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EMC Requirements for Type Approval of Marine Electronics

Nordtest Project 1157-94

SP
Swedish National Testing and Research Institute
Physics and Electrotechnics
SP REPORT 1994:50

Abstract

An overview of the EMC specifications required by different classification societies is given in comparison with the international standard for navigational equipment and the generic standard for normal industrial equipment common for countries within the European Union (EU). The relevancy of the different methods are discussed and a proposal for a unified specification is given. The document is an interim report in a project supported by Nordtest, the object of which is to publish a Nordtest method for EMC testing of marine electronics. The intention of this method is that it can be supported by most of the classification societies. If so, it is the intention to present it as a proposal for a generic European standard for marine electronics.

Key words: EMC, test specification, marine electronics

Sveriges Provnings- och Forskningsinstitut
SP Rapport 1994:50
ISBN 91-7848-509-6
ISSN 0284-5172
Borås 1994

Swedish National Testing and Research Institute
SP Report 1994:50

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Preface

This document is an interim report in a Nordtest project on EMC requirement on marine electronics in which Det Norske Veritas and the Swedish National Testing and Research Institute are participating. This document presents an overview of existing requirements and a proposal to a unified specification. The project will proceed with activities to establish the proposal with the classification societies and also support the test program with field measurements on board ships.

Summary

This document presents an overview of existing EMC requirements on marine electronics used by the classification societies for type approval.

A worst case test program, the fulfilment of which covers all different requirements, is presented and also a proposal to a unified test program in line with European generic EMC standards.

1 Background

Marine electronic equipment is tested according to the requirements of several ship classification societies. Testing is also carried out as specified in military standards. The ship classification requirements are similar to each other but not identical, while the military requirements often significantly differ from the commercial ones and will not be treated in this report. The EU directive on EMC is applicable to marine electronics but no EN standard is available and there are no plans to come up with one.

A manufacturer who wants to have his equipment approved according to the requirements as mentioned above will have difficulties in writing a test program that covers all relevant requirements. An overview is therefore needed and a common test specification that is accepted by all classification societies.

An important but neglected EMC quality of marine electronics is the emission of electromagnetic disturbance. A low emission from electrical equipment is the main quality necessary to ensure an interference-free radio reception, which is of major importance on ships. It is surprising that emission limits are lacking in the EMC requirements of the classification societies.

2 Scope

The aim of this report is to give an overview of the different approval rules and to draw up a plan that minimises the tests required for approval by most classification societies. A proposal to a test plan in line with international basic EMC tests adapted to the ship environment is also given. This proposal will be presented to the classification societies, national directorates and the EU-commission in order to be treated by the relevant working group responsible for presenting a proposal to an EN standard.

3 Classification Societies

There are about 50 classification societies in the world. Most of them have no specific EMC requirements and will not be noted in this report. They normally accept the requirements of other societies or IACS's (International Association of Classification Societies) unified rules. The largest international societies with unique explicit EMC requirements are the British Lloyd's Register of Shipping, Det Norske Veritas DNV, the French Bureau Veritas BV, Germanischer Lloyd GL and Registro Italiano Navale RINA. Thus it is an overview of their requirements in comparison with international basic and generic EMC standards that will be presented in this report. IEC publ 945; "Marine navigational equipment - General requirements - Methods of testing and required test results" will also be included in the comparison because this standard is newly reedited with an ambitious EMC test program.

The EMC requirements on equipment and systems on ships are published in the type approval specifications of the societies as listed below:

Society	Name of test specification
DNV	Type approval of Instrumentation and Automation Equipment (Certification Notes No.2.4), 1988 (a revision will probably be ready in 1994)
LR	Type Approval System (Test Specification Number 1), 1990
GL	Regulations for the Performance of Type Tests, Part 1. Test requirements for Electrical/Electronic Equipment, Computers and Peripherals; Sept. 1993
BV	Rules and Regulations for the Classification of Ships (Section 19-25); Jan. 1991
RINA	Tentative rules for electromagnetic susceptibility tests, July 1987
IACS	IACS WP/EL; Unified environmental test specification for testing procedure for electrical, control and instrumentation equipment, marine computers and peripherals covered by classification, 1990

4 Test Specifications

4.1 General

During EMC testing the test objects are normally operational. This means that the test objects shall perform as in "normal operation" during the test. When testing objects with long time working cycles, the tests may be very comprehensive and expensive. Thus it is normal practice that the specific test program has a detailed performance test program in order to limit the test time. It is the responsibility of the applicant in collaboration with the test laboratory to propose a performance test program that is possible to run during the test. Prior to the testing is started, this test program shall be accepted by the classification society.

