



DPC: 25 / 30440618 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000

Fax: +44 (0)20 8996 7400

www.bsigroup.com

Date: 26 February 2025

Origin: International

Latest date for receipt of comments: 16 April 2025

Project No. 2021/01795

Responsible committee: JPEL/18 Electrical installations of ships and of mobile and fixed offshore units

Interested committees:

Title: Draft BS EN 60533 Ed.4.0 Electrical and electronic installations in ships - Electromagnetic compatibility (EMC)

Please notify the secretary if you are aware of any keywords that might assist in classifying or identifying the standard or if the content of this standard

- i) has any issues related to 3rd party IPR, patent or copyright
- ii) affects other national standard(s)
- iii) requires additional national guidance or information

**WARNING: THIS IS A DRAFT AND MUST NOT BE REGARDED OR USED AS A BRITISH STANDARD.
THIS DRAFT IS NOT CURRENT BEYOND 16 April 2025**

This draft is issued to allow comments from interested parties; all comments will be given consideration prior to publication. No acknowledgement will normally be sent. **See overleaf for information on the submission of comments.**

No copying is allowed, in any form, without prior written permission from BSI except as permitted under the Copyright, Designs and Patent Act 1988 or for circulation within a nominating organization for briefing purposes. Electronic circulation is limited to dissemination by e-mail within such an organization by committee members.

Further copies of this draft may be purchased from BSI Shop <http://shop.bsigroup.com> or from BSI Customer Services, Tel: +44(0) 20 8996 9001 or email cservices@bsigroup.com. British, International and foreign standards are also available from BSI Customer Services.

Information on the co-operating organizations represented on the committees referenced above may be obtained from <http://standardsdevelopment.bsigroup.com>

Responsible Committee Secretary: **Mr Michael Peace (IET) (BSI)**
Direct tel: **01438 765566**
E-mail: **michaelpeace@theiet.org**

Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

For national standards, comments will be reviewed by the relevant UK national committee and the resulting standards published as a British Standard.

UK Vote

Please indicate whether you consider the UK should submit a negative (with supporting technical reasons) or positive vote on this draft. Please indicate if you are aware of any reason why this draft standard should not be published as a British Standard.

Submission of Comments

- **Annotated drafts are not acceptable and will be rejected.**
- All comments should be submitted online at <https://standardsdevelopment.bsigroup.com/>. You will need to register in order to comment.

Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
------------------	------------------------

1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/Figure/ Table/Note	Type of comment	Commend (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	



18/1956/CD

COMMITTEE DRAFT (CD)

PROJECT NUMBER:

IEC 60533 ED4

DATE OF CIRCULATION:

2025-02-21

CLOSING DATE FOR COMMENTS:

2025-05-16

SUPERSEDES DOCUMENTS:

18/1732/RR

IEC TC 18 : ELECTRICAL INSTALLATIONS OF SHIPS AND OF MOBILE AND FIXED OFFSHORE UNITS

SECRETARIAT:

Norway

SECRETARY:

Mr Arild Røed

OF INTEREST TO THE FOLLOWING COMMITTEES:

TC 22,TC 77,TC 80,TC 81,ACEC

HORIZONTAL FUNCTION(S):

ASPECTS CONCERNED:

Electromagnetic Compatibility,Safety

This document is still under study and subject to change. It should not be used for reference purposes.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Recipients of this document are invited to submit, with their comments, notification of any local regulations or technical reasons that may exist and should be considered should this proposal proceed, recognizing that failure to address such requirements could result in the need for new or existing "In Some Countries" clauses. (SEE [AC/22/2007](#) OR [NEW GUIDANCE DOC](#)).

TITLE:

Electrical and electronic installations in ships - Electromagnetic compatibility (EMC)

NOTE FROM TC/SC OFFICERS:

This revision includes the content of IEC 62472 related to EMC for Ships with non-conductive hulls

Copyright © 2025 International Electrotechnical Commission, IEC. All rights reserved. It is permitted to download this electronic file, to make a copy and to print out the content for the sole purpose of preparing National Committee positions. You may not copy or "mirror" the file or printed version of the document, or any part of it, for any other purpose without permission in writing from IEC.

CONTENTS

1		
2		
3	FOREWORD.....	9
4	INTRODUCTION.....	11
5	1 Scope.....	13
6	2 Normative references	14
7	3 Terms and definitions	16
8	3.1 Terms and definitions	16
9	3.1.1 General	16
10	3.1.2 Installation measures	20
11	3.1.3 Testing	22
12	3.1.5 Zoning	25
13	3.2 symbols and abbreviated terms	26
14	4 General	28
15	4.1 Basic assumptions	28
16	4.2 Roles	28
17	4.3 Risk and Rule based	28
18	4.3.1 Rule-based approach	28
19	4.3.2 Risk-based approach	29
20	4.3.3 Risk and rule-based combined	29
21	4.3.4 Liability	30
22	4.4 Zones and power supply grids	30
23	4.4.1 Introduction.....	30
24	4.4.2 EMC zones in power supply grids	30
25	4.4.3 EMC zones in spaces.....	30
26	5 Ship's owner/operator	31
27	5.1 Rule-based approach	31
28	5.2 Risk-based approach.....	31
29	5.3 Maintenance	32
30	6 Yard	33
31	6.1 Rule-based approach	33
32	6.2 Risk-based approach.....	33
33	6.2.1 EMC management plan	34
34	6.2.2 EMC maintenance and inspection plan	34
35	6.3 Ships with a non-intentionally conductive hull and/or superstructure	35
36	6.3.1 Introduction.....	35
37	6.3.2 Ship layout.....	35
38	6.3.3 Whip antennas	35
39	6.3.4 Earthing systems	36
40	6.3.5 Earth plate	36
41	7 Electrical system integrator (ESI)	38
42	7.1 Rule-based approach	38
43	7.1.1 Equipment in the accommodation zone	38
44	7.1.2 Applicable standards/rules	38
45	7.1.3 System aspects.....	38
46	7.2 Risk-based approach.....	39

47	7.2.1	EMC control plan	39
48	7.2.2	EMC implementation plan	39
49	7.2.3	EMC verification	40
50	7.2.4	EMC validation plan	40
51	7.2.5	Equipment generating high levels of disturbance	43
52	7.3	Ships with a non-intentionally conductive hull and/or superstructure	43
53	7.3.1	Introduction	43
54	7.3.2	Shielding	43
55	7.3.3	Earthing and equipotential bonding system	44
56	7.3.4	Unbalanced systems	47
57	7.3.5	Cables and cable routing	47
58	8	Equipment/component manufacturer	48
59	8.1	Introduction	48
60	8.2	EMC test plan	48
61	8.2.1	Objective	48
62	8.2.2	Configuration of marine electrical equipment under test (EUT)	48
63	8.2.3	Test pre-conditioning	49
64	8.2.4	Acceptance criteria	49
65	8.2.5	Scope of EMC testing	50
66	8.3	Emission requirements	50
67	8.3.1	Introduction	50
68	8.3.2	Conditions during the emission tests	50
69	8.3.3	Interference protection to digital mobile phones	56
70	8.4	Immunity requirements	56
71	8.4.1	Conditions during the immunity tests	56
72	8.4.2	Minimum immunity requirements	56
73	8.5	Test results and test report	64
74	8.6	Compliance statement	64
75	9	Maintenance, repairs and retrofits	66
76	9.1	Introduction	66
77	9.2	Maintenance and repair	66
78	9.3	Retrofits	67
79	9.3.1	Introduction	67
80	9.3.2	Ship's owner	67
81	9.3.3	Yard	67
82	9.3.4	Electrical system integrator	67
83	9.4	Ships with a non-intentionally conductive hull and/or superstructure	68
84	Annex A (informative)	Risk based EMC	69
85	A.1	Surveyor	69
86	A.2	EMC management plan	69
87	A.2.1	General	69
88	A.2.2	EMC advisory group	69
89	A.2.3	Liability	69
90	A.2.4	Power grid supply configuration	70
91	A.2.5	Responsibility matrix	70
92	A.2.6	Deviations from EMC plans	71
93	A.3	EMC control plan	72
94	A.3.1	Introduction	72
95	A.3.2	Initial analysis	72

96	A.3.3	Top deck design evaluation	74
97	A.3.4	Below deck design evaluation.....	78
98	A.3.5	Mitigation measures	81
99	A.3.6	EMC zone plans.....	81
100	A.4	EMC implementation plan.....	81
101	A.5	EMC verification plan	82
102	A.5.1	Introduction.....	82
103	A.5.2	Check if installed equipment complies with the defined EMC standards	82
104	A.5.3	Visual inspection.....	82
105	A.5.4	Checks if cable glands/transits are installed correctly	83
106	A.5.5	Checks if cable separation is conducted correctly	83
107	A.5.6	Checks if earth connections are created in a correct manner.....	83
108	A.5.7	Checks if EMC filters are installed correctly	84
109	A.6	EMC validation plan	84
110	A.6.1	Introduction.....	84
111	A.6.2	Evaluation of disturbance levels at receiver inputs	84
112	A.6.3	Transmitter-receiver interaction test	90
113	A.6.4	Mobile radio test	91
114	A.6.5	Goodput test.....	93
115	A.6.6	Load steps.....	94
116	A.6.7	GSM test	95
117	A.6.8	Signal stability verification	96
118	Annex B (informative)	EMC zones	98
119	B.1	Introduction.....	98
120	B.2	Zoning	98
121	B.3	Spatial EMC zones for radiated disturbances	99
122	B.3.1	Introduction.....	99
123	B.3.2	Antenna zone.....	99
124	B.3.3	Deck, EMC outer deck & bridge zone	100
125	B.3.4	Accommodation zone	101
126	B.3.5	General inner deck zone	101
127	B.3.6	Special power distribution zone	102
128	B.3.7	Spatial zones defined by user.....	102
129	B.3.8	Examples of assigning spaces to spatial EMC zones	102
130	B.4	EMC power grid zoning	103
131	B.4.1	Introduction.....	104
132	B.4.2	Residential grid	104
133	B.4.3	Industrial grid.....	104
134	B.4.4	Special power distribution grid.....	104
135	B.4.5	EMC power grid zones defined by user.....	105
136	B.4.6	Example of EMC power grids with EMC zoning	105
137	Annex C (informative)	Measurement techniques for common mode voltages	107
138	C.1	Introduction.....	107
139	C.2	Source of common mode voltages	108
140	C.3	Common mode voltage appearance	111
141	C.4	Measurement equipment	114
142	C.4.1	Artificial neutral point/midpoint	114
143	C.4.2	Data logging, sample frequencies and anti-aliasing filter	115
144	C.4.3	(Post)processing	116

145	C.5	Suggested maximum common mode levels on equipment level.	116
146	C.5.1	Introduction.....	116
147	C.5.2	Common mode measurements	117
148	C.5.3	Suggested maximum CM levels for equipment designed to operate in a maritime power supply grid.....	118
150	C.6	Common mode voltage on supply grid level.	120
151	C.6.1	Introduction.....	120
152	C.6.2	Common mode compatibility levels for maritime power supply grids	121
153	C.7	Examples and simulations	121
154	Annex D (informative)	Mitigation guidelines	124
155	D.1	Applicability	124
156	D.2	General technical measures	124
157	D.2.1	General	124
158	D.2.2	Earthing.....	124
159	D.2.3	Selection of applied data busses and signal types	125
160	D.2.4	Cable separation and segregation	126
161	D.2.5	Filtering and overvoltage protection	129
162	D.3	Special measures for equipment.....	129
163	D.3.1	Measures for radio communication and navigation equipment	129
164	D.3.2	Measures for power generation and conversion equipment	130
165	D.3.3	Measures for equipment operating with pulsed power	131
166	D.3.4	Measures for switchgear and controlgear assemblies.....	131
167	D.3.5	Measures for intercommunication and signal processing equipment and control systems.....	132
169	D.4	Ships with a non-intentionally conductive hull and/or superstructure	132
170	D.4.1	Function of shielding	132
171	D.4.2	Earthing systems	133
172	D.4.3	Protection against RF fields.....	134
173	D.4.4	Protection against induced currents	134
174	D.4.5	Filtering	134
175	D.4.6	Room layout	135
176	D.4.7	Transmitter location	136
177	D.4.8	Overvoltage protection from lightning strikes	136
178	Annex E (informative)	EMC test report	137
179	E.1	EMC test report - IEC 60533 compliant equipment	137
180	E.2	EMC test report - integration tests on board.....	137
181	Annex F (informative)	Justification of deviation from generic EMC standards.....	139
182	F.1	Introduction.....	139
183	F.2	Immunity.....	139
184	F.2.1	Electrostatic discharge (ESD) IEC 61000-4-2.....	139
185	F.2.2	Radiated radio-frequency EM fields IEC 61000-4-3	139
186	F.2.3	Electrical fast transient/burst (EFT-B) IEC 61000-4-4	140
187	F.2.4	Surge IEC 61000-4-5	140
188	F.2.5	Conducted disturbances induced by radio-frequency fields IEC 61000- 4-6.....	140
190	F.2.6	Power frequency magnetic field IEC 61000-4-8.....	140
191	F.2.7	Voltage & frequency variation IEC 61000-4-11 & IEC 61000-4-34.....	140
192	F.2.8	Voltage dips IEC 61000-4-11 (AC) IEC 61000-4-29 (DC).....	140
193	F.2.9	Short interruptions IEC 61000-4-11 (AC) IEC 61000-4-29 (DC)	141

