BS IEC 60533:2015

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Electrical and electronic installations in ships — Electromagnetic compatibility (EMC) — Ships with a metallic hull

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee JPEL/18, Electrical installations of ships and of mobile and fixed offshore units.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Published by BSI Standards Limited 2015

ISBN 978 0 580 83060 0
ICS 33.100.01; 33.100.10; 47.020.60

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2015.

Amendments/corrigenda issued since publication

Date	Text affected

IEC 60533

Edition 3.0 2015-08

INTERNATIONAL STANDARD

Electrical and electronic installations in ships – Electromagnetic compatibility (EMC) – Ships with a metallic hull

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.100; 33.100.10; 47.020

ISBN 978-2-8322-2849-4

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ELECTRICAL AND ELECTRONIC INSTALLATIONS IN SHIPS – ELECTROMAGNETIC COMPATIBILITY (EMC) – SHIPS WITH A METALLIC HULL

FOREWORD

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International Standard IEC 60533 has been prepared by IEC technical committee 18: Electrical installations of ships and of mobile and fixed offshore units.

This third edition cancels and replaces the second edition, published in 1999. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

– Introduction has been supplemented;
– scope and title have been modified to limit the application of the standard to installations in ships with metallic hulls only;
– the normative references have been updated;
– further explanation for in-situ testing has been given in 5.1;
– numbering of CISPR-Standards in Tables 1, 2 and 3 has been updated;

– title of Annex B has been changed;
– requirements on cable routing in Annex B have been amended;
– new Annex C EMC test report has been added.

The text of this standard is based on the following documents:

FDIS	Report on voting
18/1460/FDIS	18/1471/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this standard may be issued at a later date.

INTRODUCTION

Electrical installations of ships with electric and/or electronic systems need to operate under a wide range of environmental conditions.

The control of undesired electromagnetic emission ensures that no other device on board will be unduly influenced by the equipment under consideration. Suitable limits are specified.

On the other hand, the equipment needs to function without degradation in the normal electromagnetic environment. The limit values for immunity, specified in this International Standard, have been chosen under this assumption. Equipment which is tested and installed in accordance with this International Standard meets the relevant IMO requirements. Special risks, for instance lightning strikes, transients from the operation of circuit breakers and electromagnetic radiation from radio transmitters are also covered.

Complex electric and/or electronic systems require EMC planning in all phases of design and installation, considering the electromagnetic environment, any special requirements and the equipment performance.

This third edition of IEC 60533 is applicable to electromagnetic compatibility of all electrical and electronic installations in ships with metallic hull.

It is based on the assumption that the ship is constructed in such a way that metallic hull and structure parts will significantly attenuate electromagnetic disturbance from the outer deck environment to the inner deck environment and vice versa.

ELECTRICAL AND ELECTRONIC INSTALLATIONS IN SHIPS – ELECTROMAGNETIC COMPATIBILITY (EMC) – SHIPS WITH A METALLIC HULL

1 Scope

This International Standard specifies minimum requirements for emission, immunity and performance criteria regarding electromagnetic compatibility (EMC) of electrical and electronic equipment for ships with metallic hull. Additional or divergent requirements for ships with non-metallic hull will be given in a future International Standard (IEC 62742).

This International Standard assists in meeting the relevant EMC requirements as stated in SOLAS 74, Chapter IV, Regulation 6 and Chapter V, Regulation 17. Reference to this International Standard is made in IMO Resolution A.813(19).

The normative part of this International Standard has been prepared as a product family EMC standard.

This International Standard further gives guidelines and recommendations on the measures to achieve EMC in the electrical and electronic installations of the following equipment groups:

a) group A: maritime navigation and radio communication equipment and systems;
b) group B: power generation and conversion equipment;
c) group C: equipment operating with pulsed power;
d) group D: switchgear and controlgear;
e) group E: intercommunication and signal processing equipment and control systems;
f) group F: non-electrical items and equipment;
g) group G: integrated systems.

The basic EMC standard for groups A and C is IEC 60945. The EMC requirements according to IEC 60945 apply additionally for

- bridge mounted equipment;
- equipment in close proximity to receiving antennas;
- equipment capable of interfering with the safe navigation of the ship and with radio communication.

Effects on humans, like exposure to electromagnetic fields, and basic safety requirements such as protection against electric shock and dielectric strength tests for equipment are not within the scope of this International Standard.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050 (all parts), International Electrotechnical Vocabulary (available at: www.electropedia.org)

IEC 60945, Maritime navigation and radiocommunication equipment and systems – General requirements – Methods of testing and required test results

IEC 61000-4-2, Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test

IEC 61000-4-3, Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test

IEC 61000-4-4, Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test

IEC 61000-4-5, Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test

IEC 61000-4-6, Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields

IEC 61000-4-11, Electromagnetic compatibility (EMC) – Part 4-11: Testing and measurement techniques – Voltage dips, short interruptions and voltage variations immunity tests

IEC 61000-4-16, Electromagnetic compatibility (EMC) – Part 4-16: Testing and measurement techniques – Test for immunity to conducted common mode disturbances in the frequency range 0 Hz to 150 kHz

IEC 61000-6-1, Electromagnetic compatibility (EMC) – Part 6-1: Generic standards – Immunity for residential, commercial and light-industrial environments

IEC 61000-6-3, Electromagnetic compatibility (EMC) – Part 6-3: Generic standards – Emission standard for residential, commercial and light-industrial environments

CISPR 16-1-2, Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Coupling devices for conducted disturbance measurements

CISPR 16-1-4, Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – Antennas and test sites for radiated disturbance measurements

CISPR 16-2-1, Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements

CISPR 16-2-3, Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-3: Methods of measurement of disturbances and immunity – Radiated disturbance measurements

IACS E10, Test specification for type approval

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-161 and the following apply.

3.1
electromagnetic compatibility
EMC
ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment

[SOURCE: IEC 60050-161:1990, 161-01-07)

3.2
electromagnetic influence
effect of electromagnetic quantities on electrical and electronic circuits, equipment, systems or humans

3.3
electromagnetic interference
EMI
degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance

Note 1 to entry: In French, the terms "perturbation électromagnétique" and "brouillage électromagnétique" designate respectively the cause and the effect, and should not be used indiscriminately.

Note 2 to entry: The English words "interference" and "disturbance" are often used indiscriminately.

[SOURCE: IEC 60050-161:1990, 161-01-06)

3.4
degradation
<of performance> undesired departure in the operational performance of any device, equipment or system from its intended performance

Note 1 to entry: The term "degradation" can apply to temporary or permanent failure.

[SOURCE: IEC 60050-161:1990, 161-01-19]

3.5
loss of function
loss of function of a device beyond that permissible and where the function can be restored only by technical measures

Note 1 to entry: A special case of loss of function is destruction.

Note 2 to entry: Loss of function may be permanent or temporary:

- technical measures to correct permanent loss require the use of tools or spare parts;
- technical measures to correct temporary loss require simple operator actions such as resetting a computer or reswitching.

3.6
electromagnetic disturbance
any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter

Note 1 to entry: An electromagnetic disturbance may be an electromagnetic noise, an unwanted signal or a change in the propagation medium itself.

[SOURCE: IEC 60050-161:1990, 161-01-05]

3.7
emitter
<of electromagnetic disturbance> device, equipment or system which gives rise to voltages, currents or electromagnetic fields that can act as electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-01-23]

3.8
susceptible device
device, equipment or system whose performance can be degraded by an electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-01-24]

3.9
emission
electromagnetic emission
phenomenon by which electromagnetic energy emanates from a source

[SOURCE: IEC 60050-161:1990, 161-01-08]

3.10
immunity
ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance

[SOURCE: IEC 60050-161:1990, 161-01-20]

3.11
coupling
interaction of circuits between which energy can be transferred

3.12
insertion loss
logarithmic ratio of the magnitude of the power which a load picks up when fed directly from the power source, to the magnitude of the power which the load picks up after inserting a two-port network (for example a filter) between source and load

3.13
return loss
a
logarithmic ratio of the reciprocal value of the reflection factor:

$$a = 20 \times \lg \frac{1}{r};$$

where

r is the ratio of return wave to forward wave

Note 1 to entry: r = 0, a = ∞, if the impedance of the protection circuit is matched to the wave impedance of the connected cable.

3.14
EMC analysis
compilation and interpretation of EMC data to determine the degree of influence with electrical devices

3.15
electromagnetic interference matrix
EMI matrix
structure where emitters are set against susceptible devices

Note 1 to entry: At the crosspoints of lines and columns the extent of electromagnetic interference is noted.

3.16
system
set of devices and/or components which interact according to a design

EXAMPLE Hardware (controlling system, controlled system), software, human interaction.

Note 1 to entry: The total ship with its equipment may be considered to be a system.

3.17
subsystem
single device and/or component intended to perform a given function, combining a number of sub-units, electrically and mechanically

3.18
integrated system
combination of separate systems intended to perform a given function

EXAMPLE Integrated cargo monitoring system with sensors and equipment in different zones.

3.19
ground
earth
point, plane, or surface designated as the zero potential (nominally) and serving as a common reference potential for electrical or electronic equipment

EXAMPLE Ship's metallic structure and all other metal parts conductively interconnected.

Note 1 to entry: For EMC purposes, interconnections between metal parts equalize the different potentials and require a low impedance in the frequency range considered. The frequency range considered includes the operating as well as the disturbing frequencies. This frequency range and the physical size of the electrical device determine the achievable equalization of potentials and thus the effectiveness of the grounding. The ground (earth) does not in all cases meet the personnel safety requirements of the protective earth.

Note 2 to entry: For ships with a non-metallic structure, all conductively interconnected metal parts (including earth/ground plate if existing) form the common ground (earth).

3.20
grounding
establishing of potential difference minimizing electrical connections

Note 1 to entry: The term "bonding" is normally used for the act of creating a conductive path between two conductive surfaces.

Note 2 to entry: The term "earthing" (US, CA: "grounding") is normally used for measures to prevent the danger of an electric shock by connection to earth. Additionally, "earthing/grounding" are used for the act of creating a return path to the power source.

3.21
type test
test for a sample item of equipment to ascertain that it meets the requirements according to this International Standard

3.22
port
defined interface of an equipment with the external electromagnetic environment through which disturbances may be received or emitted

Note 1 to entry: Conductive interfaces may also consist of cables, bond straps or mechanical interfaces such as metallic pipes and mounting provisions.

Note 2 to entry: No testing needs to be performed on the ground port.

Note 3 to entry: See Figure 1.