4.2 Immunity to radiated disturbance

4.2.1 Overwiew

The table below is an overview of the different specifications:

All requirements are based on IEC publ 801-3 which prescribes exposure to the field from an antenna as the normal test method. The frequency range is 27-500 MHz and in the revised draft the frequency range is proposed to be 80-1000 MHz. However, all classification requirements extend the frequency range to about 30 kHz. The test procedure below 27 MHz will thus be rather unspecified. In IEC 945 no reference to IEC 801-3 or any other test method standard is made. This is very annoying since IEC 945 seems to become a standard widely used. The reproducibility of a radiated disturbance test is very dependent on the method and that everybody is using the the same method.

Specification	Frequency range MHz		Severity V/m		Modulation %	Note
	start	stop	below deck	above deck	(1 kHz)	
DNV	0.03	200	10	10	0	
LR	0.027	500	10	10	30	
GL.	0.03	500	3	10	0	
BV	0.03	500	10	10	0	
RINA	0.03	300	1	10	30	
IACS	0.03	300	10	0	0	
IEC945	0.4	300	1	10	0	
EN 50082-2[1]	80	1000	10	10	80	
worst case	0.027	1000	10	10	80	

[1]proposed generic standard for industrial environment.

4.2.2 Considerations

- Test should primarily be performed in accordance with IEC 801-3. For the time being the current edition is not relevant anymore since the development of the second edition has been in progress in so many years, and is still only a draft revision[2], that some proposed changes have become "standard practice". For example the frequency range has been extended to 1000 MHz and 80% amplitude modulation at 1 kHz is normally used. It is also normal laboratory practice to control the exposure by using a calibration file, obtained during a calibration session where the test object has been exchanged for a reference field strength meter. The former practice used to measure the field strength close to the test object is not advisable since the test object will distort the field. Because of the irrelevancy of the IEC 801-3 from 1984 and the lack of a new revised standard, CENELEC has published a European pre standard, ENV 50140, which can be used temporarily while waiting for the revised edition of IEC 801-3. ENV 50140 is based on a proposed revision of this standard.

- In IEC 945 an RF radiated immunity test is specified (clause A.6) which is not adequate from several reasons:

  - The artificial mains networks AMN's (called stabilising networks), specified in accordance with CISPR 16, are unspecified in a wide range of the test frequencies. The CISPR-AMN shall be used below 30 MHz for measuring conducted disturbances from apparatus supplied from the mains. Above 30 MHz its characteristics are not specified and thus it should not be used.

  - The cable layout does not correspond to a real installation. To split the power supply cable into two directions will change the normal relationship between common and differential mode disturbances.

  - The use of a metallic ground plane is not advisable. An equipment placed on a ground plane may be screened to a degree much better than in a real installation. The use of a metallic test table should only be used when it is known to simulate the real installation. In type approval specifications it is better to require intrinsic immunity from the equipment itself than rely on possible disturbance mitigation by the installation.

  - It is required that the field strength shall be measured with a CISPR receiver. This is unnecessarily complicated. A broadband field sensor is quite suitable.

  - The requirement 1V/m seems, in comparison with normal requirements for CE marking on any apparatus (at least 3V/m for domestic, commercial and light industry equipment), too low even considering the screening effect of the structure of a ship. Portable transmitters, such as mobile telephones, may be used below deck.

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[2]latest draft reference number is 65A/77B(Central Office)40/24, 1994-08-12. Voting on this draft shall be terminated 1994-12-15.

- The lower frequency range is covered by a RF conducted immunity test (see below). Radiated tests in this frequency area are only relevant for portable equipment (without external cables) which would otherwise not be tested for those frequencies. When testing radio receivers for immunity, CISPR 20 (EN55020) should be used.

4.2.3 Proposal

The recommended common specification will be:

Frequency range:	80-1000 MHz
Severity:	10 V/m (carrier)
Modulation:	80% AM at 1 kHz
Sweep rate:	frequency increment: 1% /3s (0.0015 decades/s)
Antenna dist.:	minimum 1 m
Reference:	IEC publ. 801-3. 1 ed. with deviations as mentioned above (frequency range, modulation and calibration method); When the new edition has been published, this shall be used as reference. The use of ENV 50140 is recommended.