194	F.2.10	Conducted low frequency interference IEC 61000-4-16	141
195	F.2.11	Radiated field in close proximity IEC 61000-4-3 & IEC 61000-4-39	141
196	F.2.12	Broadband radiated immunity IEC 61000-4-41	141
197	F.2.13	Other tests	141
198	F.3	Emission	142
199	F.3.1	Protection of on-board receivers	142
200	F.3.2	Common mode emission	142
201	F.3.3	Conducted emission (> 10 kHz)	144
202	F.3.4	Radiated emission	145
203	Annex G (informative)	Cross reference list previous editions standard	148
204	G.1	Cross reference list IEC 60533 edition 3 versus 60533 edition 4	148
205	G.2	Cross reference list IEC 62742 edition 1 versus 60533 edition 4	152
206	Bibliography		154
207			
208	Figure 3-1	– Examples of basic electronic power converters	19
209	Figure 3-2	– Examples of ports	25
210	Figure 6-1	– Unscreened cable penetrating the antenna earth plane	36
211	Figure 7-1	– Double-tree earthing system	45
212	Figure 7-2	– Strap connection of antenna earth plane with earth plate	46
213	Figure 7-3	– Tape connection of antenna earth plane with earth plate	47
214	Figure 8-1	– Voltage and frequency variation test	62
215	Figure A.1	– Top deck EMC analysis flow	75
216	Figure A.2	– Evaluation of the correct installation of cable feedthroughs	83
217	Figure A.3	– Mobile radio test positions	92
218	Figure B.1	– Example of an antenna zone	100
219	Figure B.2	– Example of EMC power grids with EMC zoning	106
220	Figure C.1	– three-phase two level inverter	109
221	Figure C.2	– Common mode voltages	109
222	Figure C.3	– Equivalent circuit model of an AFE motor drive solution	110
223	Figure C.4	– Common mode current paths using earthing capacitors (C_{HF})	110
224	Figure C.5	– Common mode current paths without earthing capacitors	111
225	Figure C.6	– General common mode voltage source	111
226	Figure C.7	– common mode voltages in AC TT/TN (neutral earthed) systems	112
227	Figure C.8	– common mode voltages in DC TT/TN (earthed DC side) systems	112
228	Figure C.9	– Common mode voltages in IT (unearthed) systems	112
229	Figure C.10	– Voltages and currents in rectifier fed power system	113
230	Figure C.11	– Voltages and currents in a power converter system. The midpoints of	
231		AFE 2 and INU 3 are identical, but they have their own symbols for clarity	114
232	Figure C.12	– Voltages and currents in an AFE (or equivalent) system	114
233	Figure C.13	– Circuit for measuring common mode voltages	115
234	Figure C.14	– Common mode voltage measurement circuit for a common mode source	117
235	Figure C.15	– CM voltage measurement circuit for an active front motor drive or an AC	
236		frequency/voltage changer	117
237	Figure C.16	– CM voltage measurement circuit for a CM source including filter	
238		components	

239	Figure C.17 – CM voltage measurement circuit for multiple CM sources including filter	
240	components	118
241	Figure C.18 – Suggested maximum common mode emission levels	119
242	Figure C.19 – CM voltage measurement circuit to measure disturbance levels in a	
243	power supply grid	120
244	Figure C.20 – Typical waveforms and spectrum of the CM voltage $U_{1n\text{-earth}}$	
245	(Figure C.10) of an inverter fed by a diode rectifier. $Z_{\text{grid/earth}} = 10 \text{ nF}$, $Z_{\text{load/earth}} =$	
246	45 nF	122
247	Figure C.21 – Typical waveforms and spectrum of the CM voltage $U_{1n\text{-earth}}$	
248	(Figure C.11) of an AFE inverter connected to a motor. $Z_{\text{grid-earth}} = 10 \text{ nF}$,	
249	$Z_{\text{load/earth}} = 45 \text{ nF}$	122
250	Figure C.22 – Typical waveforms and spectrum of the CM voltage $U_{1n\text{-earth}}$	
251	(Figure C.12) of an AFE inverter connected to a battery. $Z_{\text{grid-earth}} = 10 \text{ nF}$, $Z_{\text{DC-}}$	
252	$\text{earth} = 10 \text{ }\mu\text{F}$	123
253	Figure D.1 – Example of an earthing system with shielded spaces	134
254	Figure D.2 – Principle of single protection layer	135
255	Figure D.3 – Principle of multiple protection layers	136
256		
257	Table 7-1 – Measurement settings for EM noise level measurements at the input of	
258	radio receivers in or below VHF band	41
259	Table 8-1 – Resolution bandwidth requirements	51
260	Table 8-2 – Emission limits antenna zone	51
261	Table 8-3 – Emission limits deck, EMC outer deck & bridge zone	53
262	Table 8-4 – Emission limits general inner deck zone	54
263	Table 8-5 – Minimum immunity requirements for AC power ports	57
264	Table 8-6 – Minimum immunity requirements for DC power ports ^a	59
265	Table 8-7 – Minimum immunity requirements for I/O ports, signal/control ports	60
266	Table 8-8 – Minimum immunity requirements for enclosure ports	61
267	Table 8-9 – Test levels for proximity fields from RF wireless communications	
268	equipment	64
269	Table 8-10 – Emission and immunity requirements per zone and grid	65
270	Table 9-1 – Relevant documentation for retrofits, upgrades and replacements	66
271	Table A.1 – Responsibility matrix, explanation of symbols	70
272	Table A.2 – Example responsibility matrix	71
273	Table A.3 – Example of Transmitter-receiver matrix (TRM)	76
274	Table A.4 – TRM, explanation of symbols	77
275	Table A.5 – Example SVM Matrix	79
276	Table A.6 – Measurement settings for EM noise level measurements at the input of	
277	radio receivers operating above the VHF band	87
278	Table B.1 – Examples of space allocation in different EMC zones for ships with a steel	
279	hull 103	
280	Table C.1 – Example of sample frequencies, anti-aliasing cut off frequencies and	
281	minimum resolutions for CM measurements	115
282	Table C.2 – Settings for data analysis	116
283	Table C.3 – Suggested maximum CM emission levels from f_{nom} up to 9 kHz for	
284	equipment designed to operate in a maritime power supply grid	119

285	Table C.4 – Suggested maximum CM emission levels from 9 kHz up to 1 MHz for	
286	equipment designed to operate in a maritime power grid	119
287	Table C.5 – CM compatibility levels from f_{nom} up to 9 kHz for IT maritime power	
288	supply grid	121
289	Table C.6 – CM compatibility levels from 9 kHz up to 1 MHz for IT maritime power	
290	supply grids	121
291	Table D.1 – Cable separation: Signal types and cable categories	127
292	Table D.2 – Cable segregation distances (cm)	128
293	Table G.3 – Cross reference list IEC 60533 edition 3 versus 60533 edition 4	148
294	Table G.4 – Cross reference list IEC 60533 edition 1 versus 60533 edition 4	152
295		
296		

INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ELECTRICAL AND ELECTRONIC INSTALLATIONS IN SHIPS –
ELECTROMAGNETIC COMPATIBILITY (EMC)****FOREWORD**

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch> shall not be held responsible for identifying any or all such patent rights.

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

This fourth edition cancels and replaces the third edition, published in 2015. This edition constitutes a technical revision.

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

- a) It is recognised that in the ship building process different parties are involved with each its specific role. In this edition requirements are linked to the different roles.
- b) It is recognised that not all equipment onboard a ship is specifically designed for the maritime environment. For that reason, the risk-based approach is introduced to minimise risks on interference from non-maritime equipment.

- c) The number of EMC zones have been increased, and the zones have been divided into two groups: spatial zones (separated by steel bulkheads, decks and distance) and power grid zones (separated by transformers, converters and filters). This was done to cover risk areas, such as those near antennas, and to allow dealing with the fact that the boundaries of EMC spatial zones and EMC power grid zones usually not align.
- d) The upper frequency limit has been increased to match new technological developments.
- e) The requirements from IEC 62742 [2] have been integrated in this document, where applicable, since there are more and more ships where composite and metal construction materials are combined.

The justification of the emission limits and immunity test levels can be found in Annex F. An overview in which clauses reused information from the third edition of this document and of the first edition of IEC 62742 [2] can be found is given in Annex G.

The text of this International Standard is based on the following documents:

Draft	Report on voting
XX/XX/FDIS	XX/XX/RVD

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

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

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

INTRODUCTION

The electric and/or electronic systems of ships need to operate under a wide range of environmental conditions, such as temperature ranges, salinity etc. This document deals with the electromagnetic (EM) aspects of the environment and defines how to construct reliable electrical and electronic installations on board. It considers the fact that in these installations, both equipment specifically designed for a maritime EM environment as well as equipment used outside its intended EM environment is installed. For this reason, the document specifies requirements on the level of the whole ship (clause 5, 6 and 7) and also for equipment designed for the maritime environment (clause 8). The application of equipment designed for the maritime EM environment, compliant with this document, reduces the risk of non-conformity at the ship's level. The control of undesired EM emission from pieces of equipment ensures that no other equipment on board will be unduly influenced. Suitable limits are specified for maritime equipment and reference values are given at ship's level.

On the other hand, the equipment needs to function without degradation in the normal maritime EM environment. The test values for immunity at equipment level, specified in this document, have been chosen under this assumption.

In order to separate sensitive and disturbing equipment, mitigation measures such as EMC zones are defined. This approach also assists in integrating non-maritime equipment (equipment not specifically designed for the marine EM environment).

A ship built, tested and with equipment and systems installed in accordance with this document, meets the relevant IMO requirements. Special risks, such as for instance transients from the operation of circuit breakers, EM radiation from radio transmitters and equipment applied outside its intended EM environment are also covered.

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

This document is applicable to all electrical and electronic installations on board all ships, both those with and without an intentionally conductive hull. It assumes that the ship is constructed in such a way that intentionally conductive structural parts will significantly attenuate EM disturbance from the outer deck environment to the inner deck environment and vice versa.

This document recognizes that both equipment designed for a maritime EM environment and equipment that is designed for a different EM environment (i.e. standard commercial equipment of various kinds) will be used on board. That is why two different approaches are combined in this document:

- a) rule-based approach;
- b) risk-based approach.

The rule-based approach focuses primarily on the equipment level and applying equipment in the EM environment for which it was developed.

The risk-based approach focuses on ensuring that even if equipment is placed outside its intended EM environment, no equipment will be unduly influenced. The risk-based approach does not require any calculations to determine the chance of interference but rather points out the risk for the ship builder and the electrical system integrator (ESI) that modifications are required if the installation doesn't meet the EMC tests during Harbour Acceptance Tests (HAT) or Sea Acceptance Tests (SAT).

This document is intended to be applied on the ship's level; however, clause 8 is specifically intended for equipment manufacturers for the maritime market. There are several standards that require that equipment, for which they are applicable, comply with IEC 60533. For such equipment, clause 8 is mandatory and only the rule-based approach can be applied. It might be

429 beneficial to state compliancy with this document, if the focus of the manufacturer is to deliver
430 components/equipment for the maritime market, even if compliance with this document is not
431 mandatory. A statement of compliancy with this document in relation to components/equipment
432 shows that the components/equipment are designed for a maritime EM environment, reducing
433 the risks for the yard/ESI on interference when it is installed on board.