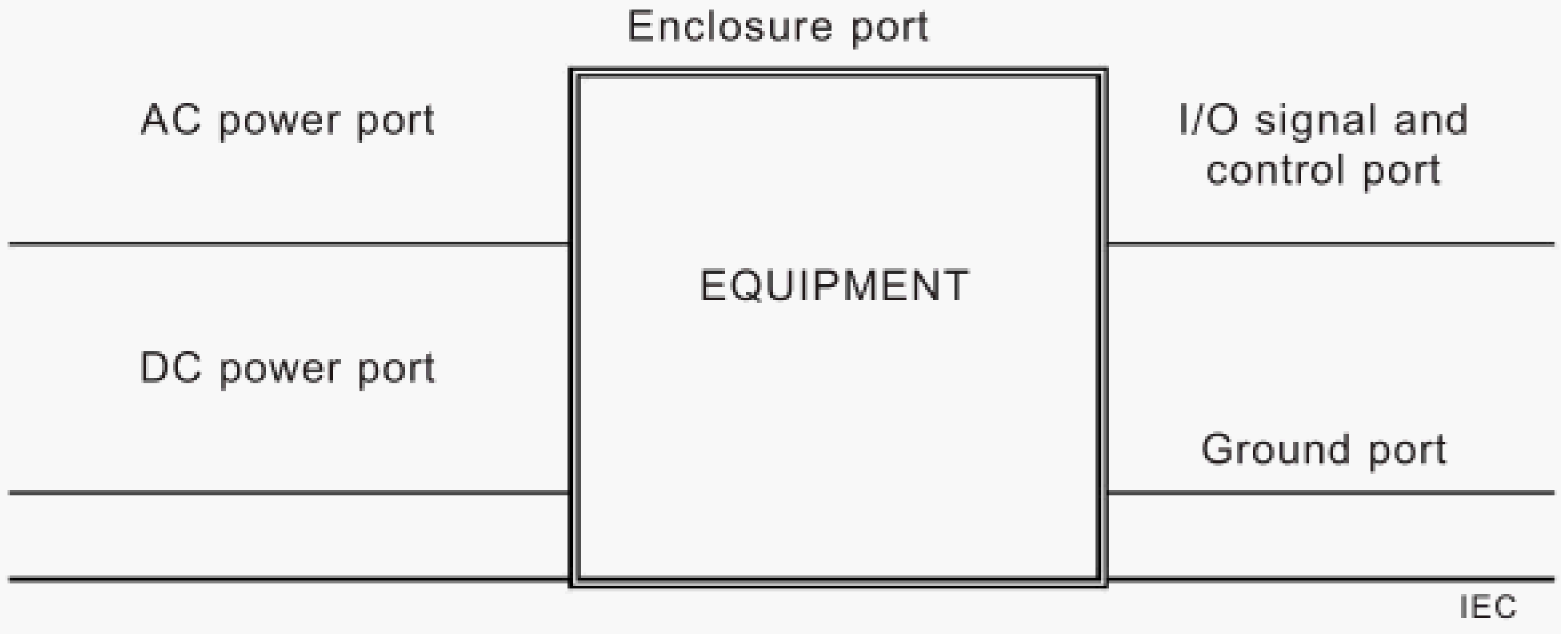

Figure 1 – Examples for ports

3.23
zone
area characterized by sensitive and/or disturbing devices located therein

SEE: Figure 2.

3.24
deck and bridge zone
area in close proximity to receiving and/or transmitting antennas and the wheelhouse as well as the control rooms, characterized by equipment for intercommunication, signal processing, radio communication and navigation, auxiliary equipment and large openings in the metallic structure

SEE: Figure 2.

3.25
general power distribution zone
area characterized by normal consumers

SEE: Figure 2.

3.26
special power distribution zone
area characterized by propulsion systems, bow thrusters, etc.

SEE: Figure 2.

Note 1 to entry: The generated emissions exceed the limits given in Table 3.

3.27
accommodation zone
area characterized by equipment that is non-essential for the ship's purpose

SEE: Figure 2.

EXAMPLE Crew quarters; offices; mess; lounges; passenger cabins.

Note 1 to entry: Precautions should be taken for a sufficient decoupling of the accommodation zone from all other zones.

3.28
normal consumers equipment
for ship's operation

EXAMPLE Machinery, control equipment, static convertors.

3.29
cable selection
allocation of cables to categories depending on signal type and level

3.30
cable separation
routing of cables of different categories with intermediate free space in order to reduce interference

3.31
in-situ testing
testing at the mounting place

Note 1 to entry: In-situ testing cannot be performed with standardized procedures under controlled conditions. That means only test facilities can be standardized, not the test and environmental conditions.

Note 2 to entry: In-situ testing can be performed, for example, in case of large and or heavy installations.

3.32
metallic hull
watertight main part or body of a ship made of metal or other equivalent conductive material

Note 1 to entry: It can be assumed that a metallic hull significantly reduces electromagnetic field strengths.

Note 2 to entry: Aside from that, measures are taken to reduce disturbance currents from entering or leaving the inner deck environment.

4 General

Ships' equipment and systems can be exposed to various kinds of electromagnetic disturbances conducted by power or control lines or directly radiated from the environment. The types and levels of disturbances depend on the particular conditions in which the system, the subsystems or the equipment are installed and to be operated.

The individual equipment of a ship can also be a source of electromagnetic disturbances over a wide frequency range, conducted through power and signal lines, or directly radiated, affecting the performance of other equipment or influencing the external electromagnetic environment.

The acceptance criteria for the tests for immunity requirements are related to performance criteria which are defined in terms of operational requirements.

For the emission limits, the objective of these requirements is to ensure that the disturbances generated by the equipment and systems do not exceed a level which could prevent other equipment and systems from operating as intended.

The emission limits of this International Standard may not, however, provide adequate protection against interference to radio receivers when other ship equipment is used closer than 3 m to the receiving antenna, see Annex A.

In special cases, for instance when highly susceptible equipment is being used closer than 3 m to a transmitting antenna, additional mitigation measures may have to be employed to increase the electromagnetic immunity beyond the limits specified in Clause 7.

NOTE The minimum immunity requirements in Clause 7 represent a typical electromagnetic environment and have been selected so as to ensure an adequate level of immunity for ships.

5 EMC test plan

5.1 Objective

Prior to performing the tests, an EMC test plan shall be established. It shall contain as a minimum the elements given in 5.2 to 5.5.

Tests detailed in this International Standard are normally conducted as type tests and shall be carried out whenever possible at an EMC test laboratory. For test procedures, reference is made to IEC basic standards.

However, in cases where type tests are impracticable (e.g. large mechanical dimensions of equipment, functional control), individual tests may be performed. This can be done in situ, if necessary, and in accordance with a tailored test procedure. In-situ testing is not as repeatable as testing on a test site. Therefore, care should be taken when using the results of in-situ testing on one site to predict compliance for a product from series production.

5.2 Configuration of equipment under test (EUT)

5.2.1 General

Ships' systems are not uniform assemblies. The type, number and installation of equipment, whether installed individually or integrated, may vary from system to system. Hence it is not reasonable to test every possible arrangement; however, it is recommended to carry out type tests.

For a realistic simulation of the EMC situation (related both to emission and immunity), an assembly of EUT with its auxiliary equipment, such as cabling, power supplies, etc. shall be built to represent a realistic installation. This assembly shall be operated as far as possible under normal conditions (including the software).

5.2.2 Assembly of EUT

If the EUT to be type tested is a system, subsystem or equipment likely to be installed at distributed locations, one or more typical configurations with all components of the EUT shall be chosen to reproduce the real installations. A justification for the chosen configurations shall be provided in the EMC test plan.

NOTE The type test certificate issued after the test is valid only for the EUT composition listed in the EMC test plan.

5.2.3 EUT interconnecting cables

A sufficient number of interconnecting cables shall be selected. At least one of each type of interconnecting cable shall be used during testing in a representative configuration.

Interconnecting cables shall be standardized types, see Table B.1. Where special cables are required, the manufacturer of the EUT should provide the specification.

5.2.4 Auxiliary equipment

A list of all auxiliary equipment shall be provided. The auxiliary equipment enumerated shall be sufficient to simulate all realistic operational conditions and to ensure that all feasible types of operation can be performed.

5.2.5 Cabling and grounding

The EUT shall be connected with all necessary cables and connected to ground in accordance with the manufacturer's specifications and the installation requirements. There shall be no additional grounding connections.

5.3 Test pre-conditioning

5.3.1 Operational conditions

Typical operating modes of the EUT shall be defined by the manufacturer before testing, considering that only the most typical functions of the equipment can be tested, for example analogue signals at 0 %, 50 % and 100 % magnitude, or digital signals with typical impulse trains. Particular attention shall be paid to the choice of critical mode.

5.3.2 Environmental conditions

EMC tests shall be performed under normal environmental conditions. Normal environmental conditions shall consist of any convenient combination of temperature in the range +15 °C to +45 °C and relative humidity in the range 20 % to 75 %.

When it is impractical to perform the tests under the environmental conditions defined above, a note to this effect stating the actual environmental conditions prevailing during the tests shall be appended to the test report.

5.3.3 Test software

The test software used for different modes of operation shall be identified.

5.4 Acceptance criteria

Pass/fail criteria for each port and test shall be specified. The acceptance criteria shall be specified as quantitative values where possible.

For evaluation, the performance criteria are as follows:

Performance criterion A

The EUT shall continue to operate as intended during and after the test. No degradation of performance or loss of function is allowed as defined in the relevant equipment standard and in the technical specification published by the manufacturer.

Performance criterion B

The EUT shall continue to operate as intended after the test. No degradation of performance or loss of function is allowed as defined in the relevant equipment standard and in the technical specification published by the manufacturer. During the test, degradation or loss of function or performance which is self-recoverable is however allowed; but no change of actual operating state or stored data is allowed.

Performance criterion C

Temporary degradation or loss of function or performance is allowed during and after the test, provided the function is self-recoverable, or can be restored by the operation of the controls as defined in the relevant equipment standard and in the technical specification published by the manufacturer.

5.5 Scope of EMC testing

Each test to be applied shall be specified in the EMC test plan based on the equipment test matrix in Table 1. The description of tests, the test methods, the characteristics of the tests and the test set-ups are given in the basic standards which are referred to in 6.2 and 7.2. In addition, information needed for the practical implementation of the tests is given in this International Standard. In some cases the EMC test plan should specify the application in detail.

Performance criteria for the individual tests are given in Table 1.

NOTE Normally, no additional EMC tests are required beyond those stated in this International Standard.

6 Emission requirements

6.1 Conditions during the emission tests

Measurements shall be made with the EUT in the operating condition that produces the highest emission level in the frequency band being investigated, see Clause 5.

NOTE 1 The conducted emission limits covered here are given on a port-by-port basis.

The radiated emission requirements within the range of receiving frequencies presume in the deck and bridge zone a minimum distance of 3 m between the emitters and the receiving antennas. For distances less than 3 m, a special compatibility analysis shall be carried out.

Measurements shall be performed in well-defined and reproducible conditions for each type of emission.

The description of the tests, the test methods and the test set-ups are given in the basic standards as stated in Table 2 and Table 3. Measurements shall be performed with a quasi peak detector.

The measuring bandwidth stated in CISPR 16-1-1 is 200 Hz in the frequency range 10 kHz to 150 kHz, 9 kHz in the frequency range 150 kHz to 30 MHz and 120 kHz in the frequency range 30 MHz to 2 000 MHz. According to IEC 60945, the measuring bandwidth shall be 9 kHz in the frequency range 156 MHz to 165 MHz, a peak detector or frequency analyser may be accepted in accordance with the manufacturer of the EUT and the test laboratory.

Table 1 – Equipment test matrix

Group	Equipment- and installation groups	Examples of applicable devices		Conducted emission CISPR 16-2-1	Radiated emission CISPR 16-2-3	Conducted low frequency IEC 61000-4-16	Power supply variation IEC 61000-4-11	Power supply failure IEC 61000-4-11	Electrical fast transients IEC 61000-4-4	Surge voltage IEC 61000-4-5	Conducted radio frequency IEC 61000-4-6	Electrostatic discharge (ESD) IEC 61000-4-2
A	Radio communication and navigation equipment	Maritime radiocommunication and navigation equipment and systems	Transmitters and receivers for maritime radiocommunication and navigation services	x	x	x	x	x	x	x	x	x
B	Power generation and conversion equipment	Electric machinery	Induction motors/generators	–	–	–	–	–	–	–	–	–
			Synchronous machines	x	x	–	–	–	–	–	–	–
			DC-machines	x	x	–	–	–	–	–	–	–
			El. machines controlled by electronic equipment	x	x	x	x	x	x	x	x	x
			Special electrical machines	x	x	x	x	x	x	x	x	x
		Electronic exciters	AVR's: Automatic Voltage Regulators	x	x	x	x	x	x	x	x	x
			AVR's - additional equipment	x	x	x	x	x	x	x	x	x
		Converters	Cyclo-converters	x	x	x	x	x	x	x	x	x
			Synchro-converters (DC-link)	x	x	x	x	x	x	x	x	x
			Pulse-width-converters	x	x	x	x	x	x	x	x	x
			DC-converters	x	x	x	x	x	x	x	x	x
		Transformers		–	–	–	–	–	–	–	–	–
C	Equipment operating with pulsed power	Maritime navigation equipment	Radar and sonar systems, echosounders	x	x	x	x	x	x	x	x	x
D	Switchgear and control systems	Circuit breakers/contactors	without electronics	–	–	x	–	–	–	–	–	–
		Electronic control devices		x	x	x	x	x	x	x	x	x
		Relay operated control devices		–	–	–	–	x	–	x	–	–
E	Intercommunication and signal processing equipment	Electronic alarm monitor		x	x	x	x	x	x	x	x	x
		Electronic control system		x	x	x	x	x	x	x	x	x
		Automation system		x	x	x	x	x	x	x	x	x
		Computers, sensors		x	x	x	x	x	x	x	x	x
F	Non-electrical items and equipment	Rigging	Generation of parasitic broadband interference	not applicable								
G	Integrated systems	Cargo monitoring system with sensors and equipment in different zones	Tests on individual equipment/systems	x	x	x	x	x	x	x	x	x
		Integrated Navigation System (INS)	Tests on individual equipment/systems	x	x	x	x	x	x	x	x	x
		Integrated Bridge System (IBS)	Tests on individual equipment/systems	x	x	x	x	x	x	x	x	x

x test required
– test not required

6.2 Emission limits

6.2.1 General

Equipment not permanently installed which is intended to be operated in the accommodation zone (non-essential equipment) shall comply with IEC 61000-6-1 and IEC 61000-6-3 or equivalent standards.

