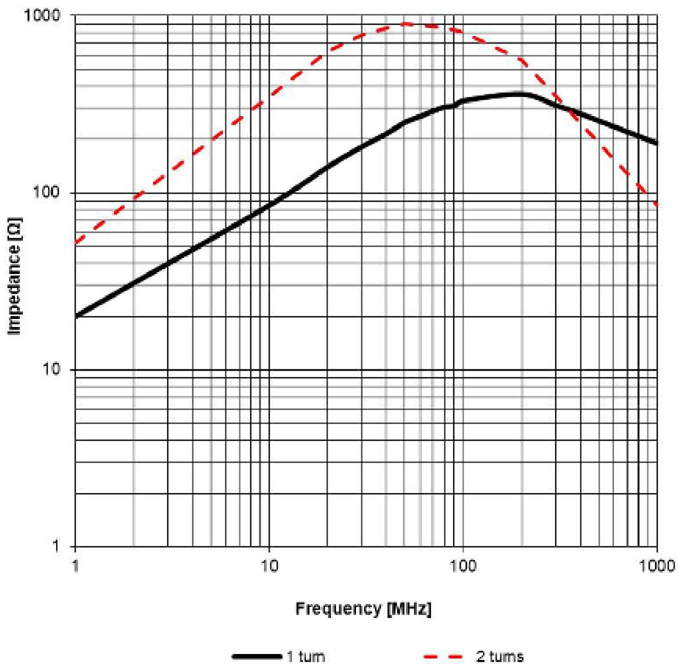

Fig. 4. Typical example of impedance in frequency range characteristic of ferrite [http://we-online.com (access 16.04.2018)]

EMC grids are helpful when it is not possible to close the device tightly and the emission level exceeds the permissible level. They are often used when ventilation holes are needed in the device. The nets are also used as sealing in cable glands. The density of such a grid should be chosen due to the technical possibilities of cooling the device and also due to the frequency (wavelength) of the emission.

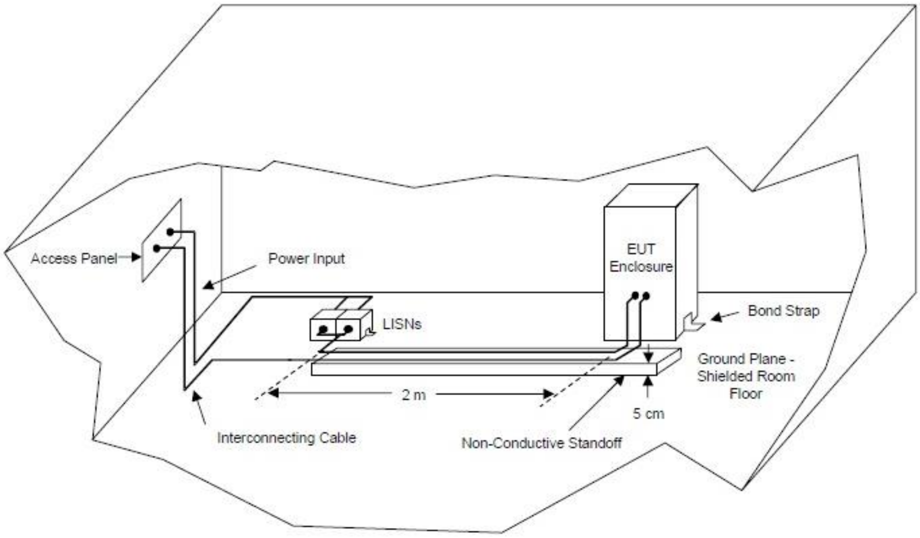

Fig. 5. Test set-up for free standing EUT in shielded enclosure according to NO-06-A500:2012 [7]