434 A compliance statement with this standard for components/equipment means that the product
435 complies with the applicable requirements as given in clause 8. The applicable requirements
436 follow from the statement of the manufacturer for which zone and supply grid the product is
437 intended.

438

439

ELECTRICAL AND ELECTRONIC INSTALLATIONS IN SHIPS – ELECTROMAGNETIC COMPATIBILITY (EMC)

1 Scope

This document contains requirements and guidelines to ensure electromagnetic compatibility on board all types and sizes of ships unless more specific standards are applicable for specific types or sizes of ships. These requirements and guidelines can be applied during the building process but also when maintenance or upgrades are required.

When equipment standards refer to this document, especially the requirements in clause 8 are applicable.

EXAMPLE IEC 60092-306:2022 [3] (maritime luminaires) and IEC 60092-504:2025 [4] (maritime automation, control and instrumentation equipment) refer to this document.

This document includes:

- Assistance in defining the proper EMC requirements at ship, system, sub-assembly and equipment level.
- Assistance in the delegation of EMC related tasks.
- Tests and measurements to evaluate the EMC performance at ship and system level.
- Emission and immunity requirements for equipment developed for a maritime environment from the grid frequency up to 6 GHz.

NOTE 1 This document assists in meeting the relevant EMC requirements as stated in SOLAS [5] Chapter IV, Regulation 6 and Chapter V, Regulation 17. Reference to this document is made in IMO Resolution A.813(19) [6].

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

This document excludes:

- Equipment in the scope of TC 80.

NOTE 2 Equipment in the scope of TC80: 'Maritime navigation and radiocommunication equipment and systems' needs to comply with IEC 60945 which already covers the requirements stated in this document.

- The topic of harmonic distortion since it is discussed in IEC 60092-101 and IEC 60092-201 [7].
- The topic of termination of cable screens since it is discussed in IEC 60092-401.
- The topic of lightning and lightning protection on board ships since it is discussed in IEC 60092-401.

NOTE 3 Additional information on lightning protection may be found in DO-160G [8] section 22 & 23 Lightning and IEC 62305, especially part 1 [9] and 2 [10].

- Effects on humans, such as exposure to EM fields, and basic safety requirements such as protection against electric shock.

NOTE 4 Requirements to protect people from non-ionising are given by ICNIRP [11], [12]. National legislation might be more stringent.

NOTE 5 Common mode voltage in IT grids may exceed insulation values and cause a safety risk, which is not part of this standard. Especially in the frequency range of tens of kHz, filter components may be at risk.

NOTE 6 More information on "Basic safety" can be found in IEC Guide 104.

- The effect ripple voltage might have on components such as batteries and fuel cells.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

CISPR 25:2021, Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of on-board receivers

IEC 60092-101, Electrical installations in ships - Part 101: Definitions and general requirements

IEC 60092-401, Electrical installations in ships - Part 401: Installation and test of completed installation

IEC 60092-507, Electrical installations in ships - Part 507: Small vessels

IEC 60945:2002, 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 4-5: Testing and measurement techniques - Surge immunity test

IEC 61000-4-11, Electromagnetic compatibility (EMC) - Part 4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity tests for equipment with input current up to 16 A per phase

IEC 61000-4-14, Electromagnetic compatibility (EMC) - Part 4-14: Testing and measurement techniques - Voltage fluctuation immunity test for equipment with input current not exceeding 16 A per phase

IEC 61000-4-28, Electromagnetic compatibility (EMC) - Part 4-28: Testing and measurement techniques - Variation of power frequency, immunity test for equipment with input current not exceeding 16 A per phase

- 521 IEC 61000-4-29, Electromagnetic compatibility (EMC) - Part 4-29: Testing and measurement
522 techniques - Voltage dips, short interruptions and voltage variations on d.c. input power port
523 immunity tests
- 524 IEC 61000-4-30, Electromagnetic compatibility (EMC) - Part 4-30: Testing and measurement
525 techniques - Power quality measurement methods
- 526 IEC 61000-4-34, Electromagnetic compatibility (EMC) - Part 4-34: Testing and measurement
527 techniques - Voltage dips, short interruptions and voltage variations immunity tests for
528 equipment with input current more than 16 A per phase
- 529 IEC 61000-4-39, Electromagnetic compatibility (EMC) - Part 4-39: Testing and measurement
530 techniques - Radiated fields in close proximity - Immunity test
- 531 IEC 61000-4-41, Electromagnetic compatibility (EMC) - Part 4-41: Testing and measurement
532 techniques - Broadband radiated immunity tests
- 533 IEC 61000-6-4:2018, Electromagnetic compatibility (EMC) - Part 6-4: Generic standards -
534 Emission standard for industrial environments
- 535 IEC 62388:2013, Maritime navigation and radiocommunication equipment and systems -
536 Shipborne radar - Performance requirements, methods of testing and required test results

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1 Terms and definitions

3.1.1 General

3.1.1.1

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 60050-161:2018, 161-01-07]

3.1.1.2

electromagnetic disturbance

electromagnetic phenomenon that can degrade the performance of a device, equipment or system, or adversely affect living or inert matter

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

Note 2 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 3 to entry: In English, the terms "electromagnetic disturbance" and "electromagnetic interference" designate respectively the cause and the effect, and should not be used indiscriminately.

[SOURCE: IEC 60050-161:2018, 161-01-05]

3.1.1.3

electromagnetic interference

EMI

degradation in the performance of equipment or transmission channel or a 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: In English, the terms "electromagnetic disturbance" and "electromagnetic interference" designate respectively the cause and the effect, and should not be used indiscriminately.

[SOURCE: IEC 60050-161:2018, 161-01-06]

3.1.1.4

electromagnetic noise

a time-varying electromagnetic phenomenon apparently not conveying information and which may be superimposed on or combined with a wanted signal

[SOURCE: IEC 60050-161:1990, 161-01-02]

3.1.1.5**common mode voltage**

CM voltage

asymmetrical voltage

the mean of the phasor voltages appearing between each conductor and a specified reference, usually earth or frame

Note 1 to entry: This means that conductors bonded with the ship's hull are not incorporated in common mode voltage measurements.

[SOURCE: IEC 60050-161:1990, 161-04-09, modified – note added]

3.1.1.6**common mode current**

CM current

in a cable having more than one conductor, including shields and screens if any, the magnitude of the sum of the phasors representing the currents in each conductor

[SOURCE: IEC 60050-161:1990, 161-04-39]

3.1.1.7**common mode generating equipment**

common mode source

Equipment likely to cause common mode disturbance

EXAMPLE Inverters, active front ends, μ -grid converters or active infeed converters.

3.1.1.8**electromagnetic emission**

phenomenon by which electromagnetic energy emanates from a source

[SOURCE: IEC 60050-161:2019, 161-01-08]

3.1.1.9**immunity (to a disturbance)**

susceptibility

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

[SOURCE: 161-01-20: 1990]

3.1.1.10**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]

3.1.1.11**victim**

a component, apparatus or system which does not operate as intended due to electromagnetic disturbance

3.1.1.12**risk-based approach**

a process to reach electromagnetic compatibility that assesses the intended use of the ship, the overall installation on board and defines the risks and identifies mitigation methods with the use of any EMC standard in combination with installation techniques. This approach includes a process of verification and validation to prove that no significant, deleterious interference occurs

3.1.1.13**rule-based approach**

a process to reach electromagnetic compatibility on board the ship by applying only marine electrical equipment, placed in their intended zones, and installed according to the manufacturer's instructions. This approach doesn't require EMC testing on board

3.1.1.14**electromagnetic interference matrix**

EMI matrix

table or matrix 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.

3.1.1.15**EMC analysis**

compilation and interpretation of EMC data to determine the degree of influence of electrical devices with one another

3.1.1.16**Source-victim matrix**

table or matrix intended to prevent interference where disturbance sources are set against susceptible devices

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

3.1.1.17 Transmitter-receiver matrix

an in-depth source-victim matrix intended to assist in reaching compatibility with respect to radio communication on the top deck where intentional radio-emitters and relevant disturbance are set against radio-receivers and susceptible devices

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

3.1.1.18**equipment/component manufacturer**

manufacturer which produces marine electrical equipment and/or components especially designed to withstand the conditions onboard a ship

Note 1 to entry: Reference is made to clause 8 for marine electrical equipment.

3.1.1.19**essential services/equipment**

services/equipment essential for the navigation, propulsion, steering or manoeuvring of the ship, or for the safety of human life, or for special characteristics of the ship where a failure of equipment increases the risk of damage to human life and/or the environment

EXAMPLE 1 Essential equipment according SRtP Rules on passenger vessels.

EXAMPLE 2 Reference systems on DP-Class vessels.

Note 1 to entry: The details and amount can be part of a discussion/definition between shipyard, owner and class/flag state.

3.1.1.20**marine electrical equipment**

Electrical equipment manufactured for use onboard ships compliant with clause 8 of this document and other relevant maritime standards

EXAMPLE Electrical equipment developed for the use onboard ships such as for example: rotating machines, switchboards, control panels, lighting fixtures, onboard communication equipment, and navigation instruments.

Note 1 to entry: Relevant maritime standards can be parts of the IEC 60092 series.

Note 2 to entry: Instead of compliancy with clause 8 of this document other relevant maritime EMC standards may also be applied. E.g. IEC 60945, MIL STD 461 when tested for a naval environment.

3.1.1.21

(electronic) (power) converter

operative unit for electronic power conversion, comprising one or more electronic valve devices, transformers and filters if necessary and auxiliaries if any

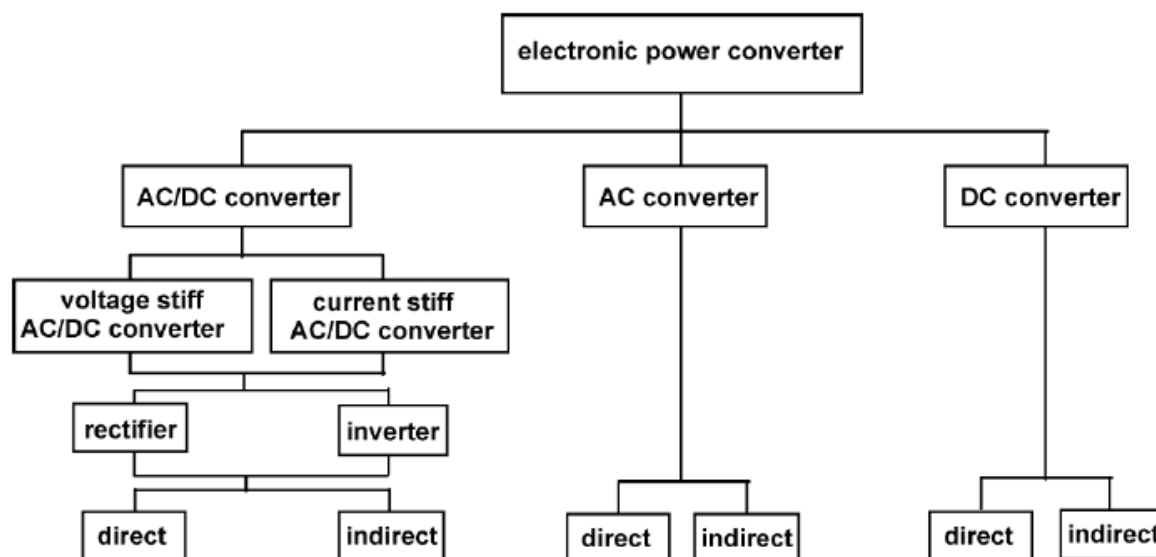


Figure 3-1 – Examples of basic electronic power converters

Note 1 to entry: English, the two spellings "convertor" and "converter" are in use, and both are correct. In this document, the spelling "converter" is used in order to avoid duplications.

[SOURCE: IEC 60050-551:1998, 551-12-01]

3.1.1.22

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.

3.1.1.23

subsystem

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

3.1.1.24

IT grid

power supply grid where all live conductors are isolated from earth, or one point is connected to earth through a high impedance and exposed-conductive-parts are connected to earth

[SOURCE: IEC 60364-1, modified - summarised]

3.1.1.25

TN-S grid

power supply grid where all live conductors are isolated from earth, or one point is connected to earth through a high impedance and exposed-conductive-parts are connected to earth

[SOURCE: IEC 60364-1, modified - summarised]

3.1.1.26**TT grid**

power supply grid where the neutral point, mid-point or a line conductor is connected to earth and exposed-conductive-parts are connected to earth, independent of the earthing of the live parts of the electric system

[SOURCE: IEC 60364-1, modified - Summarised]

3.1.2 Installation measures**3.1.2.1****antenna earth plane**

flat conductive surface that is at the same electric potential as reference ground, which is used as a common reference for the ship's antennas

3.1.2.2**to bond**

creating an electrically conductive path between two or more conductors with as low an impedance as necessary for the application

EXAMPLE A bond can be established by welding, bolting/clamping or with a special strap.