Precautions should be taken for a sufficient decoupling of the accommodation zone from all other zones.

Figure 2 is an example schematic diagram of zones.

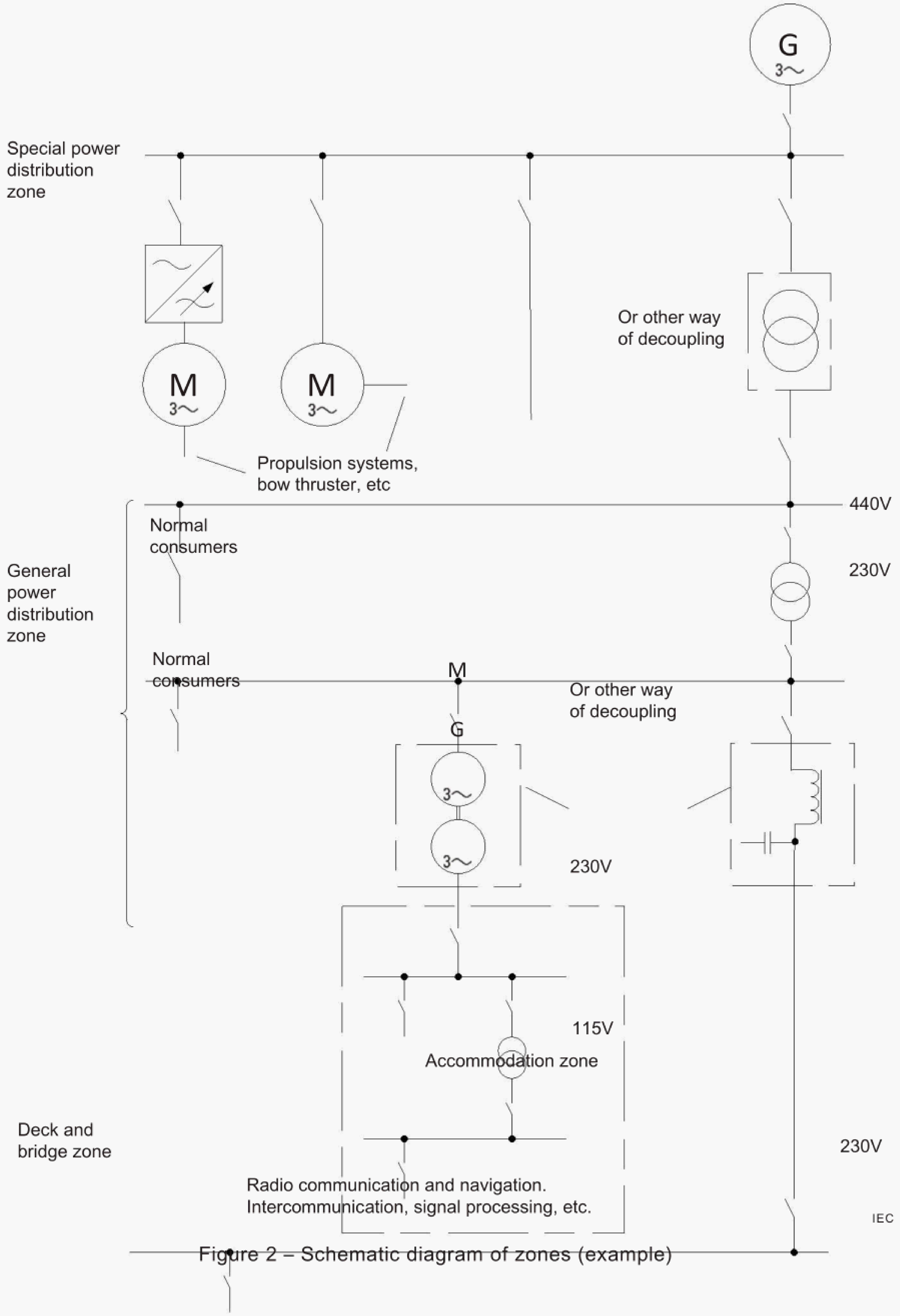

Figure 2 – Schematic diagram of zones (example)

6.2.2 Emission limits for equipment installed in the deck and bridge zone

Emission limits for equipment installed in the deck and bridge zone are given in Table 2.

Table 2 – Emission limits (deck and bridge zone)

Port	Frequency range	Limits	Basic standard
Enclosure (radiated emission)	150 kHz to 300 kHz	80 dBμV/m to 52 dBμV/m [c]	CISPR 16-1-4 [a]
	300 kHz to 30 MHz	52 dBμV/m to 34 dBμV/m [c]	CISPR 16-2-3 [a]
	30 MHz to 2 GHz [c)]	54 dBμV/m	
	except: 156 MHz to 165 MHz [c)]	24 dBμV/m [a]	CISPR 16-2-3
		30 dBμV/m [b]	CISPR 16-2-3
Power, I/O signal and control (conducted emission)	10 kHz to 150 kHz	96 dBμV to 50 dBμV	CISPR 16-1-2 CISPR 16-2-1
	150 kHz to 350 kHz	60 dBμV to 50 dBμV	
	350 kHz to 30 MHz	50 dBμV	

[a] Measured at a distance of 3 m.

[b] Measured with a peak detector or a frequency analyser at a distance of 3 m.

[c] Values in accordance with IACS E10, applicable for intended operation in ship's environment.

6.2.3 Emission limits for equipment installed in the general power distribution zone

Emission limits for equipment installed in the general power distribution zone are given in Table 3.

Table 3 – Emission limits (general power distribution zone)

Port	Frequency range	Limits	Basic standard
Enclosure (radiated emission)	150 kHz to 30 MHz	80 dBµV/m to 50 dBµV/m	CISPR 16-1-4 [a]
	30 MHz to 100 MHz	60 dBµV/m to 54 dBµV/m	CISPR 16-2-3 [a]
	100 MHz to 2 000 MHz	54 dBµV/m	
	except:		
	156 MHz to 165 MHz	24 dBµV/m	CISPR 16-2-3 [a]
		30 dBµV/m	CISPR 16-2-3 [b]
Power, I/O signal and control (conducted emission)	10 kHz to 150 kHz	120 dBµV to 69 dBµV	CISPR 16-1-2
	150 kHz to 500 kHz	79 dBµV	CISPR 16-2-1
	500 kHz to 30 MHz	73 dBµV	
Between the general power distribution zone and the special power distribution zone, a decoupling device should be installed in the power supply circuit (see Figure 2) capable of achieving a decoupling equivalent to the difference of the limits of the general power distribution zone and the existing emissions of equipment installed in the special power distribution zone. NOTE 1 Between the deck and bridge zone and the general power distribution zone an RFI filter could be installed in the power supply circuit (see Figure 2) capable of achieving a decoupling of about 30 dB in the frequency range of 10 kHz to 30 MHz.			
a Measured at a distance of 3 m. b Measured with a peak detector or a frequency analyser at a distance of 3 m.			

6.2.4 Emission limits for equipment installed in the special power distribution zone

For the special power distribution zone where semiconductors are connected having a total system rating representing a significant portion of the total system rating, it may not be feasible to suppress the low frequency as well as the high frequency harmonics. Appropriate measures should be taken to attenuate these effects on the distribution system so that safe operation is assured. Care should be taken in selecting consumers supplied from an electric power supply system with a higher harmonic content than specified. An agreement should be reached between the manufacturer of the equipment and the user. Further requirements are not defined for equipment installed in this zone.

7 Immunity requirements

7.1 Conditions during the immunity tests

The measurements shall be made with the EUT operating such that any reaction to the tests allows the required performance criteria to be recognized, see Clause 5.

The configuration and modes of operation during immunity tests shall be precisely noted in the test report.

Tests shall be applied to the relevant ports according to Table 4.

The tests shall be performed in accordance with the basic standards.

7.2 Minimum immunity requirements

The minimum immunity requirements and tests are given in Table 4.

Table 4 – Minimum immunity requirements for equipment

Port	Phenomenon	Basic standard	Performance criteria	Test value
AC power	Conducted low frequency interference	IEC 61000-4-16	A	10 % AC supply voltage 50 Hz to 900 Hz; 10 % to 1 % 900 Hz to 6 000 Hz; 1 % 6 kHz to 10 kHz
	Power supply variation	IEC 61000-4-11	B	voltage: ± 20 % for 1,5 s frequency: ± 10 % for 5 s
	Power supply failure	IEC 61000-4-11	C	60 s interruption
	Electrical fast transient (burst)	IEC 61000-4-4	B	2 kV[c]
	Surge voltage	IEC 61000-4-5	B	0,5 kV[a,h] and 1 kV[b,h]
	Conducted radio frequency interference	IEC 61000-4-6	A	3 Vrms[c]; (10 kHz)[f] 150 kHz to 80 MHz sweep rate ≤1,5 × 10^{-3} decade/s[g] modulation 80 % AM (1 kHz)
DC power	Conducted low frequency interference	IEC 61000-4-16	A	10 % DC supply voltage 50 Hz to 10 kHz
	Power supply variation	IEC 61000-4-11	B	Voltage + 20 % / – 25 % equipment non-connected to battery
	Power supply failure	IEC 61000-4-11	C	60 s interruption
	Electrical fast transient (burst)	IEC 61000-4-4	B	2 kV [c]
	Surge voltage	IEC 61000-4-5	B	0,5 kV[a] and 1 kV[b]
	Conducted radio frequency interference	IEC 61000-4-6	A	3 Vrms[c]; (10 kHz)[f] 150 kHz to 80 MHz sweep rate ≤1,5 × 10^{-3} decade/s[g] modulation 80 % AM (1 kHz)
I/O ports, Signal/ control	Electrical fast transient (burst)	IEC 61000-4-4	B	1 kV[d]
	Conducted radio frequency interference	IEC 61000-4-6	A	3 Vrms[c]; (10 kHz)[f] 150 kHz to 80 MHz sweep rate ≤1,5 × 10^{-3} decade/s modulation 80 % AM (1kHz)
Enclosure	Electrostatic discharge (ESD)	IEC 61000-4-2	B	6 kV contact and 8 kV air
	Electromagnetic field	IEC 61000-4-3	A	10 V/m[e] 80 MHz to 2 GHz sweep rate ≤1,5 × 10^{-3} decade/s modulation 80 % AM (1 kHz)

Equipment not permanently installed which is intended to operate in the passenger accommodation zone is not required to comply with any immunity requirements.

Precautions should be taken for a sufficient decoupling of the passenger accommodation zone from all other zones.

a Line to line.

b Line to ground.

c Capacitive coupling.

d Coupling clamp.

e Special situations to be analysed.

f Test procedure to be described in the test report.

g For equipment installed in the deck and bridge zone, the test levels shall be increased to 10 V r.m.s. for spot frequencies in accordance with IEC 60945 at 2 MHz / 3 MHz / 4 MHz / 6,2 MHz / 8,2 MHz / 12,6 MHz / 16,5 MHz / 18,8 MHz / 22 MHz / 25 MHz. For shielded cables a special test set-up shall be used enabling the coupling into the cable shield.

h Values in accordance with IACS E10, applicable for intended use in ship's environment.