The EUT shall be placed on a wooden table (or equivalent) and the cables shall be exposed to the field from the antenna on at least 1 m of its length closest to the EUT. The exposure shall be performed with both horizontally and vertically polarised antenna.

A system consisting of different apparatus located far apart from each other, should normally be tested one apparatus at a time.

The test set-up shall be (in principle) as in the figure 1 and 2 below. It shall be arranged in conditions as close as possible to installed conditions, but without extra screening structures (e.g. metallic cable shelves) often found in installations, not called for in the manufacturers' installation specification.

The equipment shall be in its housing with all access panels in place, unless otherwise stated in the test plan. If the equipment is designed to be mounted in a screening panel, rack or cabinet, it should be tested in this configuration.

If the wiring to and from the equipment is not specified, an unshielded parallel conductor cable shall be used and left exposed for at least 1 m from the point of connection to the EUT. After this, the wiring may be interfaced with EMI filters and screened for its excess length to test equipment or power supply.

The 1 m length of the exposed wiring shall be placed to the side of EUT, then either up or down (at the convenience of the test engineer). This horizontal/vertical arrangement helps to ensure worst-case conditions.

Besides the normal radio transmitters, e.g. GSM telephones are growing more and more popular. The fields from GSM telephones are pulse modulated with a period of 4,62 ms. An additional test is specified in prEN 50082-2 with a 200 Hz pulse modulated carrier at 900 MHz. The test is described in ENV 50140.

The acceptance criterion is generally "normal performance", i.e. the EUT shall perform within its normal specification during the test. As was mentioned above, it is not possible to control all technical specifications during the EMC tests. The test plan shall specify how the performance monitoring shall be done.