3.1.2.3**cable category**

group of cables based on similar signal types and levels

3.1.2.4**cable segregation**

routing of cables of different categories where cables belonging to different categories are segregated with intermediate free space in order to reduce interference

3.1.2.5**cable separation**

routing of cables where cables of different categories are separated into different bundles and cables of similar categories are bundled together in order to reduce interference

3.1.2.6**earth**

ground, US, CA

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 intentionally conductive 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 earthing. The earth (ground) does not in all cases meet the personnel safety requirements of the protective earth.

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

3.1.2.7**earthing**

grounding, US, CA

establishing of electrical connections minimizing the potential difference between different conductive parts

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

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

747 **3.1.2.8**
748 **protective earthing**
749 protective grounding, US, CA
750 earthing for purposes of electrical safety

751 [SOURCE: IEC 60050-195:2021, 195-01-11]

752 **3.1.2.9**
753 **reference earth**
754 reference earth potential
755 ground, US, CA
756 point, plane, or surface designated as the zero potential (nominally) common reference point
757 for electrical or electronic equipment

758 **3.1.2.10**
759 **reference earthing**
760 reference grounding, US, CA
761 method of establishing a n electrical connection between a conductive item to earth potential

762 **3.1.2.11**
763 **equipotential bonding**
764 set of electric connections intended to achieve equipotentiality between conductive parts

765 [SOURCE: IEC 60050-195:2021, 195-01-10]

766 **3.1.2.12**
767 **earth loop**
768 A circuit where there are multiple earth paths in parallel. Potential differences or time varying
769 magnetic fields may introduce currents in these loops. If cable screens are part of these loops
770 and they are poorly terminated, or of poor quality, these currents may cause interference

771 **3.1.2.13**
772 **intentionally conductive**
773 The material used to create the hull and/or superstructure is applied to attenuate EM fields and
774 divert screen currents. However, it is not per definition suited to be used for protective earthing
775 or as a PE conductor in case the material is non-metallic

776 EXAMPLE Steel, carbon fibre, epoxy-glass resin with metal mesh.

777 **3.1.2.14**
778 **screen**
779 conductive layer around a cable intended to reduce the emission/reception of electric fields and
780 reduce the emission/reception of magnetic fields by providing a current path for disturbance
781 currents

782 **3.1.2.15**
783 **screening**
784 applying screens to reduce the coupling between cables and their environment

785 Note 1 to entry: In this document shielding is used in relation to spaces and enclosures and screening is used in
786 relation to cables.

787 **3.1.2.16**
788 **shield**
789 electrically conductive or magnetic material barrier or enclosure

790 EXAMPLE Metal plate, wire mesh, metal foil.

791 Note 1 to entry: Conductive ship structures can act as a shield.

792 **3.1.2.17**
793 **shielding**

794 construction method to protect against disturbing electromagnetic emissions and/or to prevent
795 unintended electromagnetic emissions

796 EXAMPLE Use of a conductive layer or enclosure.

797 Note 1 to entry: In this document shielding is used in relation to spaces and enclosures and screening is used in
798 relation to cables.

799 **3.1.2.18**
800 **shielded enclosure**

801 a mesh or sheet metallic housing designed expressly for the purpose of electromagnetically
802 separating the internal and the external environment

803 [SOURCE: IEC 60050-161:1990, 161-04-37]

804 **3.1.2.19**
805 **return loss**

806 a
807 the modulus of the reciprocal of the reflection factor, generally expressed in decibels

808
$$a = 20 \times \lg \frac{1}{r};$$

809 where

810 r is the ratio of return wave to forward wave

811 Note 1 to entry: $r = 0$, $a = \infty$, if the impedance of the protection circuit is matched to the wave impedance of the
812 connected cable.

813 [SOURCE: IEC 60050-161:1992, 702-07-25, modified formula adapted from impedance to
814 waves]

815 **3.1.3 Testing**

816 **3.1.3.1**
817 **inherently benign equipment**

818 Equipment from which its inherent physical characteristics are such that both:

- 819 1) it is incapable of generating or contributing to electromagnetic emissions which exceed
820 a level allowing radio and telecommunications equipment and other equipment to
821 operate as intended; and
822 2) it will operate without unacceptable degradation in the presence of the electromagnetic
823 disturbance normally present in its intended environment.

824 EXAMPLE 1 Cables;

825 EXAMPLE 2 Equipment containing only resistive loads without any automatic switching device; e.g. simple
826 domestic heaters with no controls, thermostat, or fan;

827 EXAMPLE 3 Batteries and accumulators (without active electronic circuits);

828 EXAMPLE 4 Corded headphones, loudspeakers without amplification;

829 EXAMPLE 5 Pocket lamps (including those containing LEDs) without active electronic circuits;

830 EXAMPLE 6 Induction motors without electronic circuits;

831 EXAMPLE 7 Switches which do not contain any active electronic components;

832 EXAMPLE 8 Passive antennas;

833 EXAMPLE 9 Electromagnetic relays without active electronic parts;

834 EXAMPLE 10 Electromagnetic locks without active electronic parts;

835 EXAMPLE 11 Protection equipment which only produces transitory disturbances of short duration during the clearing
836 of a short-circuit fault or an abnormal situation in a circuit and which do not include active electronic components,
837 such as fuses and circuit breakers without active electronic parts or active components.

838 [SOURCE: Guide for the EMCD (Directive 2014/30/EU) [13], 1.1.4, modified - Summarised]

839 3.1.3.2

840 **auxiliary equipment**

841 equipment necessary to provide the equipment under test (EUT) with the signals required for
842 normal operation

843 Note 1 to entry: Auxiliary equipment can be useful for monitoring the EUT.

844 [SOURCE: IEC 61000-4-6:2023, 3.2]

845 3.1.3.3

846 **category A equipment**

847 marine electrical equipment compliant with the emission requirements of this document and
848 additionally tested to demonstrate to have low disturbance levels in the frequency bands in use
849 by cellular phones

850 3.1.3.4

851 **category B equipment**

852 marine electrical equipment compliant with the basic immunity requirements of this document
853 and additionally tested to demonstrate their resilience against close proximity fields of below
854 deck transmitters, suited for generic and specifically safety critical applications.

855 3.1.3.5

856 **degradation** (in performance)

857 an undesired departure in the operational performance of any device, equipment or system from
858 its intended performance

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

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

861 3.1.3.6

862 **goodput**

863 the amount of data that is correctly received within a certain period of time

864 Note 1 to entry: This figure is equal or smaller than the throughput since that is a measure of all the data that is
865 received within a certain period of time.

866 3.1.3.7

867 **throughput**

868 all the data that is received within a certain period of time

869 Note 1 to entry: This figure is equal or higher than the goodput since that is a measure of all the correct data that
870 is received within a certain period of time.

871 3.1.3.8

872 **insertion loss** (of a two-port device)

873 the ratio, generally expressed in decibels, of the apparent power at a point in a transmission
874 channel to the power at the same point after insertion of a given two-port device into the
875 transmission channel immediately ahead of this point

876 Note 1 to entry: If the ratio defining the insertion loss is less than one, its decibel value is negative, and its converse
877 or opposite decibel value called "insertion gain" may be used.

878 [SOURCE: IEC 60050-702:1992, 702-07-08]

879 **3.1.3.9**

880 **in-situ testing**

881 testing at the location where the equipment/system was installed

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

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

885 **3.1.3.10**

886 **loss of function**

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

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

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

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

894 **3.1.3.11**

895 **sensitivity** (of a receiver)

- 896 1) ability of a radio receiver to provide an output signal of required level and quality from a
897 weak input signal
- 898 2) the minimum level of signal at the input of a radio receiver which produces an output
899 signal of specified level and quality

900 Note 1 to entry: The output signal quality is usually expressed by a signal-to-noise ratio or an error ratio.

901 [SOURCE: IEC 60050-713:1998, 713-10-52]

902 **3.1.3.12**

903 **point of common coupling**

904 **PCC**

905 point of a power supply network, electrically nearest to a particular load, at which other loads
906 are, or may be, connected

907 Note 1 to entry: These loads can be either devices, equipment or systems, or distinct customer's installations.

908 Note 2 to entry: In some applications, the term "point of common coupling" is restricted to public networks.

909 [SOURCE: 60050-161:1990, 161-07-15]

910 **3.1.3.13**

911 **port**

912 particular interface of an equipment which couples this equipment with the external
913 electromagnetic environment (161-01-01) and through which the equipment is influenced by
914 this environment

915 **EXAMPLE** Examples of ports of interest are shown in Figure 3-2. The enclosure port is the physical boundary of
916 the apparatus (e.g. enclosure). The enclosure port provides for radiated and electrostatic discharge (161-01-22)
917 energy transfer, whereas the other ports provide for conducted energy transfer.

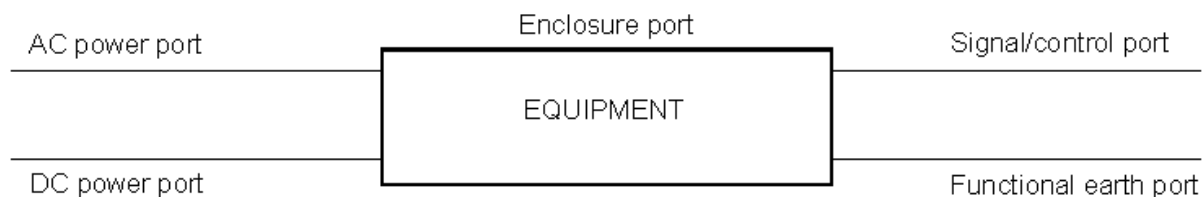


Figure 3-2 – Examples of ports

Note 1 to entry: Ports in the subject area of electromagnetic compatibility are specific cases of the port defined in 131-12-60.

[SOURCE: IEC 60050-161:2014, 161-01-27]

3.1.4

3.1.4.1 type test

conformity test made on one or more items representative of the production to ascertain that it meets the requirements according to this document

[SOURCE: IEC 60050-151:2001, 151-16-16, MOD – added purpose of test to the definition]

3.1.5 Zoning

3.1.5.1

zone

either an EMC power grid or a spatial EMC zone

3.1.5.2

spatial EMC zone

area characterized by sensitive and/or disturbing devices located therein

Note 1 to entry: The concept is similar to the EMC power grids.

3.1.5.3

accommodation zone

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

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.

3.1.5.4

antenna zone

the area near an antenna for which the view towards the antenna is not obstructed by large conductive objects. The boundary of this area is limited by a distance starting at 1 m from the antenna and ending at 15 m from the antenna

Note 1 to entry: Reference is made to Figure B.1.

3.1.5.5

deck, EMC outer deck & bridge zone

area in which there is a high risk of interference between antennas and/or related equipment, and other equipment, but which is at least 15 m separated from these antennas. This area may include the wheelhouse as well as the control rooms, characterized by equipment for intercommunication, signal processing, radio communication and navigation and other spaces with large openings in the intentionally conductive structure

3.1.5.6**general inner deck zone**

area characterized by normal consumers protected from electromagnetic phenomena originating outside the ship

3.1.5.7**special power distribution zone**

below deck area characterized by severe electromagnetic disturbance sources

EXAMPLE Propulsion systems, bow thrusters, etc.

3.1.5.8**compartment**

subdivision of the hull formed by bulkheads

3.1.5.9**hull**

watertight main part or body of a ship

3.1.5.10**room**

subdivision of a compartment or deck space

3.1.5.11**EMC power grid**

galvanically separated part of the power supply grid in order to separate potential victims from disturbance sources.

Note 1 to entry: The concept is similar to the spatial EMC zones.

3.1.5.12**compatibility level**

(electromagnetic) compatibility level

the specified electromagnetic disturbance level used as a reference level for co-ordination in the setting of emission and immunity limits

Note 1 to entry: By convention, the compatibility level is chosen so that there is only a small probability that it will be exceeded by the actual disturbance level. However electromagnetic compatibility is achieved only if emission and immunity levels are controlled such that, at each location, the disturbance level resulting from the cumulative emissions is lower than the immunity level for each device, equipment and system situated at this same location.