7.3 System aspects

If higher levels or tests of other phenomena under special system aspects are necessary (for example, equipment very close to transmitting antenna) the immunity shall be increased or mitigation measures in the installation shall be applied.

8 Test results and test report

The test results shall be recorded in a comprehensive test report. The test report shall accurately, clearly, unambiguously and objectively present the objective, the results and all relevant information of the tests. The test report shall clearly define the EUT, including the cable layout, cable types and the auxiliary equipment used. Any deviation from the EMC test plan shall be mentioned, see Annex C.

Annex A
(informative)

General EMC planning procedures

A.1 Overview

Annex B contains guidelines for achieving EMC for ships and their equipment. The general procedures for achieving EMC are described.

By using this International Standard, an adequate consideration of EMC matters in the planning, construction and operation stages can be reached. This allows EMC measures to be realized in timely fashion during the course of the project, whilst respecting the necessary coordination.

During the lifetime of the ship, it is important that the EMC is not impaired by maintenance procedures and that, for modifications and extensions, maintenance is achieved by the application of minimum requirements.

A.2 General procedures

The aim of Annex A is to support the manufacturer responsible for the overall performance of the ship in achieving the EMC of the system. Since EMC is a quality related feature, it is necessary to treat it in the same way as general quality assurance.

Depending on the complexity of the system, EMC management needs to control and monitor the following activities for achieving EMC:

– EMC analysis;
– planning and performing EMC measures;
– checking EMC measures on equipment;
– checking implementation and effectiveness of EMC measures in the system;
– ensuring EMC measures remain effective during the system's lifetime.

A.3 EMC management

A.3.1 General

For most merchant ships, EMC management is a general management task, normally assigned to one responsible person. Appropriate skills are expected to be found in the electrical and electronic department of the shipyard.

For more complex ships more extensive skills and knowledge might be necessary. In this case, an EMC advisory group should be established to support the management in making the appropriate decisions in EMC matters.

A.3.2 EMC advisory group

The EMC advisory group should be established during the planning phase of the system. The group is chaired by the person responsible for EMC matters.

In the group, experts from different disciplines work together to define the EMC requirements of the system, sufficiently and economically justified by the occurrence of potential EMC problems, technology know-how and assessment of EMC measures.

Members of the EMC advisory group should include:

- representative of the contractor;
- representative of the customer;
- representatives of the suppliers of EMC-related equipment;
- representative of the classification society;
- independent EMC experts.

Not all members of the group are necessarily permanent members. The contractor has the authority to invite temporary members, depending on the subject treated.

A.3.3 EMC management tasks

The basic sequence of management tasks to achieve EMC is as follows:

- carry out a rough EMC analysis;
- establish EMC requirements for the equipment;
- define required operational conditions;
- define installation recommendations;
- define quality assurance measures;
- discuss results of preceding steps;
- perform additional EMC measures.

A.3.4 Rough analysis

The initial analysis of the EMC situation shall answer the following questions.

a) Which equipment could be influenced by transmitting antennas?

   The primary influence mode is radiation. Consequently all above-deck equipment may be influenced. Below-deck equipment may profit from the shielding properties of the metal hull. However, electronic equipment installed in the deck and bridge zone should be considered.

b) Which equipment could interfere with receiving antennas?

   Influence also comes from radiation. Only strong radiating equipment in the deck and bridge zone should be considered. It is difficult to prevent system interference due to the number of transmitting and receiving antenna systems on the top deck. Systems that radiate/receive in-band and near-band with other systems require spectrum planning and precise antenna location and design. A compatibility matrix should be made to prevent inter system EMI from intentional emitters to all receivers. During the design phase the locating and relocating of the different antennas and sensors on the top deck will use the results of this matrix.

   The strict emission requirement in the VHF-range between 156 and 165 MHz is based on the requirement by the telecommunication authority.

c) Which electronic equipment could be disturbed by radiating electric power lines and equipment?

   Radiation coming from electric power lines and equipment normally decays with distance. Therefore, only equipment in close proximity to the radiating electric power lines and equipment need be considered.

d) Which electronic equipment could suffer interference from inadequate network quality?

   Standard ship's power supply system characteristics are defined in IEC 60092-101. Disturbance may occur when susceptible electronics and emitting power electronics are connected to the same busbar.

A.3.5 EMC requirements for equipment

The primary requirement of equipment before installation on board the ship is compliance with the applicable EMC standards. This should be certified in the manufacturer's specifications. Every case of non-compliance shall result in additional analysis work, and, in many cases, consideration during designing or additional EMC measures.

A practical requirement is reliable and interference-free operation in the environment where the equipment is installed. For this, suppliers of equipment need to be informed about the EMC-features of the environment.

A.3.6 EMC interface agreements

When simultaneous operation of equipment combinations is subject to the risk of mutual EM-interference, the contractor should require the suppliers of the equipment to come to an agreement about measures necessary for undisturbed operation. Such an agreement should describe measures, responsibilities and quality assurance procedures.

A.3.7 Installation recommendations

Installation recommendations with special consideration of EMC are contained in Annex B.

Special installation requirements may result from the rough analysis, for example when spacing between devices is mandatory.

A.3.8 Assessment of conformity with EMC regulations

A.3.8.1 General

Assessment of conformity with the EMC regulations is a subtask of general quality assurance. Appropriate measures may be assigned to one of the following levels:

– equipment level;
– production supervision level;
– system level.

Similar to the general quality assurance, EMC assurance shall be performed in agreed cooperation between the appropriate bodies[1] and the quality assurance staff of the manufacturer.

A.3.8.2 Equipment level of conformity with EMC regulations

For equipment conformity, presentation of appropriate certificates is satisfactory. If such certificates cannot be presented for individual systems, agreed tests should be carried out in cooperation with the appropriate bodies.

A.3.8.3 Production supervision for EMC

During the ship's construction the applicable measures of Annex B should be observed. Special attention should be given to the performance of "decoupling by design", i.e. spacing between radiating and susceptible equipment should not be reduced, unintended disturbance connection to susceptible equipment via the same busbar should be avoided, etc.

____

1 Government authorities, notified bodies, classification societies, etc.

A.3.8.4 System level of conformity with EMC regulations

The standard procedure to prove EMC of the system is the "switch-on/switch-off test". During this test combinations of electrical and electronic devices are operated and observed to detect effects possibly caused by electromagnetic influence. If such effects occur, the source should be identified by sequentially switching off and on those devices that are likely to produce interference.

The evaluation of electromagnetic influence effects should conform to the performance criteria defined in this International Standard, unless otherwise specified.

A.3.9 Additional measures

If, due to the complexity of the ship, additional measures beyond the basic tasks described in A.3.3 are required by the appropriate bodies, an analysis as described in Clause A.4 should be carried out.

If this analysis reveals the need for additional EMC measures, planning and realization should be performed as described in Clause A.5.

The verification of the efficiency of the above-mentioned EMC measures is carried out by testing and inspection as described in Clause A.6.

A.4 Full EMC analysis

A.4.1 General

EMC analysis can be used to specify limits for equipment and units within systems. A flow chart for the analysis of equipment is given in Figure A.1. A similar procedure applies to subsystems.

A full EMC analysis can be performed and in the case of complex systems this is often necessary. In some cases it is sufficient to perform only parts of an analysis: for example, preparing frequency or level surveys or specifying compatibility levels.

A.4.2 Electromagnetic interference matrix (EMI matrix)

In the case of a full EMC analysis, an EMI matrix is drawn up. EMI relevant data on the ship's equipment is collected and recorded on EMI sheets. This equipment, potential emitters as well as susceptible devices are entered into the matrix. At each of the crosspoints an analysis is performed to ascertain whether the pieces of equipment interfere with one another. The result is noted by means of symbols at the crosspoints and then the matrix is analysed. Conclusions can be drawn from the analysis concerning the EMI levels of the equipment and EMC measures to be taken for the system.

Figure A.2 shows an example of an electromagnetic interference matrix (EMI matrix). Emitters of disturbance are recorded in the columns, and susceptible devices are recorded in the rows. Equipment will normally appear in both the columns and the rows. Each piece of equipment is designated by a matrix number. In addition, data from the electromagnetic environment is recorded in the matrix.

A.4.3 Collection of data

To conduct an EMC analysis, various data have to be obtained. These include:

a) emission and immunity levels;
b) dimensions of equipment;
c) distances between the units;

d) data concerning cables, both power and signal cables;
e) electric and electronic data of the equipment, such as:
   1) power;
   2) frequencies / frequency ranges;
   3) the sensitivity level of receivers;
   4) the transmitting power of transmitters, etc.

Also necessary are:

f) data concerning the details of the installation;
g) levels in the electromagnetic environment.

Preferably data from test reports have to be used. If these are not available, it may be necessary to estimate levels on the basis of the operation of equipment. These levels can then be employed until more accurate ones become available.

The way in which the equipment is installed and cables are connected needs to be known. This applies to the equipment configuration, the cable laying and the distances between these items. The EMC measures already planned for the system need to be known.

A questionnaire may be helpful to obtain this data from the equipment suppliers.

A.4.4 Data processing

A.4.4.1 EMI sheet

For each equipment the data are collected in a data base or on a separate "EMI sheet". This document is given a number, which is recorded in the EMI matrix for the fast retrieval of data. The sheet can be replaced if there are any changes of the data on the document.

A.4.4.2 Frequency surveys

On the basis of the data collected, a frequency survey is produced for the operating frequencies and their harmonic components. This applies especially to all frequency ranges in which equipment has frequencies either above the emission limit or below the immunity limit. An example is given in Figure A.3.

It is practical to carry out two types of survey, one for conducted interference and one for radiated interference.

The survey is especially important for the several transmitting and receiving pieces of equipment of the system. The frequency survey can be used to find out whether transmitting and receiving equipment are operating in the same frequency bands.

A.4.4.3 Level surveys

Level surveys indicate the emission and immunity levels in the frequency ranges. Figure A.4 gives an example of this. Surveys often only record levels that deviate from standard limits: for example, the emission level of a transmitter or the immunity level of a receiver. By including the limits contained in the relevant EMC-specification, it is also possible to see how far these levels either exceed the emission limits or fall below the immunity limits.

For conducted interference, the level survey will show whether the pieces of equipment will interfere with each other. In the case of conducted interference, not much damping usually occurs in wires or cables.

For interference resulting from crosstalk, the coupling impedance needs to be known, and no conclusions can be drawn before a calculation has been performed.

A similar situation applies in the case of level surveys for interference. Before any conclusions can be drawn, distances and shielding objects (such as other equipment, metal components, etc.) need to be taken into account by calculating levels at the location of the equipment susceptible to disturbance.