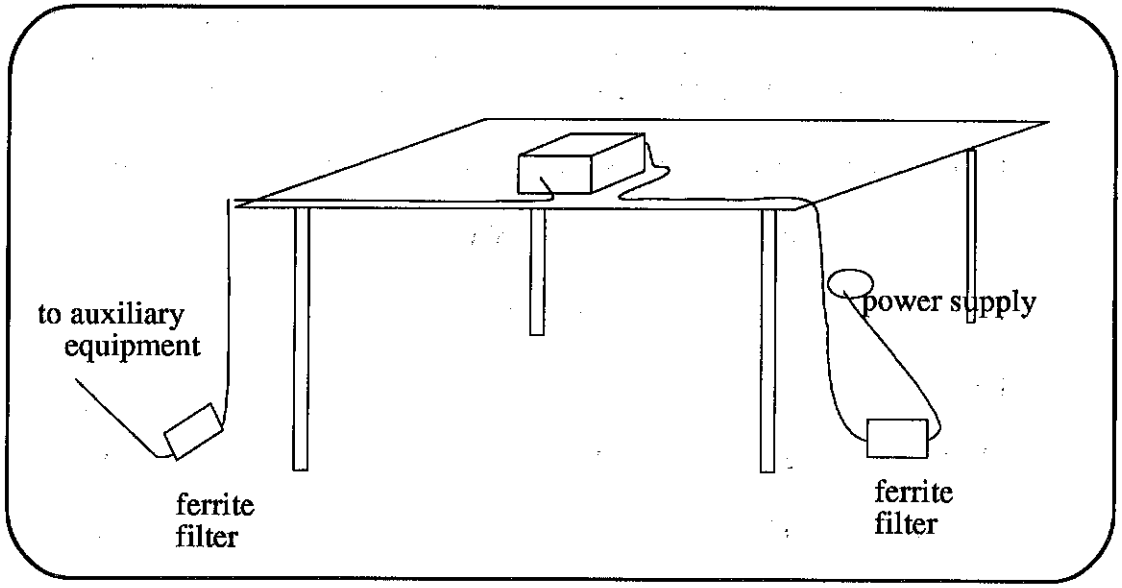

Figure 1. 1-module set-up

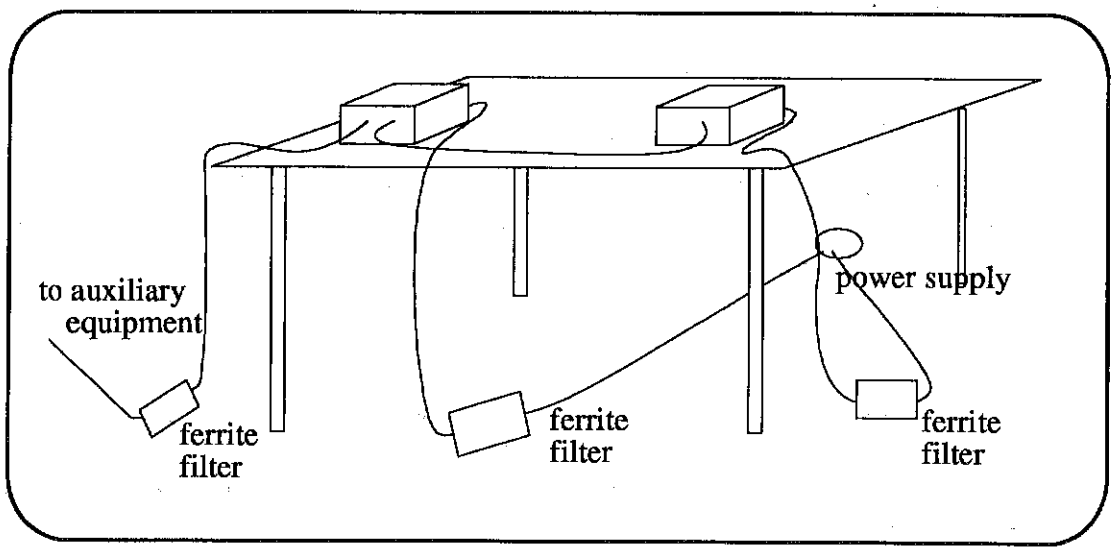

Figure 2. 2-module set-up

4.3 Immunity to electrostatic discharges

4.3.1 Overview

Electrostatic discharges are not a serious problem for equipment installed in ships. Nevertheless, such equipment should be protected since susceptibility to ESD is an indicator of poor shielding/grounding. There is no reason why an equipment installed on a ship should be of inferior quality than a standard product for usage on land.

Specification	Severity, kV	No of discharges	Interval, s	Note
DNV	8	10/ test point		1
GL	6/8	>10/test point	>1	2
BV	8			
IACS	8	10/test point		1
IEC 945	4/8			2
EN50082-2	4/8	10/test point	>1	2
worst case	6/8	10/test point	>1	2

Note 1: Reference to IEC 801-2, ed. 1.
Note 2: Reference to IEC 801-2, ed. 2.

4.3.2 Considerations

The current standard is IEC 801-2, ed 2 (draft IEC 1000-4-2). Correctly applied, the severity should be either level 2 (4 kV contact discharge and 4 kV air discharge) or level 3 (6 kV contact discharge and 8 kV air discharge). It is the responsibility of the test engineer to specify the test points.

4.3.3 Proposal

The situation is simple. It is quite natural to use the established standard, IEC 801-2, 1991, as it is. The proposed severity should be level 3 with 10 discharges of each polarity and type (contact/air) at each selected test point (selection made by the test engineer if not specified elsewhere).

It is not in general necessary to require normal performance of the tested equipment during the test. Depending upon the mission of the equipment, different requirements may be stated. It is, for example, not permitted that the response of the equipment to the test causes dangerous actions in its intended use or that the time to recover full performance after the test is unacceptable long. Several classification societies are

accepting "temporary degradation of performance which do not unduly affect the function". This formulation of the acceptance criteria is proposed.

4.4 Immunity to conducted radio frequency disturbance

4.4.1 Overview

No reference to any standard is given by any of the classification societyies. Nevertheless, the test performances are similar which is evident from the table below.

Specification	Frequency range,MHz Start	Stop	Severity V_{rms}	Modulation, % 1kHz	Note
LR	0.01	50	1	30	only power lines
GL	0.01	50	3	30	
RINA	0.01	30	1	30	only power lines
IACS	0.01	50	1	30	Note 1
IEC945	0.01	50	1	80	only power lines
EN50082-2	0.15	80	10	80	Note 2
worst case	0.01	80	10	80	

Note 1: Reference is made to draft IEC 801-6.
Note 2: Reference is made to ENV 50141 (draft IEC 801-6)

4.4.2 Considerations

All test levels, unless referring to IEC 801-6, are levels measured on the line of the tested object connected to the 50 ohm disturbance generator. When referring to IEC 801-6, the test level signifies the emf (electromotoric force = measured output from the unloaded generator) of the 150 ohm disturbance generator. Thus it is not so easy to compare the different specifications. Depending upon actual cable impedance as seen by the disturbance generator $1V_{rms}$ measured directly on the line may, in extreme cases, be more than 10 V_{rms} calibrated according to the IEC 801-6 procedure.