Note 2 to entry: The compatibility level may be phenomenon, time or location dependent.

[SOURCE: IEC 60050-161:1990, 161-03-10]

3.1.5.13**composite**

composition of several materials, usually consisting of a core with several layers

EXAMPLE Glass reinforced plastic (GRP).

3.1.5.14**coupling**

interaction of circuits between which energy can be transferred

3.2 symbols and abbreviated terms

λ	Wavelength
A FE	Active front end
AIS	Automatic identification system
ALSE	absorber lined shielded enclosure

1001	CISPR	International Special Committee on Radio Interference
1002	CM	Common Mode
1003	COMSAR	Sub-committee on radiocommunications and search and rescue
1004	EM	Electromagnetic
1005	EMC	Electromagnetic compatibility
1006	EMI	Electromagnetic interference
1007	ESD	Electrostatic discharge
1008	ESI	Electrical system integrator
1009	EUT	Equipment under test
1010	FAT	Factory acceptance test
1011	GCPC	Grid connected power converters
1012	GMDSS	Global maritime distress and safety system
1013	GNSS	Global navigation satellite systems
1014	HAT	Harbour acceptance test
1015	HERP	Hazard of EM radiation to personnel
1016	HVAC	Heating ventilation air conditioning
1017	ID	Integrity display
1018	INU	Inverter unit
1019	PDS	Power drive system
1020	RADHAZ	Radiation hazard
1021	RF	Radio frequency
1022	RSSI	Received signal strength indicator
1023	SAT	Sea acceptance test
1024	SNR	Signal to noise ratio
1025	SOLAS	Safety of life at sea
1026	SVM	Source-victim matrix
1027	TRM	Transmitter-receiver matrix
1028	VDES	VHF data exchange system
1029	VHF	Very high frequency

4 General

4.1 Basic assumptions

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

EXAMPLE EM disturbance originating from the environment can be radio transmitters onboard other ships, lightning, disturbance on the shore supply, etc.

The individual equipment installed on a ship can also be a source of EM 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 EM 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.

In special cases, for instance when susceptible equipment is being used in the antenna zone of a transmitting antenna, additional mitigation measures may have to be employed to increase the EM immunity beyond the limits specified in subclause 8.4.

NOTE The minimum immunity requirements in subclause 8.4 represent a typical EM environment and have been selected to ensure an adequate level of immunity for ships.

4.2 Roles

Many different parties cooperate in the process of building a ship. To ensure that the total ship operates without electromagnetic interference (EMI) it is of the utmost importance that there is a clear understanding which party will be responsible for which task. This document defines several roles to allocate the responsibilities. A role can be taken on by any suited party and assists in the definition of responsibilities, rights and obligations between the parties taking part in the building process. If required, other roles may be defined under the condition that the responsibilities, rights and obligations are well defined. Roles used in this document are:

- ship's owner or operator,
- yard,
- electrical system integrator,
- equipment component manufacturer,
- surveyor (informative).

A party may declare compliance with this standard as long as it meets the requirements in this document for the role it undertakes.

NOTE A yard can for example have the role of yard and that of ESI.

4.3 Risk and Rule based

4.3.1 Rule-based approach

The rule-based approach can be applied on two levels: equipment and ship's level.

If an equipment or component manufacturer claims compliance with this document, it means that:

- 1072 1) the equipment or components they produce are tested against and meet the applicable
1073 emission requirements stated in subclause 8.3;
- 1074 2) the equipment or components they produce are tested against and meet the applicable
1075 immunity requirements stated in subclause 8.4;
- 1076 3) the manufacturer shall provide the required information stated in subclause 8.6.

1077 Only when all three of these requirements are met, may compliance with this document for
1078 marine electrical equipment and components be stated.

1079 Compliance at ship's level can be claimed based on different approaches. The yard shall inform
1080 the ship owner which approach was followed. If the rule-based approach is followed, the yard
1081 shall follow the requirements stated in subclause 6.1.

1082 **4.3.2 Risk-based approach**

1083 Another approach to claim compliance at ship's level is the risk-based approach. This approach
1084 focusses more on the ship as a complete system. All involved parties collaborate in the process
1085 of designing and building a ship that is electromagnetically compatible with its environment, just
1086 like that the systems on board are electromagnetically compatible with one another. Measures
1087 to reach electromagnetic compatibility shall be taken where they are most effective at the lowest
1088 overall costs. This will also determine which party is responsible for implementing the
1089 measures. To do this in a structured manner, the following documents shall be created:

- 1090 1) An EMC management plan in which the responsibilities of the different involved parties
1091 are laid down.
- 1092 2) An EMC control plan which deals with the risk on interference between:
- 1093 i) the ship and its environment, and
- 1094 ii) between systems/equipment found on board.
- 1095 3) An EMC implementation plan which describes how the mitigation measures defined in
1096 the EMC control plan shall be implemented on board.
- 1097 4) An EMC verification plan which describes the tasks that shall be conducted to check if
1098 the mitigation measures are implemented correctly.
- 1099 5) A validation plan which describes the tasks that shall be conducted to check if the
1100 mitigation measures are effective.

1101 Guidance on the content of the above listed documents can be found in Annex A. The yard has
1102 the responsibility to show that the final installation complies with the basic requirements that
1103 prevent interference.

1104 **4.3.3 Risk and rule-based combined**

1105 It is usually not feasible to build a ship by just following the rule-based approach. In these
1106 cases, both approaches can be combined. In this combined approach the risk on interference
1107 shall be reduced by complying, whenever feasible, with the following guidelines:

- 1108 • Apply marine electrical equipment tested for the maritime environment and compliant with
1109 either:
 - 1110 • this document clause 8;
 - 1111 • IEC 60945;
 - 1112 • or EMC test requirements from classification societies.
- 1113 • Install marine electrical equipment in an EMC power grid and EMC zone for which the
1114 equipment is intended.
- 1115 • Install marine electrical equipment according to the instructions of the manufacturer.
- 1116 • Build the ship and its electrical installation in line with the guidance given in Annex C.

1117 If this approach is chosen, it still means that the risk-based procedures shall also be adhered
1118 to, unless some parts that can be waived based on following the guidelines in subclauses 4.3.1
1119 and 4.3.3. These waivers shall be documented.

1120 **4.3.4 Liability**

1121 In the “risk-based” and “combined risk-based and rule-based” approach there is a chance that
1122 during the building process, or shortly afterwards interference cases are discovered. The EMC
1123 management plan shall clearly indicate who is responsible for solving the interference issue
1124 and liable for the associated costs, in case all involved parties have delivered and installed their
1125 equipment according to the specifications that were agreed upon.

1126 NOTE The EMC control plan should state the requirements to all involved parties and can be an instrument to
1127 determine if parties are liable in case of interference.

1128 **4.4 Zones and power supply grids**

1129 **4.4.1 Introduction**

1130 The definition of electromagnetic compatibility takes the environment into account. By applying
1131 zoning, different EM environments can be created onboard a ship. Different maximum levels of
1132 disturbance and emission may apply for each EM zone. Since conducted disturbance
1133 propagates and is attenuated in a different way than radiated disturbance, the zone borders
1134 between EMC power grids and spatial zones may be located at independent positions. For this
1135 reason, this document defines zones in the power supply grids and spatial zones.

1136 **4.4.2 EMC zones in power supply grids**

1137 EMC zones in power supply grids can be separated by filters, isolation transformers, or
1138 frequency converters depending on the phenomena that need to be attenuated. This document
1139 defines 3 different EMC power grids. These may not necessarily be present in each ship and
1140 additional EMC power grids may be defined in the EMC control plan.

- 1141 • residential grid,
- 1142 • industrial grid,
- 1143 • special power distribution grid.

1144 More information on how these grids can be used is given in annex B.4.

1145 **4.4.3 EMC zones in spaces**

1146 Spatial EMC zones can be separated from one another by intentionally conductive bulkheads,
1147 decks or distance. This document defines 5 different spatial EMC zones. These may not
1148 necessarily be present in each ship and additional EMC zones may be defined in the EMC
1149 control plan.

- 1150 • antenna zone,
- 1151 • deck, EMC outer deck & bridge zone,
- 1152 • general inner deck zone,
- 1153 • accommodation zone,
- 1154 • special power distribution zone.

1155 More information on how these zones can be used is given in annex B.3.

5 Ship's owner/operator

5.1 Rule-based approach

When the ship's owner, in consultation with the yard, requires that the ship is built based on the rule-based approach, all equipment on board, wherever feasible, shall be marine electrical equipment. For equipment placed in the accommodation zone subclause 7.1.1 applies. For equipment that is not compliant with this document, a risk evaluation shall be made, and that evaluation shall be documented, similarly to what is done in the rules for the risk-based approach.

NOTE Everywhere in this document where reference is made to the ship's owner, one may also read owner's representative.

5.2 Risk-based approach

The ships' owner shall define additional requirements that are made to the ship and the installations on board in addition to those required for basic safety, taking into consideration that the baseline is defined by A.813(19) [6]. Basic safety includes special operation modes and equipment that makes or requires non-standard requirements to its EM environment. The yard may assist the ship's owner by listing several topics in the contract negotiations as defined in subclause 6.2.1.

EXAMPLE 1 Example of additional requirements: Light fluctuations are not allowed under transient conditions.

EXAMPLE 2 Example of special operations modes: The ship needs to maintain all functionality even during a direct lighting strike.

EXAMPLE 3 Example of equipment making non-standard requirements to its EM environment are: Non-maritime radio communications systems; weather radar systems; and measurement systems operating with low signal levels.

EXAMPLE 4 For certain areas and countries, limited values for transmitting are mandatory and stated by the appropriate authority.

The flag state, classification society, customer and yard shall agree upon the EMC validation tests that shall at least be conducted, to prove that the electrical installations comply with the relevant standards and is reliable. Guidance can be found in annex A.6.

The ship's owner shall ensure that the latest EMC documentation related to the risk-based approach is on board when the ship is in service. These documents shall represent the actual state of installation and shall be available to any party that maintains, replaces, updates equipment and/or (parts of) the electrical installation on board during the lifetime of the ship. The EMC documentation shall consist of at least the following documents:

- EMC management plan,
- EMC control plan,
- EMC implementation plan,
- EMC verification plan,
- EMC validation plan, and
- EMC maintenance and inspection plan.

When new equipment is brought on board, or equipment is replaced, these EMC plans and the documents belonging to the ship shall be consulted to determine if the equipment is suited to be brought on board to its specific location and how it can safely be integrated in line with the approach (risk-based or rule-based), as defined in the contract. The documentation shall be updated accordingly.

1199 **5.3 Maintenance**

1200 The ship's owner shall perform inspections and conduct maintenance during the lifetime of the
1201 ship according to the instructions delivered by the yard and document these inspections. This
1202 will ensure that the performance requirements are met.

1203 NOTE Corrosion for example may reduce the effectiveness of earth connections and as a result may reduce the
1204 performance of the installation.

1205 A suitable person on board shall be appointed as EMC manager and he shall maintain EMC
1206 related documentation, document failures which are possibly EMC related, and verify if radio
1207 reception is sufficient, see annex A.6.2.

6 Yard

The yard shall discuss the rule-based and risk-based approach, described in this document, with the ship's owner and in mutual agreement decide which approach is the starting point. If the rule-based approach is the starting point, risk-based elements might be required to deal with equipment that isn't tested or doesn't comply with the test requirements as given in subclause 6.1.

If it is not known who the ship owner will be, the yard decides if the risk- or rule-based approach shall be followed.

6.1 Rule-based approach

The yard shall require by contract with all suppliers and manufacturers of electrical equipment that their delivery complies with the requirements for marine electrical equipment. For equipment placed in the accommodation zone subclause 7.1.1 applies. The yard shall inform the ESI and the suppliers delivering directly to the yard about:

- the zone in which the marine electrical equipment shall be placed;
- the type of power supply grid used to power the marine electrical equipment: TN-s, TT or IT;
- the immunity & emission levels required for these zones (defined in subclause 8.3 & 8.4).

The yard shall verify that the delivered marine electrical equipment is suited for the zone in which it is placed and for the power grid to which it will be connected. These tasks: stating requirements to the suppliers; informing suppliers of conditions on board; and verification of marine electrical equipment, may be delegated to the ESI for the part of the delivery that is purchased by the yard.