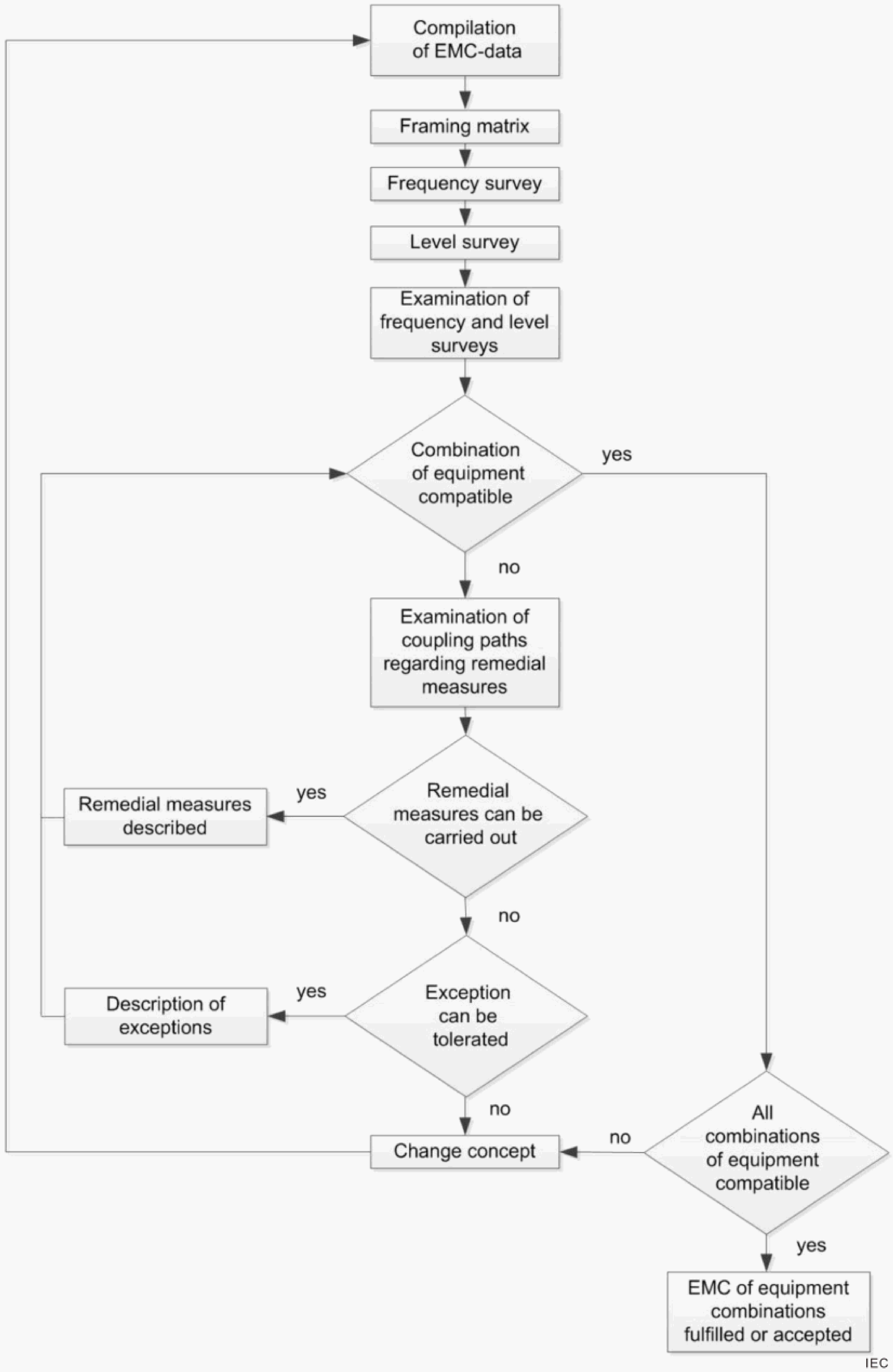

Figure A.1 – EMC analysis, flow chart

Equipment and installation groups		Examples of equipment	Type of signal		Emitters																										
			(see Annex A)	Susceptors	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	C1	C2	C3	C4	D1	D2	D3	D4	E1	E2	E3	E4	F1	G1	G2	H1	H2
A	Radio communication	GMDSS[a] equipment: receivers	Extremely sensitive	A1																											
	Radio navigation	transmitters	Extremely jamming	A2																											
		Gyro-compass	Sensitive	A3																											
		Steering system / autopilot	Sensitive	A4																											
		Integrated wireless communication systems	Sensitive	A5																											
B	Power generation and conversion	Electric machinery	Non-sensitive	B1																											
		Electronic exciters	Jamming	B2																											
		Converters	Jamming	B3																											
		Transformers	Non-sensitive	B4																											
		Lighting armatures	Non-sensitive	B5																											
C	Equipment operating with pulsed power	Radar	Jamming	C1																											
		Sonar	Jamming	C2																											
		Doppler log	Jamming	C3																											
		Echo sounder	Jamming	C4																											
D	Switchgear and control systems	Circuit breakers / contactors	Non-sensitive	D1																											
		Electronic control devices	Sensitive	D2																											
		Relay operated control devices	Sensitive	D3																											
		Electronic protection equipment	Sensitive	D4																											
E	Intercommunication and signal processing equipment	Electronic alarm monitor	Sensitive	E1																											
		Electronic control system	Sensitive	E2																											
		Automation system	Sensitive	E3																											
		Computers, sensors	Sensitive	E4																											
F	Non-electrical items + equipment	Rigging	Non-sensitive	F1																											
G	Integrated systems	Integrated navigation system (INS)	Sensitive	G1																											
		Integrated bridge system (IBS)	Sensitive	G2																											
H	Equipment in hazardous areas	Explosion proof equipment	Non-sensitive	H1																											
		Certified intrinsically safe equipment	Non-sensitive	H2																											

IEC

[a] Global Maritime Distress and Safety System.

Figure A.2 – EMC analysis, EMI matrix

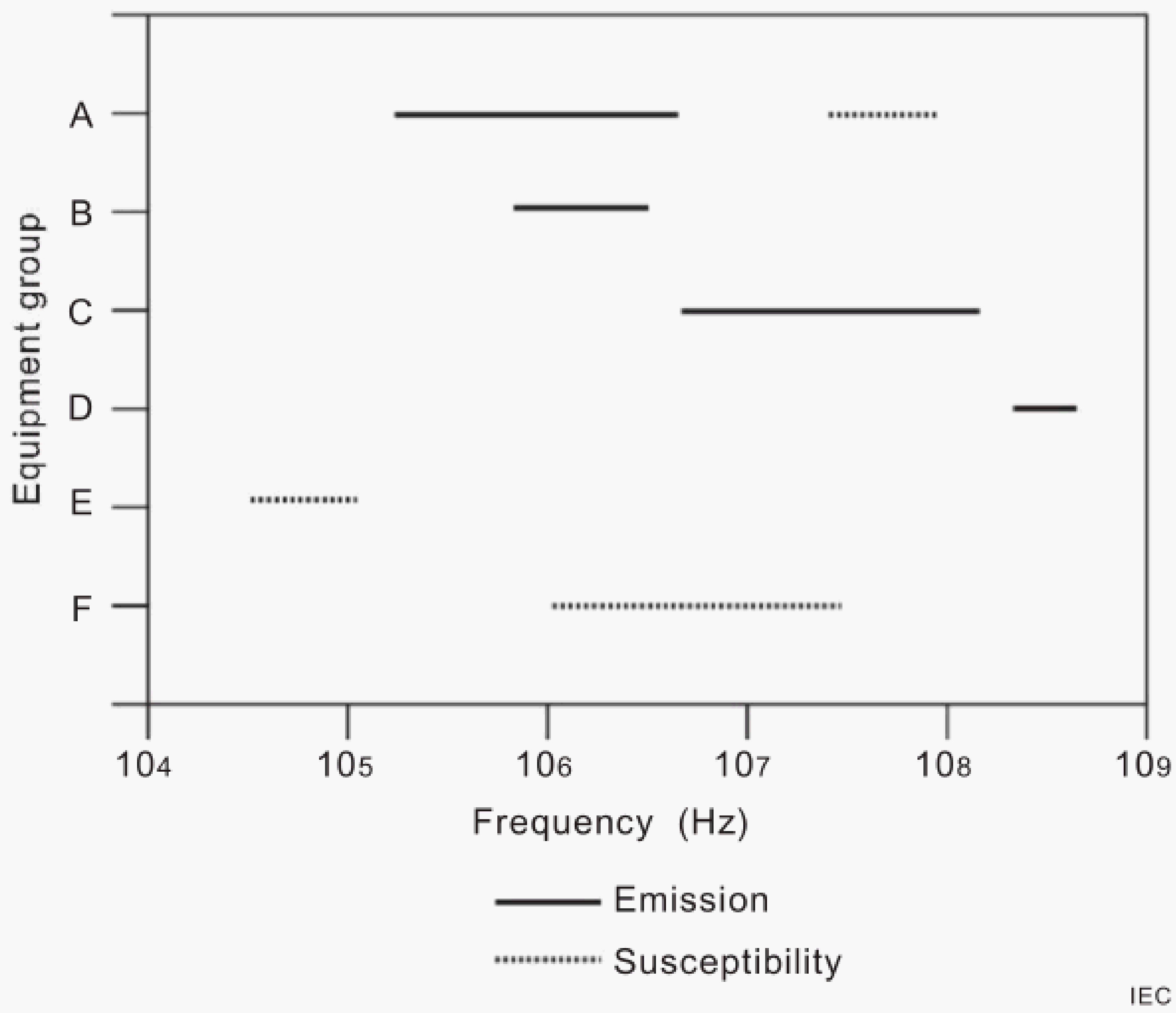

Figure A.3 – EMC analysis, frequency survey

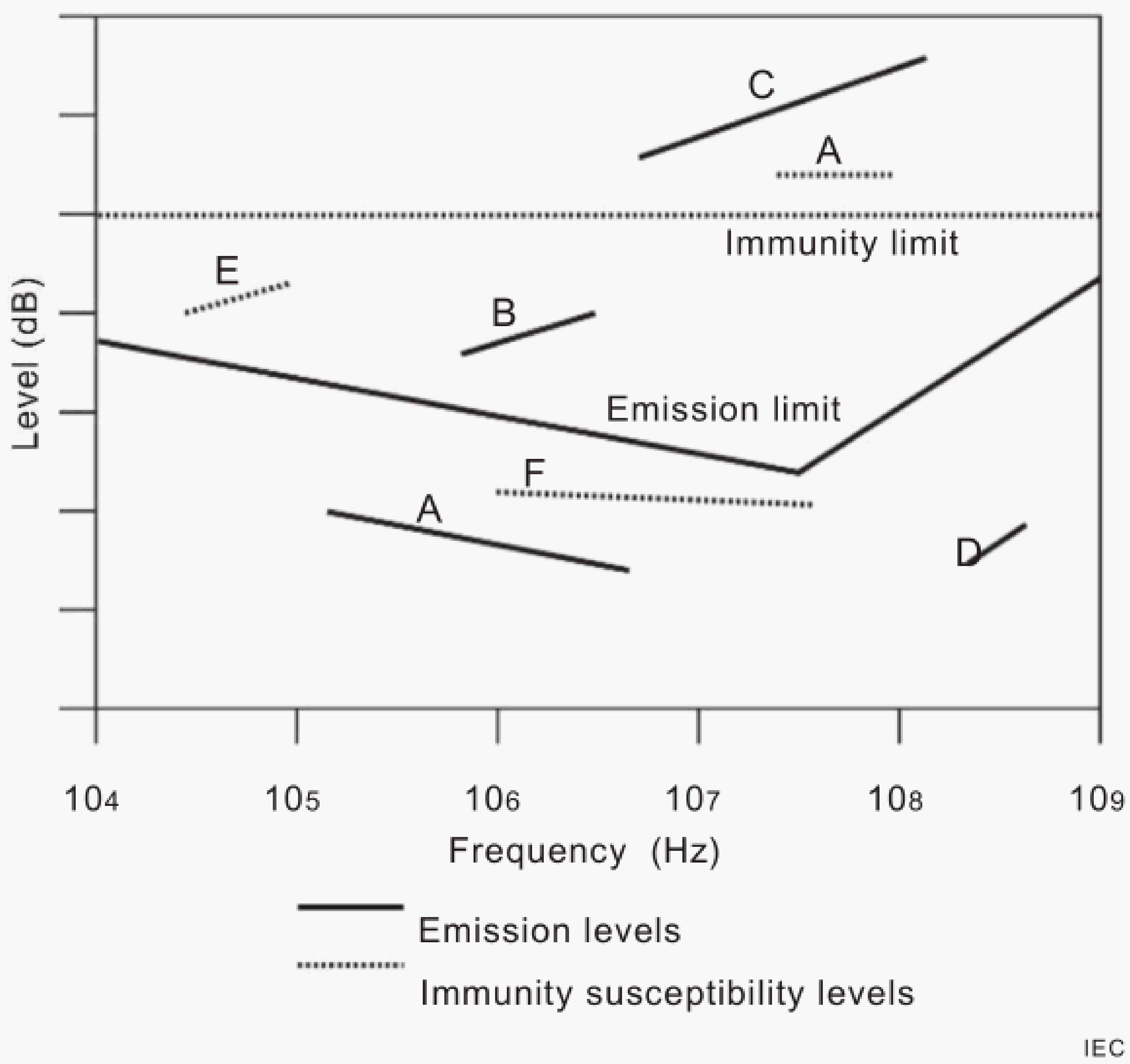

Figure A.4 – EMC analysis, level survey

A.4.5 Completing the matrix

A rough estimation of the possibility of interference between the emitters and the susceptible device is made.