Test should primarily be performed following international standard, IEC 801-6. For the time being no approved edition exists. The principle of the test is that the disturbance source shall be connected to the EUT in a way that simulates a natural coupling path from a radio frequency transmitter. The main coupling paths are cables, long enough to act as antennas for the disturbance frequencies. All types of cables, power supply, signal and control cables or earth leads, may be suspected as entrance ports of disturbances to a system.

The coupling path my be inductive, capacitive or resistive or a combination. The important thing is that a firm control must be achieved in the entire frequency range. Since all test set-ups creates complex circuits with resonances, a direct measurement of the disturbance level in the injection point will give a bad control of the test level. The measured test currents or voltages are influenced by the complex impedance in the injection point. To maintain the test level throughout the frequency range, there will always be resonance frequencies where the required output disturbance signal power will go to zero or infinity.

Two methods are available to keep a good control of the test severity.

Calibration file method

In the test circuit (see figure 3) the EUT is replaced by a standard load (150 ohm resistive is proposed in draft IEC 801-6) and a file is generated specifying the output power from the disturbance source giving the test severity for each frequency. The file is then used to control the disturbance generator with the EUT connected at the place of the standard load.

Direct control method

In the test circuit as above the disturbance source is connected so that it sees a matched load. This is achieved by using an attenuator of at least 6 dB in front of the injection point. The severity of the test is then defined as the output from the disturbance source minus the attenuator value, or in other words the output power from the disturbance source shall be adjusted to the specified test severity plus the attenuator value. In figure 3 an oscilloscope is used for monitoring and control.

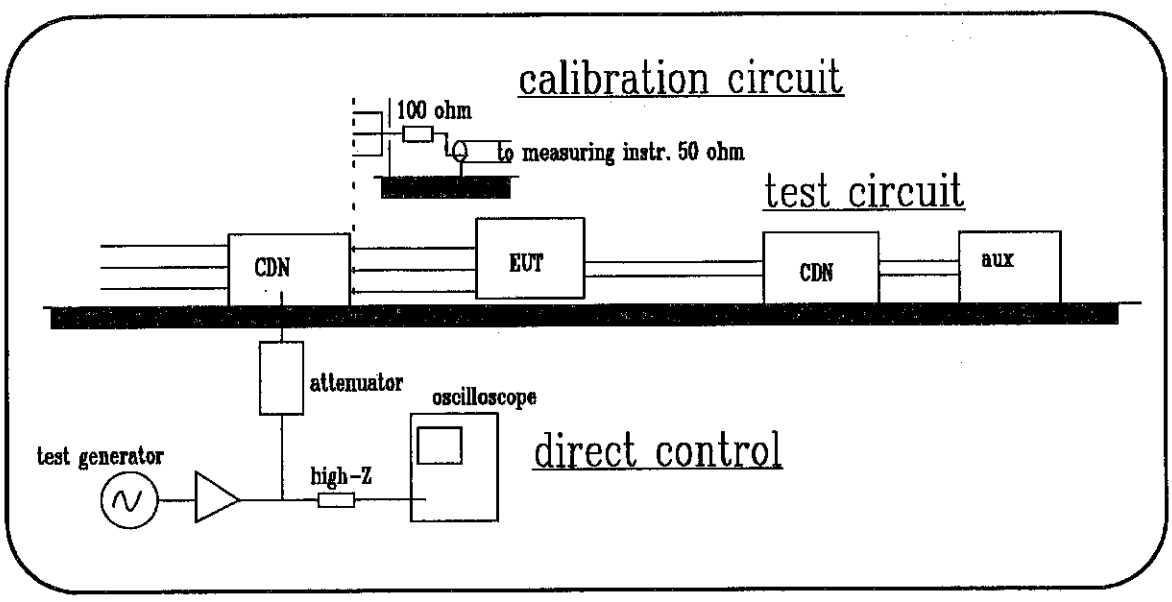

Figure 3.

The calibration file method is preferred if computer control is available. If direct control is used when the calibration file method is presumed in the test method (i.e., IEC 801-6), the matched output level from the disturbance source shall be equal to the test severity

plus the attenuator value -3 dB. This is because the severity is defined as the voltage of the unloaded disturbance source and not the actual disturbance level on the disturbed port. The attenuator is used to minimise the influence from the complex impedance of the test circuit, and the higher the attenuation the better, but the power needed will increase with higher attenuation.