NOTE 1 In an IT power supply grid higher voltages with respect to earth can occur which could stress insulation materials and filter capacitors to earth.

NOTE 2 If no ESI is formally appointed the yard will serve as it.

NOTE 3 Delegation of responsibilities should be clearly agreed, reference is made to the responsibility matrix (see Annex A.2.5).

6.2 Risk-based approach

If the risk-based approach is chosen, this shall be agreed by the contracting parties and documented. The yard is responsible for the interference-free operation of the entire ship. To reach this goal this document lists a minimum number of tasks that needs to be addressed. The responsibility matrix (see annex A.2.5) can be used as guidance and relates those tasks to certain roles. This matrix may be extended with additional tasks by the yard. The yard shall make the final decision which party is responsible for which role and what that role involves, as long as the responsibility of each topic addressed in this document is clearly appointed to a specific party, agreed by the relevant parties and documented in relation to the responsibility matrix. For tasks not formally assigned, the yard serves as the responsible party.

NOTE The yard is allowed to assign the role of yard, from EMC point of view, to a third party such as an ESI or consultancy bureau.

The yard shall:

- Discuss the power grid configuration TN-S, TT or IT with the customer including the advantages and disadvantages and decide which grid configuration(s) to use.

NOTE Annex A.2.4 gives some topics that can be taken into consideration during this discussion.

- Inform all parties involved in 'the delivery of electrical equipment' or 'the design of electrical networks', of the power supply grid configuration(s) that will be applied on board.

- 1253 • Produce an EMC management plan as described in subclause 6.2.1.
- 1254 • Ensure that all the latest EMC documentation related to the risk-based approach which
- 1255 includes at least the documents defined in subclause 6.2.1, 6.2.2 and 7.2.1 up to 7.2.4 will
- 1256 be written and delivered to the ship owner.
- 1257 • Ensure that all suppliers delivering to the yard commit to the applicable requirements for the
- 1258 suppliers following from the EMC control and implementation plan as defined by the ESI.

1259 **6.2.1 EMC management plan**

1260 The EMC management plan shall define at least the following topics:

- 1261 • EMC related requirements from the customer;
- 1262 NOTE Examples of EMC related requirements from the customer are given in subclause 5.2.
- 1263 • EMC related requirements from legislation, classification or contract;
- 1264 • The applied power grid configuration;
- 1265 • An overview of radio frequencies expected to be used with reference to the intended
- 1266 equipment;
- 1267 • A responsibility matrix that states the tasks per role;
- 1268 • A list which party takes on which role;
- 1269 • Liability of the involved parties in the building process;
- 1270 • A list of EMC zones and EMC power grids that may be applied;
- 1271 • A procedure how to deal with deviations or requirements, from the EMC management plan,
- 1272 EMC control plan, or EMC implementation plan, that cannot be met.

1273 NOTE Additional information on the EMC management plan and responsibility matrix is given in Annex A.2.

1274 **6.2.2 EMC maintenance and inspection plan**

1275 The yard shall ensure that the ship's owner receives an EMC maintenance and inspection plan.
1276 The drafting of this plan may be delegated to the ESI. The maintenance and inspection plan
1277 shall include information on necessary measures to achieve and maintain the desired level of
1278 EMC, even if these measures have been correctly designed and carefully executed, EMC
1279 measures shall be periodically visually inspected to check completeness and factual condition.
1280 The plan shall include at least the following requirements and instructions:

- 1281 • An instruction how to check radio reception;
- 1282 • Check if critical connections have not corroded;
- 1283 • Check if earth connections and EMC glands haven't come loose;
- 1284 • A requirement to verify if EMC gaskets are not corroded or painted;
- 1285 • A visual inspection to see if cable screens are not exposed;
- 1286 • Which procedure to follow when equipment is replaced;
- 1287 • Which procedure to follow when new equipment is brought on board;
- 1288 • Details of equipment and cabling to be considered during repair;
- 1289 • Where relevant, maintenance requirements from specific equipment or installations;
- 1290 • The maintenance manual shall copy, or refer to, relevant inspections, tests and
- 1291 measurements from the verification and validations plan;
- 1292 • A timetable for inspections and/or measurements, which preferably coincides with the time
- 1293 framework required for the inspection by the classification society.

1294 These inspections, tests and measurements may be extended with simple checks that help the
1295 crew determine if their ship is in good operational conditions with respect to EMC.

1296 EXAMPLE Simple checks can for example be checking the stability of analogue measurement signals (Annex A.6.8)
1297 and the noise level from the radio receiver (Annex A.6.2).

1298 Staff should also be encouraged to record any interference observed in service. This should
1299 then be investigated and corrected during maintenance services and the problems fed back to
1300 the designers of the ship for future reference.

1301 **6.3 Ships with a non-intentionally conductive hull and/or superstructure**

1302 **6.3.1 Introduction**

1303 From an EMC point of view, ships with a non-intentionally conductive hull or superstructure
1304 require additional attention since they lack the shielding provided by structural elements of
1305 ships with intentionally conductive hulls. This requires that the different parties involved in the
1306 building process take additional measures which are in their areas of responsibility. It is
1307 assumed that the yard is responsible for constructional requirements.

1308 **6.3.2 Ship layout**

1309 A measure to provide additional protection is to shield specific spaces. When identifying which
1310 spaces to be shielded, the following aspects shall be considered:

1311 NOTE From an EMC point of view, two types of spaces normally exist on board a ship with a hull that is non-
1312 intentionally conductive: shielded spaces and non-shielded spaces.

- 1313 a) the EM environment, mostly caused by the radiation of radio frequency (RF) antennas;
- 1314 b) availability of information on the emission and immunity levels of the chosen systems;
- 1315 c) cost and complexity of additional shielding of systems compared with the total cost of the
1316 shielding;
- 1317 d) risk of hazard of EM radiation to personnel (HERP);
- 1318 e) antenna earth plane;
- 1319 f) keeping EM fields low inside shielded spaces so that susceptible equipment will not exhibit
1320 EMI problems when high power transmitters are being used;
- 1321 g) the EM environment mostly caused by the radiation of RF antennas and high-power
1322 electronic equipment, such as variable frequency drives or AC/DC converters.

1323 **6.3.3 Whip antennas**

1324 **6.3.3.1 General**

1325 A suitable antenna earth plane shall be used to provide the RF currents a defined path back to
1326 their feeding point (base of antenna).

1327 NOTE 1 If a suitable earth plane is not used, the current will flow back over other (intentionally) conductive
1328 structures, for example, equipment, cables etc. This could cause worse functionality of the antenna and EMI in
1329 systems exposed to these RF currents. Therefore, the lack of conductive surfaces is not only an EMC problem, but
1330 also a problem with respect to RF radiation efficiency, where the largest possible earth plane for RF whip antennas
1331 is essential.

1332 NOTE 2 The RF whip antenna layout for the ship can be verified by use of scale models, test mock-ups or numerical
1333 simulation. Communication efficiency, radiation hazard (RADHAZ) and EMC can be checked.

1334 NOTE 3 IEC 60945 Annex C, indicates that the radiated emission limits in that standard are based upon a typical
1335 separation of 15 m between the bridge and the very high frequency (VHF) antenna, in the band 156 MHz to 165 MHz.

1336 **6.3.3.2 Antenna earth plane**

1337 To determine the size of the antenna's earth plane for an RF transmitting whip antenna, the
1338 following aspects shall be considered:

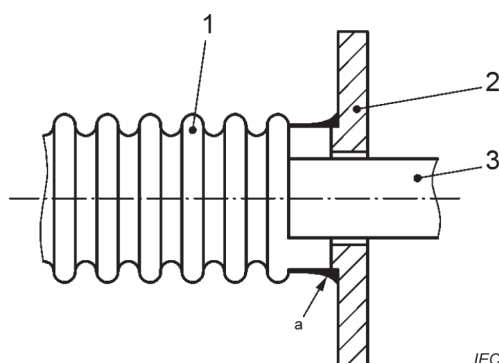
- 1339 • for acceptable communication characteristics, it can be relatively small but of high
1340 conductivity;

- for EMC reasons, this earth plane should be as large as possible.

NOTE 1 On ships without an intentionally conductive hull, the ship's own RF transmissions using whip antennas can cause major EMI problems if the antenna earth plane is of insufficient size.

NOTE 2 It is not necessary that the whole earth plane consists of the same material. The extension can also be made of metallic wire mesh or other shielding material like metal spray. However, a continuous metallic sheet is better for EMC purposes.

Screened cables etc. which penetrate the antenna earth plane shall be circumferentially bonded to the antenna earth plane. Unscreened cables shall be filtered at the entry point (see Figure D.2 and Figure D.3). Alternatively, they could be routed inside conductive pipes or conduits in the antenna zone. These pipes/conduits end at the entry point of the antenna earth plane (see Figure 6-1). There, they shall be circumferentially bonded.



Key

- 1 conduit (shielding pipe)
- 2 antenna earth plane
- 3 unscreened cable
- a circumferential connection

Figure 6-1 – Unscreened cable penetrating the antenna earth plane

6.3.4 Earthing systems

A basic system shall include an earth plate, a primary earth system and possibly several secondary earth systems. Figure 7-1 shows a typical primary earth system connected to the earth plate.

6.3.5 Earth plate

6.3.5.1 Material

The earth plates may be constructed out of any conducting metal compatible with sea water which does not form an electrochemical corrosion cell with any other immersed metallic components, for example propeller. Earth plates shall be left in their bare metallic state and not isolated by paint or coating in any way. The earth plate material shall be the best corrosion protected galvanic part in contact with seawater.

NOTE Typical materials are Cu Sn 8 (CW 453 K) or special stainless steel.

6.3.5.2 Location

The earth plate shall be located on the outside of the hull in a position that is permanently immersed during operational conditions and which, in the case where it is connected to a lightning conductor, allows the shortest practicable route for the down conductor. The plate shall be shaped to conform with the hull profile.

6.3.5.3 Dimensioning and construction

The earth plate shall be at least 10 mm thick, 250 mm wide and, to avoid dielectric breakdown of the water at the plate surface when carrying the lightning currents, it shall have a minimum contact area with the sea of 5 m². The length of the earth plate depends on the length of the ship and the number and location of connection points (see Figure 7-2).

To provide an electrical connection, a connecting pillar shall be made from the same material as the earth plate and shall have a minimum diameter of 50 mm. To withstand the severe magnetic forces produced during the passage of a lightning strike, the connecting pillar shall be solidly connected to the earth plate by brazing or welding.

Means shall be provided to allow connection of a conductor size of minimum 75 mm², directly to the earth plate to enable it to be connected to a suitable earth on shore when the ship is in dry dock or on a slipway. It is recommended to install this connection in the vicinity of the shore power supply connection.

6.3.5.4 Number

The number of earth plates required depends on the layout of the ship. There should be one main earth plate which would serve most of the ship. This could be sufficient.

However, if possible, for each lightning conductor, there should be a separate earth plate so that the down conductors are as short as possible. Also, it may be advantageous to provide earth plates and dedicated conductors for the RF transmitters and antenna ground planes to prevent RF currents flowing in the main system.

7 Electrical system integrator (ESI)

7.1 Rule-based approach

The ESI shall apply marine electrical equipment compliant with the requirements given in subclause 7.1.2 and place the marine electrical equipment in the EMC zones for which it is intended. In order to do so an EMC zone plan shall be defined by the ESI in cooperation with the yard. This EMC zone plan consists of a power grid related part and a space related part as described in subclause 4.4. Guidance can be found in Annex B. For equipment placed in the accommodation zone subclause 7.1.1 applies.

The electrical integrator shall forward information provided by the yard to the suppliers with respect to:

- The type of EMC zone in which the marine electrical equipment will be placed;
- The type of EMC power grid which powers the marine electrical equipment;
- The type of power supply grid used to power the marine electrical equipment TN-s, TT or IT; and
- the emission & immunity levels required for these zones (defined in subclauses 8.3 & 8.4).

The ESI shall verify if the marine electrical equipment ordered by him is suited to be used at the intended locations on board.

7.1.1 Equipment in the accommodation zone

Non-essential equipment, which is intended to be operated in the accommodation zone, may also comply with IEC 61000-6-1 [14] and IEC 61000-6-3 [15] or equivalent standards instead of the rules/standards listed in subclause 7.1.2. For essential equipment in the accommodation zone the requirements of subclause 7.1.2 apply.