At those locations where no disturbance is possible, the symbol "–" is marked at the crosspoint in the matrix; at locations where it is possible, the symbol "+" is marked. For these cases calculations are performed (see below). If the analysis shows no interference to be present, this is indicated in the matrix by means of the symbol "⊕"; if interference is shown to be present, this is indicated by means of the symbol "#". If necessary, the value y in dB can also be recorded. For explanation of symbols see Table A.1.

Table A.1 – EMC-matrix, explanation of symbols

Symbol	Meaning
–	No interference possible
+	Interference possible or present
⊕	Interference possible, but shown by analysis not to be present
#	Interference present or probable, according to analysis
# y(dB)	Interference present, and value according to analysis

A.4.6 Calculations

For every cross point in the matrix where a "+" occurs, a calculation is performed to establish whether the equipment causing disturbance can influence the equipment susceptible to disturbance.

For this purpose, emission levels at the location of the equipment susceptible to disturbance are calculated for all possible transmission routes and compared with the immunity levels of the equipment.

The calculations should take into account the bandwidths to which the levels apply and the prescribed margins between the levels. Since much data is estimated at this stage, the results of the calculations are not very accurate; accuracy less than the chosen margin is usually sufficient. In practice, even this is not always achievable, especially in the case of radiated interference.

A.4.7 Conclusions to be drawn from the matrix

Once the EMI matrix has been completed, it will show which equipment is likely to cause interference. On this basis, measures can be defined. These may involve improving the equipment or introducing EMC measures into the system.

A.5 Additional EMC measures

A.5.1 General

If loss of function is to be expected as a result of EMC analysis, measures for limiting the electromagnetic emission or increased immunity need to be planned and executed. In principle, measures on equipment can be taken, for example by additional interference suppression elements and/or, within the system, by separation or shielding of cables. Annex B contains a catalogue of measures which have proven practicable for all cases.

A.5.2 Limitation of electromagnetic emission

The majority of electrical and electronic equipment emits unwanted high-frequency electromagnetic oscillations (disturbing quantities). On the one hand, they may reach the antenna inputs of the radio receiving equipment and cause radio interference; and, on the other hand, they may reach the signal inputs of sensitive electronic equipment and cause degradation of performance.

Limitation of emissions with respect to other equipment is necessary for ensuring EMC. Its extent needs to be agreed between the customer and contractor, if not already regulated by international official rules or national legal requirements for maritime radio communication and navigation equipment and systems.

A.5.3 Limitation of electromagnetic influences

In a ship, it is essential to consider disturbance of electronic equipment, caused by phenomena in the electrical system itself as well as by field intensities of transmitting subsystems. Typical examples are:

- voltage drops at start-up of electric motors;
- voltage drops at switch-on of other electrical loads, for example control equipment, heating and lighting installations, voltage rises at switch-off of electrical loads;
- low- and high-frequency AC contents, caused by emissions of disturbance of the installed equipment;
- high-frequency oscillations in the on-board electrical system which is prone to resonance produced by switching activities;
- pulse-shaped disturbing voltages caused by power electronics;
- electrostatic discharges produced by operating personnel charged by touching the hull and/or all metallic parts, including the housing of the equipment;
- radiated disturbances caused by the radio transmitting plant and other equipment of the ship.

The type and level of such disturbing phenomena can be determined by measuring techniques on-board ships. In the planning stage these data can be replaced by known emission and immunity levels of equipment and data from previous case studies.

A.6 EMC testing

A.6.1 Equipment testing

All equipment trimmed by additional EMC measures to meet EMC requirements needs to be measured under simulated operational conditions prior to integration, as defined in this International Standard.

A.6.2 System testing

A.6.2.1 Visual inspection

The realization of the EMC measures during the building phase of ships should be tested in accordance with the following procedure:

- verification of the separate cable routing;
- verification of the cable shield ground connection for compliance with the maximum allowable length of bond straps;
- verification of the EMC ground connections to achieve the required small inductance values;
- verification of the observance of equipment and installation-specific EMC specifications, in accordance with the manufacturer's documentation as it relates to the project;
- inspection of the corrosion protection of the EMC ground connections.

A.6.2.2 System acceptance test

A procedure to check the performance of EMC measures is made by the EMC engineer, who proposed and installed the EMC improvements before the start of the checks.

Working to a program, the installation-specific features of EMC and the EMC parameters described by the manufacturer need to be considered. The inspections are performed during critical operating conditions, and susceptible equipment and installations are checked for possible influences. It is advisable to perform the checks with the help of an EMI matrix, see A.4.

A.6.2.3 Periodical tests during lifetime

To avoid compatibility degradation, documentation and installation descriptions should include details of equipment maintenance and cabling to be considered at repair, maintenance and regular checks. It is expedient to plan timely intervals for these measures of maintenance in the documentation, which should coincide with the time framework provided for the inspection by the classification society.

Staff should also be encouraged to record any interference observed in service. This should then be investigated and corrected during maintenance services and the problems fed back to the designers of the ship for future reference.

Annex B
(informative)

Mitigation guidelines

B.1 Applicability

Annex B contains guidelines and recommendations for organizational and technical measures to achieve electromagnetic compatibility (EMC) in ships and in ships' equipment. These preventive measures concern electric and electronic equipment and, in special cases, non-electric equipment.

These guidelines and recommendations have proven successful in practical application; however, under certain circumstances, additional measures may become necessary to achieve the desired level of EMC.

Use of these guidelines and recommendations will help ensure that the EMC performance achieved for items of equipment is maintained in an installation.

B.2 General technical measures

B.2.1 General

Effective measures to achieve EMC should be taken so that neither safety of the ship's crew and of the ship nor the reliable operation of electric installations is in any way be jeopardized.

IEC 60092-101 and IEC 60092-201 should be observed.

EMC measures should equally extend to:

- decoupling the interference path between source and affected equipment/system;
- reduction of the level of emission at its source;
- increasing the immunity to the disturbance at the affected equipment/system.

The following measures can be applied individually or in combination:

- shielding;
- grounding;
- suitable cable routing, cable separation and cable selection;
- selection of suitable equipment mounting place;
- filtering;
- use of special components (for example overvoltage protectors);
- use of special devices (for example to separate different potentials);
- organizational measures (for example alternating operation of devices).

Details can be found in B.2.3, B.2.4, B.2.5 and B.2.6. Other measures are related to equipment and installations and details can be found in Clause B.3. Organizational measures are described in Clause B.4. Special recommendations or comments concerning equipment, items or individual installations are detailed in B.2.2, groups A to F.

The combination of all equipment, items and installations interconnected for the intended performance of a given function is called an "integrated system". If certain technical measures for the integration process need to be taken, or if these measures have proven recommendable in practical applications, or, again, exceed those detailed in B.2.2, groups A to F, such measures have been listed in group G.

B.2.2 Equipment and installation groups

Group A: Radio communication and navigation equipment

Typical properties: operation with radiated signals

Examples: transmitters and receivers for maritime radio communication and navigation services and on-board communication systems

Group B: Power generation and conversion equipment

Typical properties: broadband interference

Examples: rectifiers, inverters, convertors (power electronics), rotating convertors, generators, deck machinery, domestic equipment, fluorescent lamps, discharge lamps

Group C: Equipment operating with pulsed power

Typical properties: periodical transient interferences with high energy

Examples: radar and sonar systems, echosounders

Group D: Switchgear and controlgear systems

Typical properties: transient interferences

Examples: switchboards, relay-operated control devices, motor starters, electric heating systems

Group E: Intercommunication and signal processing equipment and control systems

Typical properties: operation with analogue and digital signals

Examples: automation system, computers, sensors, public-address, signalling and alarm systems

Group F: Non-electrical items and equipment

Typical properties: generation of parasitic broadband interference

Example: rigging

Group G: Integrated systems

Typical properties: interference resulting from the simultaneous operation of equipment and installations from groups A to F

Example: navigational equipment with sensors in the upper deck area as well as keel area, integrated propulsion system, cargo monitoring system with sensors and equipment in different zones.

B.2.3 Shielding

Equipment and devices need to be effectively shielded by:

- installation in metallic enclosures;
- use of shielded cables, including suitable cable glands, preferably at the cable entry point of metallic enclosures;
- utilization of metal bulkheads and decks for shielding, and grounding of cable shields at penetration points where possible.

B.2.4 Grounding

All metallic enclosures and metallic equipment items need to be effectively grounded. The requirements of the equipment manufacturer should be observed.

The aim of all grounding procedures is to unite the reference potentials of distributed located equipment items.

In principle there are two different ways to minimize any difference in potential of different reference conductors:

1) grounding of reference conductors in a star pattern;
2) grounding of reference conductors on a ground plane pattern.

In the star pattern, all reference conductors are connected to one single point, i.e. the ground point. Only this single ground point should have a conductor to the ship's structure. For a ground plane pattern, all reference conductors should be connected to the ship's structure at the closest possible point and at as many points as is feasible. The result is a ground reference plane with the smallest possible ground loops and smallest possible inductance.

The following criteria should be used to select the proper grounding method.

a) The star pattern should be used for lighting and equipment that is connected to a socket-outlet, if the manufacturer of the equipment permits this.
b) The ground plane pattern should be used for the remaining equipment.

All ground connections should have the following properties:

– vibration-resistance of connectors and conductors;
– corrosion resistance;
– access for routine inspection.

For the ground plane pattern, the following additional properties of the ground connections apply:

– low RF impedance;
– smallest possible length (small inductance).

Contact areas shall be metallically clean, free from paint or oxides or other insulating coatings. It is recommended that corrosion protection spray or paste is applied at each contact point before final assembly. Solid metal strips of minimum length should be used instead of flexible braided bands. Ground loops should be kept to a minimum.

In order to avoid interference by undefined contact all non-electrical metallic items on the weather deck with a dimension exceeding 1 m (for example rigs) should be electrically connected to the ship's structure. In exceptional cases an object may be electrically insulated.

Wherever possible, metallic enclosures of electrical equipment should be directly screwed or welded to the ship's structure.

Separate ground conductors should be used in cases where a ground connection cannot be effected by a metallically clean screwed connection.

The contact between the ground conductor and the equipment or the ship's structure may be either screwed or welded.

Ground conductors for connection of metal items on the free deck to the ship's structure should be produced from corrosion-resistant steel (solid or flexible). Ground conductors inside the ship will generally be made from copper.

Metallic doors, protective covers, etc. should be connected to the respective enclosures by means of short, separate and possibly flexible conductors.

Pieces of cable trays and protective cable piping should have electrical connections to each other and to the ship's structure at as many points as possible.

Metallic cable jackets and cable shields should generally be grounded to the metallic enclosure of the equipment or to the ship's structure at as many points as is feasible, and at least on both ends of the cable (exception see B.3.6.4).

For ships with non-metallic structures, all conductively interconnected metal parts (including earth/ground plate if existing) will form an artificial earth/ground.

B.2.5 Cable routing

The installation requirements of the equipment manufacturer, including cable selection and cable routing, should be studied by the EMC manager and adhered to unless they compromise the ship's EMC plan. Cable separation into categories according to different signal types as stated in Table B.1, and cable installation with intermediate free spaces should be used as a major preventive measure.

Basically all cables outside the ship's structure should be metal sheathed, metal braided or otherwise adequately shielded.

Independently of the system they belong to, cables in category 1 up to and including category 4 may be bundled per category.

Single cables or bundles of cables of different categories which run parallel for distances exceeding 1 m should be installed with an intermediate free space of 10 cm minimum between the different categories of cables with the exception of categories 2 and 4 where the distance should be at least 20 cm with a maximum routing height above reference ground of 5 cm.