Direct control is presumed in IEC 945 (and in all classification requirements) but in a different manner than described above. The carrier level shall be adjusted to 1 V_{rms} at the input of the coupling/decoupling network (CDN). Such direct measurement at the injection point is not recommended due to the resonances in the test circuit as discussed above.

It is important to note that the definition of test severity is different in IEC 801-6 and IEC 945. In IEC 801-6 the severity is the unloaded level from the disturbance generator (that is the emf of the generator) while in IEC 945 the severity is the measured level at the injection point. Besides, the output impedance of the disturbance sources is different. It is not possible to convert the severities from one method to the other.

4.4.3 Proposal

The test method used by all classification societies, where the severity is controlled by direct measurement of the disturbance voltage on the tested line, is not to be recommended due to the poor reproducibility.

Since IEC 801-6 (IEC 1000-4-6) has not been approved yet, it is recommended to use the temporarily ENV 50141. In this standard the calibration procedure is described accurately and the risk of over- or undertesting is minimised.

The choice of severity is a delicate matter. The proposed generic standard for industry specifies 10 V_{rms}, and, you could ask, why should the requirement for marine electronics be less severe. Marine environment contains more transmitters than the industrial environment.

On the other hand the requirements from the classification societies today are 1 V_{rms}, which corresponds better with 3 V_{rms} than with 10 V_{rms} according to IEC 801-6. Further, the installation on a ship is normally more protected due to the metallic hull than the installation in an industry.

So, in order not to exaggerate the requirement in this attempt to unify the requirements, 3 V_{rms} will be proposed. Limitation to the frequency range above 150 kHz is justified by the fact that international standards are lacking below 150 kHz since it has not been recognised as a range causing interferences.

Recommended common requirement

Frequency range:	0.15-80 MHz
Severity:	3 Vrms (carrier)
Modulation:	80% AM at 1 kHz

Sweep rate: 1%/3 s (0.0015 dec/s)
Reference: ENV 50 141 (draft IEC 801-6/IEC 1000-4-6)

As acceptance criteria normal performance is required during and after the test. The test shall be applied on all cables of significant length as described in annex A1 in ENV 50 141.

4.5 Immunity to audio frequency disturbances

4.5.1 Overview

The test is required in the following rules and standards

Specification	Frequency range, kHz Start	Stop	Severity, V_{rms}	Note
LR	0.05	10	3/23-2.3	DC/230Vac
GL	0.05	10	3/23-2.3	DC/230Vac
RINA	0.05	10	3	DC/AC
IEC945	0.05	10	3	DC/AC
worst case	0.05	10	3/23-2.3	DC/230Vac

4.5.2 Considerations

This test is primarily a test on immunity to distorted supply voltage and covers the range from power frequency (normally 50 Hz) to about 10 kHz (200th harmonics). The test is normally performed as a swept frequency test. Corresponding tests are planned in the series of basic tests in IEC publication 1000-4-xxx, "Immunity to harmonics, inter harmonics to AC power port" and "Ripple on DC power supply Immunity test". Those tests are only proposals and not ready for use. Furthermore, most product groups do not have a history of being susceptible to distorted power supply. It is therefore not justified to have the test as a general approval test, but carefully chose the special product that should be tested (e.g. audio equipment). Equipment dealing with low level audio frequency signalling are often sensitive to such disturbances on other cables as well as on the power supply cable. Testing and interpretation of the test results on such equipment must be very carefully specified and thus special product standards should be referred to.

4.5.3 Proposal

It is proposed that a test for immunity to audio frequency disturbances shall not be included in the general approval test procedure common for all apparatus.

4.6 Immunity to transients on power supply

4.6.1 Overview

Voltage transients on power lines are normally generated during switching operations. The transients are of different kinds depending on which source it emanates from.

Sparks

The most frequent transient disturbance is generated between the contacts in mechanical switches where a train of very short transients is generated especially during the contact breaking operation. The disturbance energy is very low, but the frequency content is very high. Coupling to sensitive cables and circuits is therefore possible by very small stray capacitances or by radiation. Thus, testing of immunity to this kind of disturbance (fast transient/burst test) is performed on all cables to and from an equipment and if relevant by coupling directly to the case.