Care shall be taken to ensure sufficient decoupling of the accommodation zone from all other zones.

7.1.2 Applicable standards/rules

For an ESI to claim compliance with IEC 60533 according to the rule-based approach, the ESI shall apply only equipment that complies with one of the following rules/standards:

- Clause 8 in this document;
- IEC 60945,

NOTE 1 For IEC 60945 ED4 and earlier, this applies only to equipment installed outside the antenna zone.

- EMC test requirements from classification societies, this applies only to equipment installed outside the antenna zone.

The marine electrical equipment shall be placed in the intended EMC zone and connected to the intended EMC power grid. Marine electrical equipment intended for the 'Bridge and deck' zone may be used in the general inner deck zone. The opposite is not allowed.

NOTE 2 Based on the emission limits stated in this document, there is no equipment available that can be placed within 1 m of the ship's antennas.

7.1.3 System aspects

If higher test levels, or if other phenomena besides those described in subclauses 8.3 & 8.4 are required (for example, in case when equipment is placed very close to a powerful transmitting antenna), the immunity requirements shall be increased or mitigation measures in the installation shall be applied.

7.2 Risk-based approach

The ESI is responsible, with assistance of the yard and all others involved in the project, to meet the requirements of the EMC management plan and convert those requirements into practical instructions and test requirements. The basis of this process shall consist of four documents, from which the minimum requirements are described in subclauses 7.2.1 to 7.2.4.

The ESI shall:

a) Deliver the:

- 1) EMC control plan,
- 2) EMC implementation plan,
- 3) EMC verification plan, and
- 4) EMC validation plan.

b) Follow the installation instructions from equipment manufacturers or provide substantiation why deviation from these instructions doesn't reduce the equipment's performance or increase disturbance levels.

If no ESI is formally appointed, all tasks under the responsibility of the ESI shall be those of the yard.

7.2.1 EMC control plan

The EMC control plan shall define at least the following:

- a) A detailed EMC zone plan from location point of view. Guidance can be found in annex B.3;
- b) A detailed EMC zone plan from power grid point of view. Guidance can be found in annex B.4;
- c) A list of EMC standards with which equipment has to comply when placed in a certain EMC zone or connected to a certain EMC power grid;
- d) An overview of (potentially) required EMC mitigation measures;
- e) Earthing strategies with respect to bonding and termination of cable screens;
- f) Antenna plan;

NOTE 1 Important information is given in IMO COMSAR/1/Circ.32 [16].

- g) Approach with respect to common mode (CM) disturbances between the grid frequency and 1 MHz.

NOTE 2 Reference is made to Annex C which provides information on the sources of CM, measuring techniques and suggested maximum levels that might be applied.

- h) Disturbance sources and potential victims (source victim matrix);

NOTE 3 Mobile radios, LED drivers and frequency converters and other power electronic equipment can be sources of interference.

- i) If and where overvoltage protection measures can be applied;
- j) If dedicated measures can be applied to prevent/reduce damage by lightning.

NOTE 4 Guidance on the EMC control plan can be found in annex A.3.

7.2.2 EMC implementation plan

The EMC implementation plan shall define in detail how the EMC mitigation measures defined in the EMC control plan can be applied on board. It shall contain, or refer to, work instructions.

NOTE Guidance on the EMC implementation plan can be found in annex A.4.

7.2.3 EMC verification

The verification process is intended to be conducted as an integral part of the building process of the ship and will primarily consist of visual inspections and relatively easy to conduct measurements. Its corresponding plan shall define inspections and measurements with unambiguous verifiable pass/fail criteria to determine if the installation complies with the requirements of the EMC control plan and EMC implementation plan. Records shall be kept of the conducted inspections and measurements.

NOTE Guidance on this topic is given in Annex A.5.

7.2.4 EMC validation plan

The validation process is intended to be conducted after the building process is finalised, for example during Factory Acceptance Testing (FAT), Harbour Acceptance Testing (HAT) and Sea Acceptance Testing (SAT). The EMC validation plan shall define tests and measurements with unambiguous verifiable pass/fail criteria to determine if electromagnetic compatibility is achieved under realistic but unfavourable circumstances. The validation process shall consist of a series of tests and measurements that prove that the equipment operates as intended. During the preparations, attention shall be given to select, from EMC point of view, the most critical and worst-case situations under which these tests and measurements shall be conducted. These test and measurement procedures, and circumstances under which they are conducted, shall be recorded. One of the main topics of interest is the disturbance level at the input of radio receivers.

NOTE Additional guidance on this topic is given in annex A.6 and in IMO COMSAR/1/Circ.32. [16].

Several of these tests could follow from the EMC validation plan. Examples of such tests are given in Annex A.6. However, the following tests shall be conducted whether or not they follow from the EMC validation plan.

7.2.4.1 Intra system tests

Intra system tests shall be conducted under the responsibility of the ESI, with support of the yard. Which systems will be tested is based on the outcome of the source-victim matrix (SVM), where the combination of systems with the highest chance on interference shall be selected for evaluation. During the test the source shall operate in the modes which are expected to generate the highest levels of disturbance. The behaviour of the potential victim should be within specifications.

NOTE Support of supplier of the potential victim might be essential to conduct a proper evaluation.

7.2.4.2 Electromagnetic disturbance level measurement at the input of radio receivers

For all on board radio receivers operating in the VHF-band or below, the EM disturbance levels at the input of the receiver shall be measured and evaluated, if the receiver input is accessible. If the receiver input is not accessible and for radio receivers on board operating above the VHF-band, other evaluation methods may be applied as given in annex A.6.2. Before the measurement or evaluation, an analysis shall be made of the systems that might interfere with the respective radio receiver. Measurements shall be made twice. During the first measurement, all systems that could interfere with radio reception, including lighting, shall be switched off. During the second measurement or evaluation, all systems that could interfere with radio reception shall be switched on and be operational in their most unfavourable mode. Guidance on how these measurements or evaluations can be conducted can be found in annex A.6.2. The results of the measurements or evaluations shall be assessed by comparing the results of the first measurement with that of the second, considering the EM disturbance levels given in Table 7-1 for VHF and lower frequencies bands. Table A.6 should be used for higher frequencies. The measurement results and their interpretation shall be documented and be available on board for future reference.

NOTE Wherever possible, a measurement device with a noise floor of 6 dB below the limit line is preferred.

For many marine systems, resolution bandwidths and maximum EM disturbance levels are given in Table 7-1 or Table A.6. If this table does not list the applicable system, information shall be obtained from the supplier of the receiver.

The measurement shall be conducted with an RMS detector with a minimum sweep time calculated according to formula ((7-1).

$$t_{s_min} = \frac{150 * span}{RBW * VBW} \quad (7-1)$$

where

t_{s_min} is the minimum sweep time, expressed in seconds;

span is the frequency range over which the measurement is conducted, expressed in Hertz;

RBW is the resolution bandwidth, expressed in Hertz;

VBW is the video bandwidth, expressed in Hertz;

The measurement shall last until the level stabilises while the max hold function of the receiver is activated. When a spectrum analyser is used for measurements, the video bandwidth shall be at least three times the measurement bandwidth. If an FFT based instrument is used the minimum measurement time shall be at least 1 s.

Table 7-1 – Measurement settings for EM disturbance level measurements at the input of radio receivers in or below VHF band

System	Operating frequency range	Resolution bandwidth ^a	Maximum EM disturbance level
NAVTEX and NAVDAT	490 kHz, 405-505 kHz, 518 kHz, 4209.5 kHz	300 Hz	-107 dBm ^b
MF/HF Radiotelephone with DSC	1605 – 4000 kHz	3 kHz	16 dBμV ^c (-91 dBm)
	4 - 27.5 MHz	3 kHz	11 dBμV ^c (-96 dBm)
	2187.5 kHz	300 Hz	5 dBμV ^d MF (-105 dBm)
	4207.5, 6312, 8414.5, 12577, 16804.5 kHz	300 Hz	0 dBμV ^d HF (-107 dBm)
HF NAVTEX	4-26 MHz	300 Hz	-107 dBm
VHF Radiotelephone with DSC	156 - 162 MHz	20 kHz	-117 dBm ^e
AIS, including VHF Data Exchange System (VDES)	161.975 - 162.025 MHz	20 kHz	-117 dBm ^e
	157.175 - 157.425 MHz	120 kHz	
	161.775 - 162.050 MHz	120 kHz	
^a Larger resolution bandwidth may be applied, however, the limit value will not be adjusted			
^b Source IEC 61097-6:2005/AMD1:2011/AMD2:2019 [17] §4.5.3			
^c Source IEC 61097-9:1997 [18] §9.5.3 (for J3E)			
^d Source IEC 61097-8: 1998 [19] §8.1.2			
^e Source Report ITU-R M.2519-0:2022 [20] §2			

7.2.4.3 Power quality testing

Power quality measurements shall be conducted in each galvanically separated power supply grid that feeds more than one consumer. Power supply grids marked as special power distribution grids are exempted from this requirement.

The measurements in AC power supply grids will be conducted with class A equipment according to IEC 61000-4-30.

1551 The measurements shall basically be conducted at one central point in each power supply grid.
1552 The measurement location(s) shall be documented in the measurement report.

1553 EXAMPLE 1 This central point could be the main switchboard, an infeed transformer or a distribution board.

1554 However, the given limits apply for the entire grid and if there are substantiated reasons for
1555 concern that limits are not met at specific points, additional measurements may be conducted
1556 at the last point of common coupling. This applies only for those measurements where non-
1557 compliance with the limits is expected, e.g. because of voltage drop over cables.

1558 During the measurements the supply grid shall have a realistic configuration which is expected
1559 to produce the largest deviation in voltage and frequency. If simulations are available, the
1560 configuration shall be based on the simulation results. For different tests, different
1561 configurations might be required. The applied configuration of the grid shall be recorded in the
1562 test report.

1563 EXAMPLE 2 High levels of harmonic distortion are to be expected when the grid is powered from a single generator
1564 and the consumers are primarily B6 rectifiers. Severe voltage and frequency transients are expected when the basic
1565 load on the grid is small, few power sources are online and a big direct online load is switched on.

1566 Applicable limits for AC grids are given in IEC 60092-101. For DC grids a suitable (maritime)
1567 DC standard shall be used, limits defined by a classification society, or values agreed up on
1568 with the yard.

1569 Characteristics that shall be verified in AC grids are:

- 1570 • If the voltage levels are within tolerance (continuous);
- 1571 • If the voltage unbalance including phase voltage unbalance is within its tolerance;
- 1572 • If cyclic voltage variation are within specification;
- 1573 • If voltage transient levels (slow) are not exceeded;
- 1574 • If the voltage transient recovery time is within specification;
- 1575 • If the voltage harmonic distortion is within the applicable limits;
- 1576 • If the grid frequency is within tolerance;
- 1577 • If the cyclic frequency variation is within tolerance (continuous);
- 1578 • If frequency transient limits are not exceeded;
- 1579 • If the frequency transients recovery time is within specification.

1580 Characteristics that shall be verified in DC grids are:

- 1581 • If the steady state voltage is within tolerance;
- 1582 • If the voltage ripple (up to 9 kHz) is within the applicable limits;
- 1583 • If voltage transient levels (slow) are not exceeded;

1584 NOTE When developing this standard a maritime DC standard is being written.

1585 Guidelines for the measurement report are given in annex E.2.

1586 **7.2.4.4 Common mode levels, disturbances in power supply grids**

1587 CM disturbances shall not interfere with equipment on board. Annex C gives suggestions and
1588 recommendations on how to investigate and evaluate CM levels on board.

1589 NOTE 1 The configuration of the power supply grid has a large impact on CM levels. CM is primarily a concern for
1590 IT power supply grids, especially if equipment designed for TN-s or TT grids is used in these grids.

1591 NOTE 2 CM voltage in IT grids may exceed insulation values and cause a safety risk, which is not part of this
1592 standard. Higher frequency components of CM between 1 kHz and 150 kHz should be considered.

7.2.5 Equipment generating high levels of disturbance

Equipment that does not comply with the emission requirements for the general inner deck zone, as defined in the EMC control plan, by referring to EMC product standards, may be used on board ships as long as the ESI complies with the following requirements.