The same recommendation should be observed for cables of the same category but with differing signal levels.

A test method to determine minimum routing distances in order to avoid crosstalk of fast transients (bursts) can be found in IEC TR 62482. The test results may be applied to cable installations according to IEC 60092-352.

Cables belonging to category 1, 4 and 5 should be affixed to a metal surface (deck, bulkhead or cable duct). The metal cable ducts should be grounded to bulkheads or decks at least at both ends.

Special measures may be necessary between cables of category 3 and 4 (for example protective cable piping). The same applies to those cases where the minimum cable separation cannot be implemented.

Table B.1 – Signal types and cable categories

Cables for	Level	Emission/ immunity rating	Cable category	Cable type[d]	Applicable standard
Radio receiver signals[b] TV receiver signals Video signals	0,1 mV to 500 mV	Extremely sensitive	3	Coaxial	IEC 60096-1
Analogue and digital signals Telephone signals Loudspeaker signals Control signals Alarm signals	0,1 V to 115 V	Sensitive	2	Twisted; single shielded; shielded twisted pairs	IEC 60092-376
Power supply[a] Lighting	10 V to 1 000 V	Potentially disturbing	1	Below deck: non shielded; above deck: twisted, shielded	IEC 60092-350 IEC 60092-353
High-power transmission signals	10 V to 1 000 V	Extremely disturbing	4	Coaxial; shielded power	Special cable
Pulsed high-power signals[c] High powered semiconductor convertor	– [e]	– [e]	– [e]	Twisted, shielded	IEC 60092-350 IEC 60092-353
Special applications	– [e]	To be specified	5	– [e]	– [e]
Fibre optics	– [e]	– [e]	– [e]	– [e]	– [e]

[a] Equipment and auxiliary equipment for radio communication and radio navigation should be fitted with shielded power supply cables if the manufacturer requires so. The shielding should be provided up to the respective zone border. Penetrations should be circumferentially grounded.

[b] Receiving antenna cables should be installed with double shield cables or coaxial cables inside protective piping.

[c] Cables for radar, sonar equipment and echosounders should be double shielded cables or coaxial cables inside protective piping.

[d] The coverage for cable shields as required by the relevant IEC Standards should be adhered to and the transfer impedance at 10 MHz as determined by IEC 60096-1 should not exceed 30 mΩ/m.

[e] Under consideration.

Cable shields should be connected in connection boxes or cable drawing boxes. Cable shields should not be used as the return conductor for operating circuits except the outer conductor of coaxial cable.

Where it is impossible to meet the separation requirements, cables with high shielding effectiveness should be used, or cable bundles should be routed in metal pipes or conduits.

The pipes or conduits should have a minimum thickness of 1 mm if not otherwise specified. If a cable runs through a metal pipe or conduit, further separation with regard to the other categories is not necessary.

It is recommended to install the cables close to the metallic ship structure or on metallic cable trays.

It is recommended to ground cable shields circumferentially at those points where cables penetrate the boundary between the free deck and the ship's interior. These grounding areas should be protected against corrosion.

B.2.6 Filtering and overvoltage protection

B.2.6.1 General

The application of filters, components for overvoltage protection and the combination of both enables the manufacturer to reduce the coupling of conducted interference without simultaneous distortion of wanted signals and power. The scope of application ranges from power and control cables to cables for analogue and digital signals as well as to antennas (selection enhancement of transmitters and receivers).

B.2.6.2 Filtering

B.2.6.2.1 General

Filters may be applied to the emitter of disturbance as well as to any susceptible device. Filters should be applied to the emitter, especially when there is only one emitter or its emission level is considerably higher than those of other emitters. Application to the susceptible device is to be preferred when its susceptibility is very high compared with other susceptible devices or when the number of susceptible devices is less than the number of emitters to be filtered. The decision to apply filters is based on a trade-off between efficiency and expenditure of the configuration.

If, during the design stage, filters seem voluminous and expensive, for example due to the requirement for high insertion loss or for high currents, investigations should be made to determine whether a less costly EMC measure is preferable, for example shielding of cables or units, to reduce the influence of conducted interference and the expenditure of filters.

B.2.6.2.2 Power supply filter

B.2.6.2.2.1 General

Power supply filters are low-pass filter types. They are terminated at one end by the impedance of the equipment and at the other end by the impedance of the power supply system. As these impedances normally differ from 50 Ω or are unknown and on the other hand the insertion loss requirements are dependent on the load, a certain margin for the insertion loss should be considered.

Selection criteria:

– insertion loss;
– attenuation band;
– number of channels to be filtered;
– impedance;
– currents, voltages, permissible power factor;
– common mode/differential mode characteristic;
– leakage current;
– electric strength.

To maintain the filter characteristics under all operating conditions, B.2.6.2.2.2 to B.2.6.2.2.6 should be considered at the design stage.

B.2.6.2.2.2 Electric strength

In addition to the supply voltage, spikes and test voltages are to be considered, in order to prevent damage to components. The rating of electric strength should be in accordance with IEC 60092-101.

B.2.6.2.2.3 Current carrying capacity and thermal resistance

Supply currents and in particular peak currents may cause a reduction of the inductance of coils due to core saturation. Furthermore the permissible current depends on the ambient temperature: the higher the temperature the lower the permissible current (as specified in the data sheets).

B.2.6.2.2.4 Operational frequencies

The operational frequencies specified in the data sheets (DC, AC 50 Hz / 60 Hz /400 Hz) should be considered.

B.2.6.2.2.5 Environmental conditions

The selected components should be in accordance with the environmental requirements given for the installation.

B.2.6.2.2.6 Leakage currents

The use of power supply filters with capacitors to ground causes leakage currents to ground. If the overall capacity to ground becomes too large the operation of the ground fault detection system in IT type networks will be impaired.

B.2.6.2.3 Signal filter

The system environment defined by the EMC advisory group during definition of the interfaces and the signal transmission characteristics should be considered.

Especially in systems with long cables, filters may be necessary due to the risk of induced interferences. The inserted filters may not influence the wanted signals in an unpermissible manner. There are filters available for standard interfaces such as RS 232 or 20 mA.

Selection criteria:

- insertion loss;
- type of signal (analogue, digital) to be protected;
- matching to the characteristic impedance of the cable, the signal source or the signal receiver;
- crosstalk of multi-channel filters;
- permissible capacity due to the wanted signal;
- permissible ripple in the pass-band;
- electric strength, pulse strength;
- permissible intermodulation distortion;
- environmental compatibility.

B.2.6.3 Overvoltage protection

B.2.6.3.1 General

Components with voltage-dependent resistances, for example surge arrestors, varistors, breakdown diodes, should be applied to limit overvoltages. The components should be in accordance with IEC 60099-1 and/or IEC 60099-4.

Protection should also be ensured in case of overvoltages with steep flanking pulses.

The subsequent current should be limited after arrestor response.

B.2.6.3.2 Suppressor diodes, unipolar and bipolar

Suppressor diodes belong to non-linear components such as surge arrestors and varistors. For selection, two aspects should be considered:

– the necessary suppression of overvoltages;
– the undistorted transmission of wanted signals.

The wanted signals should have a sufficient separation from the breakdown voltage of the intended diode.

Selection criteria:

– minimum insertion loss for wanted signals (in general <1 dB);
– maximum return loss (estimated value: a ≥ 20 dB);
– sufficient peak power dissipation;
– minimum dissipation of intermodulation (for certain appliances in the high-frequency range).

B.3 Special measures for equipment groups A to G

B.3.1 General

Equipment and installed systems on ships are assigned to groups A to G. Special recommendations or notes for individual equipment items or individual installations have been compiled in groups A to F, and, for integrated systems, in group G.

B.3.2 Measures for group A

B.3.2.1 General

This group includes all equipment for radio communication and radio navigation, including equipment and installations for the Global Maritime Distress Safety System (GMDSS), and their auxiliary equipment.

The auxiliary equipment includes auxiliary operator panels, additional communication stations, transfer lines (two-wire, four-wire), plotters, printers, etc., as well as antennas and antenna auxiliary equipment, power supplies, etc.

Power supply cables from the main switchboard or emergency switchboard to the radio communication and navigation equipment should be routed separately in one continuous length as far as practical.

B.3.2.2 Equipment selection and arrangement

Radio transmitters and radio receivers with low impedance antenna interface are preferred.

Radio transmitters and receivers with high impedance antenna interface should be placed such that the antenna cable inside the deckhouse will be of minimum length.

Sufficient decoupling of equipment from surrounding items should be observed when equipment is installed in desk consoles. The original equipment enclosure should be used, or an equivalent shielding measure should be taken.

Isolating transformers with an internal shield winding should be used. The shield winding should be earthed.

All reasonable and practical measures should be taken to ensure that only equipment meeting appropriate EMC standards is installed. Any expected EMC related problems may be resolved, for example by suitable spacing of the equipment involved or by shielding.

If the radio equipment is integrated in the navigation bridge, the equipment enclosure has to be constructed so as to provide adequate shielding.

B.3.2.3 Cable routing

Signal cables and control cables should be shielded.

Cable glands should preferably ensure continuous contact between cable shield and equipment enclosure throughout the whole circumference.

In special cases, it is necessary to ground the cable shields at deck penetrations, particularly in the vicinity of transmitter or receiver antennas.

B.3.2.4 Grounding

The ground connections should be as short as possible and with a maximum cross-sectional area. Preferably, individual ground connectors should be used (e.g. for transmitters and receivers).

If dismountable ground connections (screwed connectors) are used, these should be accessible for maintenance.

B.3.2.5 Antennas

The antennas should be arranged for suitable decoupling from the ship's superstructure.

Suitable decoupling between receiving and transmitting antennas should be ensured.

Receiving antenna cables which are in close proximity to transmitting antennas should be routed in continuously grounded protective cable tubes or antenna cables should be double shielded with the outer-shield grounded at penetration points.

Low-capacitance installation should be observed for high impedance antenna interfaces.

Structural elements on the weather deck which serve as protective guards around antennas should be made of non-metallic material.

For radar waveguides see B.3.4.

Yardarms, stays, and top masts within the antenna radiation zone should be connected to ground.

B.3.3 Measures for group B

This group includes all equipment and installations for generation, conversion, periodic switching and control of electric energy.

This equipment induces non-linear loads on the AC supply with resulting voltage harmonics due to the supply network reactance. The harmonic content of the supply voltage and supply current may influence other consumers connected to the same supply, particularly:

– inductive or capacitive consumers, due to thermal influence by additional power dissipation (iron losses, dielectric losses by harmonics);

– electronic equipment, due to interference to the signal processing.

In so far as group B equipment includes both emitters and susceptible devices, recommendations for group E equipment should be observed.

The electric supply network should be designed for a large short-circuit capacity. This requirement, in turn, calls for generators with the smallest possible sub-transient reactance.

In comparison with conventional designs, these requirements may lead to increased power capacities (generator, switchgear, cables).

The choice of power supply network should be considered carefully, balancing the requirements for safety, EMC and continuity of supply against each other. This might result in a mix of power supply distribution systems on board, each dedicated for its purpose. IT, TN-S and TT type distribution systems are possible. TN-C type distribution systems are not recommended since they will cause hull currents.

Filter circuits may be installed in parallel with convertors, tuned to the fifth and/or seventh harmonic. However, power generators on ships show static and dynamic frequency deviations which are generally much higher than those of comparable land-based power supplies. This makes the layout of filter circuits difficult. In case of cycloconvertor systems it is difficult to filter out disturbances since the harmonics have varying sidebands. Furthermore, network resonances should be avoided by careful planning and design.

Careful power supply design can assure that non-linear loads, for example from convertors, will be only a fraction of the total network load. Alternately the supply can be designed with separate dedicated converter networks suitably decoupled from the main ship supply network.

Isolating transformers with a metal shield between primary and secondary winding(s) may be used to isolate interference from connected electronic equipment.

Compensation capacitors for fluorescent lighting fixtures should be equipped with inductance chokes if operated from a power supply with a high content of harmonics in order to avoid overload. If fluorescent lighting fixtures are operated without electronic starters, they should be connected in twin-lamp configurations, or with central compensation with an inductance choke for each group of lamps, or without compensation.