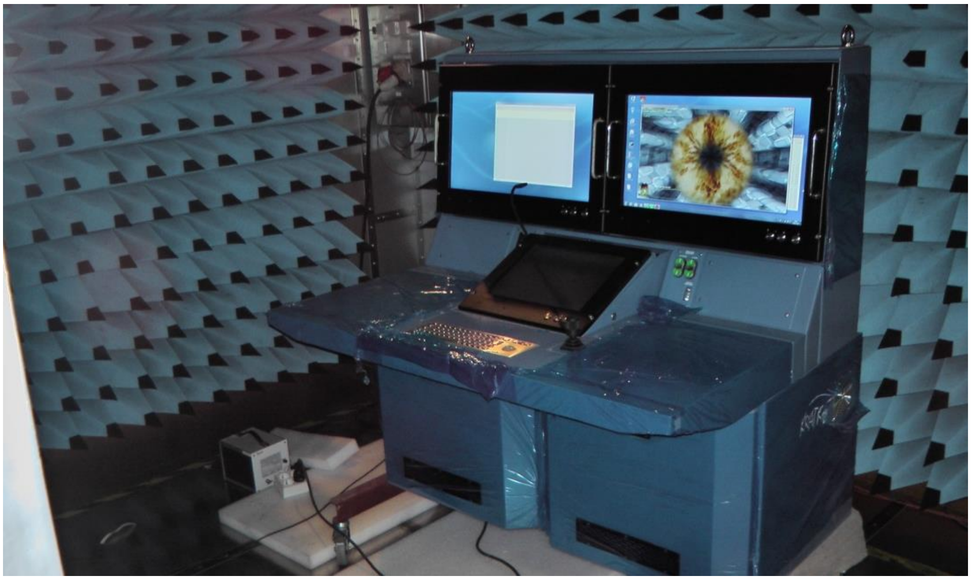

Fig. 6. Test set-up for free standing EUT in shielded enclosure according

CONCLUSIONS

Specifying the requirements of electromagnetic compatibility at each stage of the project, as well as planning the appropriate amount of time for research allows to ensure the correct operation of the system and also minimize unnecessary problems with the devices during its exploitation.

In the EMC ensuring area for marine and navy technology devices requirements and regulations can be divided in three main parts:

1. Commercial standards
   Those standards are typically harmonized with European Directives (for example 2014/30/EU, 2014/53/EU). It consists the full scope of immunity and emission tests appropriately selected depending on the tested object. Due to the development of modern technical solutions, these standards are subject to frequent reviews and updates, to keep up with market and customer demands.
2. Classification societies standards
   It is a set of requirements developed and collected in publications by international classification societies, such as Polish Register of Shipping, Det Norske Veritas, Lloyd's Register or Germanischer Lloyd. It is mostly based on the commercial EMC, environmental and safety standards, with additional not standardized test.
3. Military standards
   It is a very wide set of specialized standards, similarly prepared depending on the type and purpose of devices. Depending on the country and type of forces it can be the range of Polish Defence Standards, STANAG, MIL-STD, DEF-STAN.

Despite of similar test procedures those standards not always are correlated. For example if equipment comply classification societies standard it doesn't mean that it will comply military standards. There are differences between detail parameters or test procedures and if it is not verified at the early stage of project it rises the EMC risk.

Proper planning of EMC tests should take into account both the scope of research and the place where it will be performed. When it is necessary to use the services of an accredited laboratory, it is necessary to analyze their technical capabilities. Basic knowledge about the EMC tests would be helpful and allows for proper preparation of the test system.

REFERENCES

[1] DNVGL-CG-0339, Class Guideline, *Environmental test specification for electrical, electronic and programmable equipment and systems*, November 2015.

[2] *Guide to Marine EMC. Regulations, Tests & Preparation*, Elite Electronic Engineering, Inc.

[3] Leersum B. van, Leferink F., Rij M. van, Ven J.-K. van der, *Cost-effective Electromagnetic Compatibility Installation on Ships using a Risk Based Approach*, International Symposium on Electromagnetic Compatibility, EMC EUROPE, September 2017.

[4] Lloyd's Register, *Rules and Regulations for the Classification of Naval Ships*, January 2017.

[5] *MIL-STD-461F Requirements for the control of electromagnetic interference characteristics of subsystems and equipment*, Department of Defence Interface Standard, December 2007.