- Equipment shall be used from which the manufacturer complies with the requirements stated in subclause 8.3.2.4. The installation instructions of the manufacturer shall be adhered to.
- Equipment, generating high levels of disturbance, and thus only suited to be applied in a special power distribution grid, shall be installed only in such a grid. In that case, it shall be verified that the higher emission levels do not result in exceeding the emission limits in other EMC grids (industrial grid, residential grid).

NOTE 1 In order to eliminate interference or reduce the risk of interference isolation transformers may be used between the special power distribution grid and other supply grids. They could also be used in supply lines to protect sensitive equipment placed in the special power distribution grid if required.

- The ESI shall ensure that equipment placed in the special power distribution zone operates as intended and is not affected by the high disturbance levels present.

NOTE 2 The placement of equipment in the special power distribution zone should be limited as much as possible.

- The effects of CM disturbance, and their impact on the grid and other consumers connected to the grid, in the frequency range between 100 Hz and 150 kHz, shall be evaluated by the ESI.

NOTE 3 Examples of common mitigation measures are: global filtering, screening of cables, separation of cables, decoupling. When requested by the ESI, the manufacturer shall advise the ESI which mitigation measures are preferred based on the situation on board.

NOTE 4 Guidance for measurement and mitigation methods for CM voltages can be found in the Annex C.

Further conducted emission requirements are not defined for equipment powered from the special power distribution grid and radiated emission requirements are not defined for equipment installed in the special power distribution zone.

7.3 Ships with a non-intentionally conductive hull and/or superstructure

7.3.1 Introduction

From an EMC point of view ships with a non-intentionally conductive hull or superstructure require additional attention, since they lack the shielding provided by the structural elements of conductive ships. This requires that the different parties involved in the building process take additional measures which are in their areas of responsibility. It is assumed that the ESI is responsible for the electrical design.

7.3.2 Shielding

Ships with a non-intentionally conductive superstructure do not attenuate the RF radiation from the transmitting antennas as much as a structure of (highly) conductive material. Due to the reduced shielding, the field strengths below deck can be higher than on a ship with an intentionally conductive superstructure. This leads to the following implications which shall be considered:

- RADHAZ for crew and passengers;
- coupling of high frequency EM energy into the electrical installation.

Therefore, RF antennas and their associated feeders shall be positioned away from unshielded electronic equipment and cabling.

A significant reduction or elimination of radiated fields from the outside EM environment can be achieved by the shielding of sensitive equipment. This also applies vice-versa against the unintended radiation of electronic equipment which is mounted inside the shield.

A ship mainly constructed of non-conductive materials has a low hull conductivity. This is synonymous with decreased or absence of shielding, normally provided by an intentionally conductive structure (metal) of a conventional ship. Therefore, additional problems can be expected for electric and electronic equipment operated on board.

A study shall be made on the susceptibility of the equipment to be placed in a certain room compared with the expected EM environment, to determine if additional room-shielding is required.

NOTE 1 The result of a study can be:

- a) no susceptibility problem expected; additional room shielding is not needed;
- b) susceptibility problem expected; change arrangement of equipment, additional room shielding is not needed;
- c) susceptibility problem expected; decrease equipment susceptibility, additional room shielding is not needed;
- d) susceptibility problem expected; replace the equipment by less susceptible ones, additional room shielding is not needed;
- e) susceptibility problem expected; specify an overall shielded room if decreasing of equipment susceptibility is more burdensome than creating an additional room shielding;
- f) susceptibility problem expected; the problem can be controlled by operational regulations.

NOTE 2 Required equipment, relevant standards, specifications and rules normally influence the decisions on which rooms need to be shielded, for example for the radiocommunication room.

Which rooms to be shielded shall be identified during the design phase.

7.3.3 Earthing and equipotential bonding system

7.3.3.1 General

When selecting the earthing and equipotential bonding system, the following aspects shall be considered:

- to provide a connection between communication systems, sea and antenna earth planes;
- to provide an electronic or digital reference earth;
- to provide a conducting path for the bonding of cable screens;
- to improve EMC.

NOTE 1 Also protective earthing and lightning currents should be considered but these are outside the scope of this document.

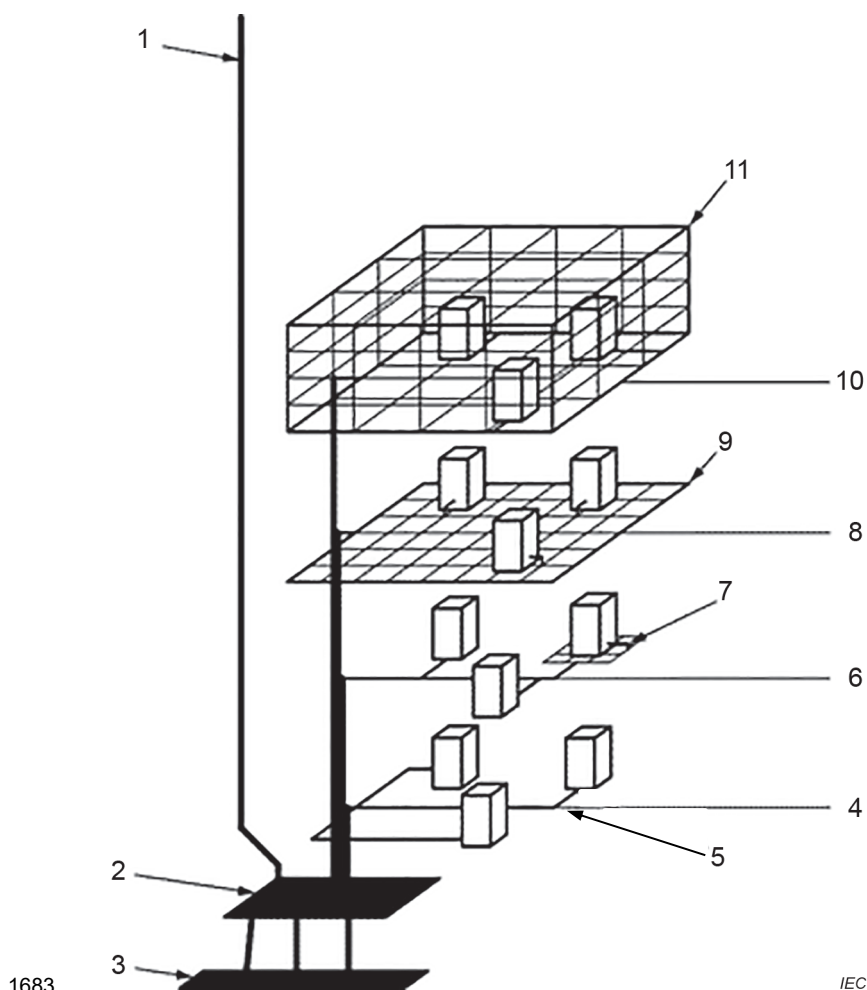
In a metallic hulled ship of conventional construction, electrical equipment is normally bonded to the nearest point on the ship's hull. In non-metallic ships, there are no inherent conducting paths and so they shall be provided in the form of an earthing system.

In general, only one earthing system is sufficient. In certain situations, for example due to functional reasons it can be useful to have more than one. All earthing systems shall be connected to the common earth plate(s). In the design, care shall be taken to prevent the creation of unintentional big loops since magnetic fields can generate considerable currents in these loops. If the loop is designed to handle large currents, then there is no objection in applying them.

NOTE 2 Additional information is given in Annex D.4.

A possible solution is shown in Figure 7-1. The impedance of the tree shaped earthing conductor(s) shall be decreased in direction to the earth plate.

NOTE 3 The mesh size depends on the frequencies which occur at the cage/floor location on the ship. An approximate value would be $\lambda/10$ for the local frequencies.



IEC

Key

- | | |
|---|--|
| 1 lightning rod | 7 tree with local mesh floor (can be located at each deck) |
| 2 main earth connection point inside the ship | 8 deck B |
| 3 earth plate/s outside the ship | 9 mesh floor (can be located at each deck) |
| 4 deck D | 10 deck A |
| 5 star (can be located at each deck) | 11 mesh cage (can be located at each deck) |
| 6 deck C | |

Figure 7-1 – Double-tree earthing system

NOTE 4 For larger ships multiple earth plates may be required.

All earth connections shall be selected to reduce the risk of corrosion.

NOTE 5 In a maritime environment there is a high risk that dissimilar metals cause galvanic corrosion which increase resistance. Reference is made to the galvanic series chart.

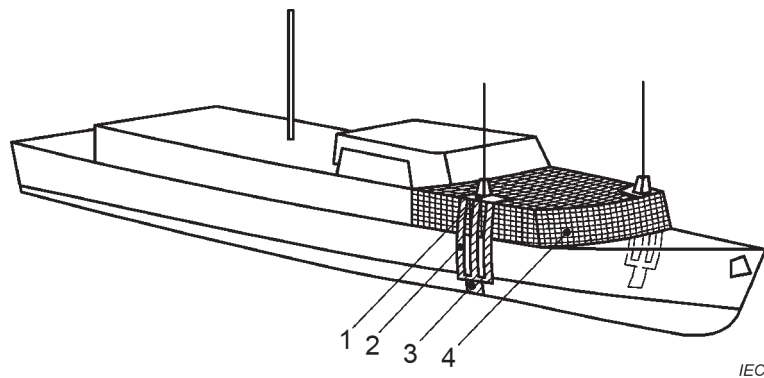
The protective earthing cable and the supply cables for a specific piece of equipment shall be placed as close together as practicable, to reduce the magnetic fields by reducing the radiating loop area.

7.3.3.2 Communication transmitter system

The antenna earth planes of the RF antennas shall be connected to the earth plate. The impedance of the connection shall be as low as possible. The reason for this is that the sea

1696 water also acts as an extension of the antenna earth plane and the return currents from the sea
 1697 need to take some path back to the base of the antenna (key 1 in Figure 7-1). The lower the
 1698 impedance of these connections, the less current will flow in the circuit formed by the ships
 1699 internal cabling etc. Capacitance between the antenna and the sea shall also be taken into
 1700 account.

1701 Different methods of achieving low impedance are possible. One method is to connect the
 1702 antenna earth plane (key 4) to the earth plates (key 3) using wide conducting straps (key 2)
 1703 routed down the side of the ship as shown in Figure 7-1.



1704

1705 Key

1706 1 antenna earth plane

1707 2 strap connection to the earth plate

1708 3 earth plate

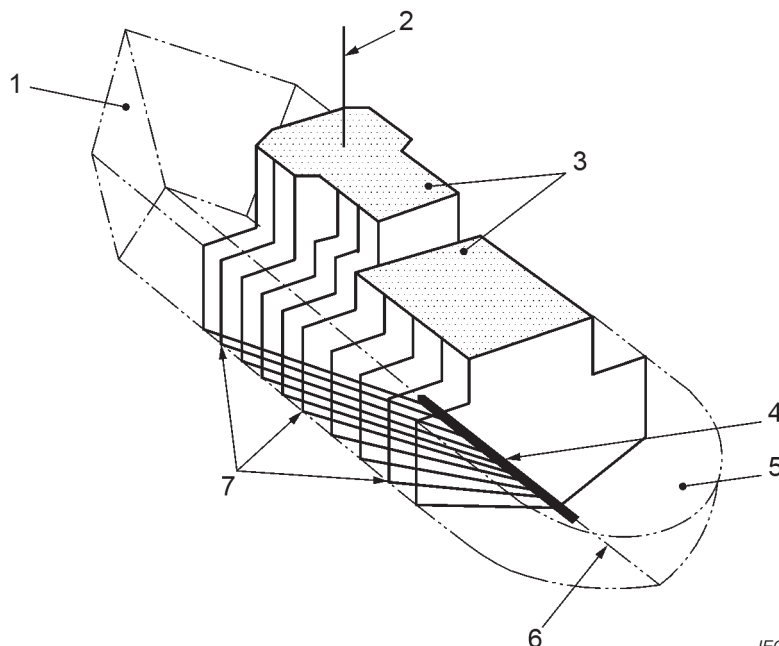
1709 4 wire mesh

1710

Figure 7-2 – Strap connection of antenna earth plane with earth plate

1711 Another possible design (see Figure 7-3) is to use a large number of conductive tapes suited
 1712 for a corrosive environment which enclose the centre section of the ship and can give a low
 1713 level of shielding against low frequency phenomena.

1714 EXAMPLE Such as the magnetic fields produced by lightning.



1715

1716 Key

IEC



Documents
 Document Sharing Hub