Power convertors which induce low power supply disturbance can be employed at the additional expense of power electronic circuits.

B.3.4 Measures for group C

Radar and sonar equipment use pulsed electric energy. The energy pulse is generated during the transmitting phase and can be the cause of interference in other equipment.

During the receiving phase, the radar and sonar equipment may be susceptible to interference from other equipment.

Sonar equipment which carries large pulsed currents should be installed either with double shielded cables, or with cables installed in continuous grounded protective cable piping.

The same cables are used to carry receiving signals (with very low signal level in the microvolt region). Therefore these cables should not be installed in the vicinity of cables with high interference levels (for example pulsed DC for degaussing system or power cables for thyristor controlled equipment).

High-power signal cables of radar transceivers should be as short as possible. These cables should not be installed near radio antenna cables, otherwise the cables should be installed in protective cable piping (waveguides are excluded: using waveguides or special cables with corrugated metal tubing is common practice).

B.3.5 Measures for group D

This group includes equipment and installations which emit temporary interference because of current switching, in particular:

– inductive consumers, for example relays, contactors, magnetic valves, solenoids, etc.;
– motor-driven consumers, for example electric drives, positioning motors, etc.;
– combinations of inductances and capacitors which tend to oscillate or resonate.

Switching of these consumers induces broad-band interference. Group D equipment should be considered as a source of interference.

Voltage surge-limiters should be installed close to the corresponding inductance, and high-frequency-absorbing elements should be installed close to switching contacts. This guideline should be observed for both DC and AC consumers.

It is recommended to use the following pulse-limiting components.

For DC:

– suppressor diodes;
– varistors;
– resistor–capacitor (RC) combination;
– free-wheeling diodes.

For AC:

– varistors;
– discharge paths with voltage-dependent resistors (VDR);
– capacitors;
– RC combination (resonance of RC combinations in conjunction with the inductivity of the circuit should be avoided).

B.3.6 Measures for group E

B.3.6.1 General

This group includes intercommunication and signal processing equipment, as well as digital and analogue transmission systems between sensors, displays, operator panels, and computers.

Equipment of this group is often equipped with switching power supplies. These power supplies, connected positioning motors, relays, electronic relays, etc. can induce considerable levels of interference. Therefore the measures for Groups B and D should also be considered.

Equipment belonging to this group is usually emitters and susceptible devices; both immunity and disturbance should be considered for this equipment.

B.3.6.2 Design considerations

Data transmission by long cables should be performed at maximum feasible signal levels. Preamplifiers at the sensor location should be used if necessary. Data transmission by long cables at low signal levels may require the use of error correction or transmission signalling protocols for satisfactory operation.

Systems should have the lowest possible impedance, particularly for system inputs, so as to reduce capacitive interference coupling (for example due to unfavourable cable routing) to an acceptable level.

Ships often show asymmetrical or common-mode interference levels from 1 V to 2 V with superimposed spikes of several hundred volts.

Instrument amplifiers, particularly precision amplifiers for low-level signals, should have sufficient resistance or protection against this type of interference.

Symmetric signal transmission is resistant to asymmetrically induced low-frequency interference and should be used where possible.

Analogue-to-digital convertors should be of integrator type.

The internal 0 V reference busbar of systems should be connected to ground at one single point. Only this central ground connection should be easily accessible to facilitate inspection and allow tests for undesired short circuits to ground.

Optocouplers or transformers can achieve galvanic separation of system components in those cases where the single point grounding for the reference potential cannot be implemented.

Computer systems can emit intense RF disturbances and are themselves susceptible to RF interference from other equipment, for example radio transmitters. Sufficient shielding should be provided in those cases where computer operation would be impeded by interference.

B.3.6.3 Instrumentation amplifiers

The input lines of instrumentation amplifiers on ships are subjected to magnetic and electric disturbance with frequencies ranging from power supply frequency up to high frequency. This results in common-mode interference.

For ideally symmetrical amplifier inputs, such common-mode noise does not lead to input differential and therefore does not have any influence. In practice, however, systems cannot be totally symmetrical over an extended frequency range. Consequently, an unwanted symmetric noise will appear in addition to the signal at the amplifier input. This effect should be reduced to a minimum by appropriate measures, for example by filtering.

B.3.6.4 Cable routing

If system selection or system design cannot effectively reduce susceptibility to disturbance, then besides cable separation (see B.2.5), cable routing and cable selection should be performed with particular care.

The following rules should be followed wherever possible:

In the frequency range up to 100 kHz and at low signal levels, the wires should be twisted tightly and shielded over the entire length. The shields should be continuous and, contrary to B.2.4, connected to ground only at one end. The ground connection should be on the sensor side if the sensor is grounded; otherwise the ground connection should be on the amplifier/computer side. The shield should be isolated from the ship's structure over the entire length to avoid galvanically coupled interference.

Alternatively, an amplification or a conversion of low signals should be considered, see B.3.6.2.

B.3.7 Measures for group F

B.3.7.1 General

Non-electric equipment items and installations can cause interference if they consist of metallic/conducting material and the contact points carry eddy currents.

Stray currents are induced by electromagnetic fields on the weather deck, for example by the transmitting antennas, and can generally be found in all parts of the hull and superstructure of the ship.

The level of disturbance increases in direct proportion to the level of the ship's vibration transmitted to the respective items and increases with the change in conductivity at the contact points, for example by corrosion.

Critical points on the weather deck can be, for example:

– loose turnbuckles of the rigging;
– loose wire ropes in railing stanchions;
– insufficient lashing of containers;
– loose derricks or other large items.

These points are called parasitic sources of disturbance and can cause broad-band interference to radio reception.

Eddy currents in below-deck areas of the vessel are caused by discharges from suppression capacitors, by transient effects in earthed distribution systems, by using the ship's structure as the common return conductor for different circuits, etc.

Sources of this type of disturbance can be, for example:

– pipe connections without earth/ground connection;
– loose metallic wall panels;
– loose or isolated parts of cable trays or other equipment.

These points cause broad-band interference which can be superimposed on low-level analogue signals by way of the reference potential.

B.3.7.2 Design considerations and installation

The type of equipment chosen for the ship, particularly with respect to sensitive receivers, sensitive (analogue) instrumentation amplifier systems and control systems, will determine if and which measures should be taken to ensure an acceptable level of EMC.

B.3.7.3 Grounding

The following measures have been proven in practical applications but do not attempt to be exhaustive. Each case needs investigation as to where and to what degree these measures should be employed.

All metallic equipment and non-electric metallic outfitting items where one dimension exceeds 1 m, installed on the weather deck in the vicinity of transmitting antennas (see B.3.2.3), should be connected to the ship's structure with a low resistance or low impedance connection. For antenna rigging see B.3.2.5.

The rig should either be galvanically connected to the ship's structure (grounding) or completely insulated from the surrounding superstructure.

Welded connections require no additional grounding measures.

Turnable outfitting items on the weather deck should have short flexible conductors bridging the hinge and providing low-impedance ground connection.

Turnbuckles, shackles, and other detachable connections should be bridged by conductors.

B.3.8 Measures for group G

B.3.8.1 General

The characteristic properties of integrated systems are distributed pieces of equipment, often from different manufacturers, connected by extended cable networks and operating together on the ship.

The installation positions of individual equipment items are subject to widely differing ambient and electromagnetic conditions (for example integrated cargo monitoring system with sensors and equipment in different zones).

The risk of interference increases with the number of possible equipment combinations.

The successful completion of EMC tests on individual equipment does not necessarily guarantee unlimited operability after integration into the overall system and under ship EMC conditions.

A special problem for large integrated systems may be their size which prevents them from being tested for EMC in the laboratory before installation on board the ship. The individual equipment items can, and usually are, tested for EMC by means of interface simulation tests.

B.3.8.2 Considerations before integration

It is recommended that equipment from critical systems be installed in an EMC laboratory in order to simulate interface conditions.

The simulation should emulate both the functional characteristics of the signal interface (signal type, signal level) and the interference parameters to be expected in the on-board installation. It should be noted that the installation of equipment items in different zones will lead to interference of a different type and different severity influencing the interfaces at the same time.

The emulated interference should represent both the conditions of conducted and of radiated interference. In critical cases, one should investigate whether radiated interference should be replaced by disturbance parameters induced in cables and metallic enclosures.

In case of system degradation of performance due to interference, special measures, for example filtering, shielding or cable routing, should be taken and possibly modified until the system degradation has been eliminated.

The simulated interference conditions and the measures which have been determined to be effective should be documented.

These measures should be applied to the later integration of the equipment on board.

B.3.8.3 Considerations during commissioning

The integration of systems may lead to noticeable interference of individual equipment items, despite careful planning and previous equipment tests. In these cases it should be investigated whether the interference results from specific properties of the mounting position on board the vessel and/or from operation in the shipboard environment. For this purpose, all individual equipment pertaining to the integrated system should be switched on one after the other and the correct function verified (sequential switch-on test).

If the sequential switch-on test does not identify a correlation between equipment disturbance and on-board operating conditions, it is necessary to investigate the electromagnetic disturbance parameters on each equipment interface of the equipment in question. The comparison between specified and measured disturbance parameters may then indicate the possible cause of disturbance, and necessary remedial action can be taken on the basis of these results.

B.4 Organizational measures

B.4.1 On-board operation

The EMC analysis or on-board operating conditions may yield electromagnetic incompatibility which cannot be solved by normal technical measures. In such cases it will be necessary to take appropriate measures to coordinate the operation of on-board system/equipment, for example:

– definition of operational or functional restraints to reduce mutual interference during simultaneous operation of multiple equipment (for example transmitting and receiving antennas);
– documentation of operating procedures and/or operational restraints which may lead to safety-critical situations if not observed (safety of the ship and personnel safety);
– warning boards restricting personnel access to certain areas on the ship with excessive electromagnetic field strength (radiation hazards to humans according to the relevant regulations/laws).

B.4.2 Maintenance and repair

Technical measures to achieve EMC may be degraded during the lifetime of the ship by external, ship-specific influences and other long-term effects, for example:

– vibration and shock;
– climatic influences;
– ageing;
– corrosion;
– overvoltage;
– stray currents.

The operating manuals should include information on necessary measures to achieve and maintain the desired level of EMC, even if these measures have been amply designed and carefully executed. EMC measures should be inspected periodically, namely:

– visual inspection of technical EMC measures to check completeness and factual condition, for example satisfactory electrically-conducting ground connections;
– repetition of performance tests, for example measuring of interference parameters on supply lines, comparison with acceptance test results and, if necessary, restoration of the original EMC parameters.

Changes or additions to the ship's equipment installation in the course of maintenance and repair, or changes to operating conditions, may lead to a degradation of the EMC environment, despite observation of EMC regulations. Resulting EMC degradation should be analysed prior to executing the aforementioned changes, and organizational measures taken, if necessary.

After completion of maintenance and repair work, tests should be performed to check the specified EMC conditions and restore the original conditions if necessary.

Annex C
(informative)

EMC test report

A test report should be prepared, including at least the following information:

a) name and address of testing laboratory and of location where the test was carried out when different from the address of the testing laboratory;

b) unique identification of the report (e.g. with a unique identification number) and of each page, indication of page number, and total number of pages;

c) name and address of client;

d) description and identification of test item;

e) date of receipt of test item and date(s) of performance of test;

f) identification of the test specification or description of the test method or procedure;

g) description of sampling procedure, where relevant;

h) any deviations, additions to or exclusions from the test specification, and any other information relevant to a specific test;

i) identification of any non-standard test method or procedure utilized;

j) measurements, examinations and derived results, supported by tables, graphs, sketches and photographs as appropriate, and any failures identified;

k) a statement on measurement uncertainty (where relevant);

l) a signature and title or a relevant marking of person(s) accepting technical responsibility for the test report and date of issue;

m) a statement to the effect that the test results relate only to the items tested;

n) a statement that the report shall not be reproduced except in full with the written approval of the testing laboratory.

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