[6] NO-06-A200:2012, *Kompatybilność elektromagnetyczna. Dopuszczalne poziomy emisji ubocznych i odporność na narażenia elektromagnetyczne*, MON, 2012 [*Electromagnetic Compatibility. Limit levels of electromagnetic interferences and susceptibility* — avaiable in Polish].

[7] NO-06-A500:2012, *Kompatybilność elektromagnetyczna. Procedury badań zaburzeń elektromagnetycznych i odporności na narażenia elektromagnetyczne*, MON, 2012 [*Electromagnetic Compatibility. Test methods of electromagnetic interferences and susceptibility* — avaiable in Polish].

[8] NO-06-A511-1:2013, *Kompatybilność elektromagnetyczna*, cz. 1, *Zarządzanie i planowanie realizacji wyrobu*, MON, 2013 [*Electromagnetic Compatibility*, Part 1, *Realization of product management and planning process* — available in Polish].

[9] NO-06-A511-2:2013, *Kompatybilność elektromagnetyczna*, cz. 2, *Elektryczne, magnetyczne i elektromagnetyczne środowisko*, MON, 2013 [*Electromagnetic Compatibility*, Part 2, *The Electric, Magnetic & Electromagnetic Environment* — available in Polish].

[10] NO-06-A511-3:2014, *Kompatybilność elektromagnetyczna*, cz. 3, *Wymagania i metody badań sprzętu wojskowego*, MON, 2014 [*Electromagnetic Compatibility*, Part 3, *Requirements and methods of testing military equipment* — available in Polish].

[11] NO-06-A511-4:2014, *Kompatybilność elektromagnetyczna*, cz. 4, *Badania i próby systemów oraz platform*, MON, 2014 [*Electromagnetic Compatibility*, Part 4, *Tests and trials of platforms and systems* — available in Polish].

[12] NO-06-A511-5:2016, *Kompatybilność elektromagnetyczna*, cz. 5, *Projektowanie i instalowanie sprzętu wojskowego*, MON, 2016 [*Electromagnetic Compatibility*, Part 5, *Design and installation military equipment* — available in Polish].

[13] Polski Rejestr Statków, *Publication No. 11/P Environmental tests on marine equipment*, Gdańsk 2016.

[14] Polski Rejestr Statków, *Publication No. 75/P Environmental tests on naval ships equipment*, Gdańsk 2006.

[15] PN-EN 55032:2015-09/AC, *Electromagnetic compatibility of multimedia equipment — Emission Requirements*, Polski Komitet Normalizacyjny, Warszawa 2016.

[16] PN-IEC 60533:2002, *Electrical and electronic installations in ships — Electromagnetic compatibility (EMC) — Ships with a metallic hull*, Warszawa 2002.

ZAPEWNIENIE KOMPATYBILNOŚCI ELEKTROMAGNETYCZNEJ NA NOWO BUDOWANYCH JEDNOSTKACH MW RP

STRESZCZENIE

Konieczność potwierdzenia zgodności z wymaganiami norm obronnych, standardów Paktu Północnoatlantyckiego oraz dokumentów towarzystw klasyfikacyjnych stawia coraz to nowe wyzwania przed producentami i dostawcami urządzeń i systemów okrętowych. Ma to związek z ciągłym rozwojem technicznym urządzeń elektronicznych i elektrotechnicznych, szczególnie w zakresie bezprzewodowej transmisji i wymiany danych. Wyzwania te dotyczą również laboratoriów badawczych, które muszą nadążać zarówno za zmianami technologicznymi badanych obiektów, jak i aktualizacją wymagań oraz dokumentów odniesienia. Wiąże się to z koniecznością ciągłego rozwoju w zakresie zaplecza technicznego i kompetencji. W artykule przedstawiono przegląd obecnie obowiązujących wymagań dla urządzeń i systemów przeznaczonych na nowo budowane jednostki, ze szczególnym uwzględnieniem obszaru kompatybilności elektromagnetycznej. Wskazano trendy w rozwoju technicznym urządzeń i omówiono na przykładach problemy oraz wyzwania, z jakimi borykają się zarówno dostawcy sprzętu, jak i inżynierowie laboratoriów badawczych.

Słowa kluczowe:
kompatybilność elektromagnetyczna, badania, wymagania.

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