Transients and surges

Another type of transient disturbance has typically a high energy content and may originate from atmospheric lightning. Such transients are much slower than the former and will normally follow the cable it initially was coupled to (normally a rather long cable or the earth lead). Lightning currents flowing in the hull of a ship creates voltage difference between components in electronic systems. Such voltages force transient currents to flow in signal cables, specially if they are connected to earth in several points.

Load switching, especially inductive loads and transformers, generates transients of intermediate energy contents and may affect electronics connected in parallel. Normally such transients are a maximum of twice the peak voltage on the supply line. When breaking the current in an inductive load, much higher transients may develop, but this transient is normally not directly connected to sensitive circuits, since the switch is open when the transient reaches its maximum. Only in the case when a mains switch is used or a fuse blows, the full transient energy from the load switching may affect other circuits (see figure 4).

Coupling to the sensor/load terminal of the sensitive electronics will be achieved by the capacitance or mutual inductance between the disturbed power cable and the sensor/load cable. With a capacitive or inductiv coupling, the common mode disturbance will dominate, since both forward and return conductor run in parallel and close to each other. Transients generated by a load on the power line will primarily generate a differential mode disturbance. A common mode transient is often converted to a differential mode transient when one of the conductors is connected to earth, like in an electric central.

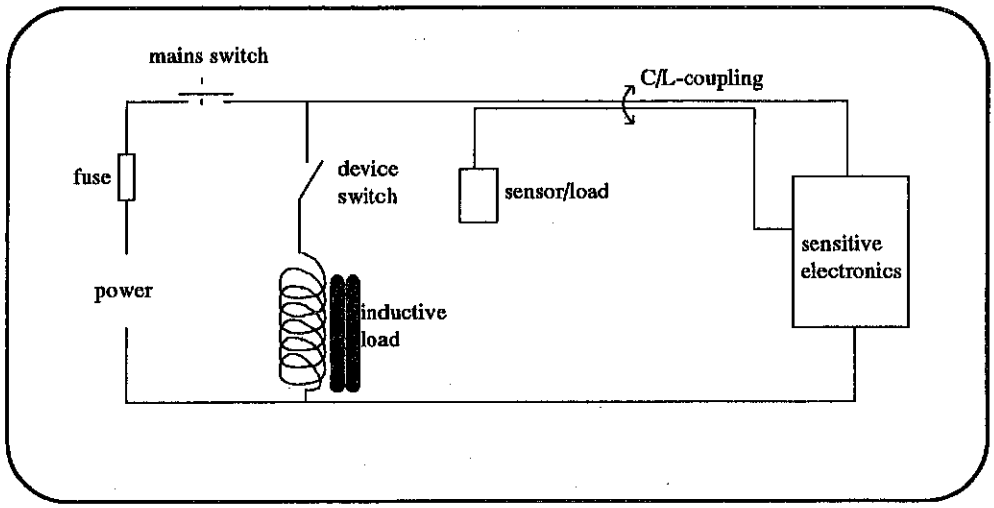

Figure 4.

Transient test specifications

In the approval requirements and standards one or two different methods are used:

1. The low energy, high frequency test: EFT (electrical fast transient)

2. The high energy, low frequency test: surge.

DNV is using a different test pulse, called 1-MHz-pule, simulating transients generated by coupling actions in electric power stations and transmitted through the mains to the comsumers. This test will be exchanged for the surge test in the revised EMC specification.

(High voltage tests, ac or transient, are considered electrical security tests and will not be treated in this report.)

Specification	Transient test		Notes
	EFT, kV	Surge, kV	
LR	1	1	power line, note 1, 2
GL	2	2/1 (com/diff)	power/signal line, note 1
DNV	1		power line, note 3
BV	2 1	2/1 (com/diff)	power line, note 1 power line, note 3
RINA	>400		power line, note 4

Specification	Transient test		Notes
	EFT, kV	Surge, kV	
IACS	2	2/1 (com/diff)	power line, note 1
	1		signal line, note 1
IEC 945		2*Û	ac power line, note 4
EN 50082-2	2	(4/2 (com/diff))	ac power line, note 1, 5
	2	(0.5/0.5 (com/diff))	dc power line, note 1, 5
	2	(2/1 (com/diff))	process line, note 1, 5
	1		signal line, note 1
worst case	2	4/2 (com/diff)	ac power line, note 1
	2	2/1 (com/diff)	dc power/signal line, note 1

Note 1. Reference to IEC 801-4 resp. IEC 801-5.
Note 2. Very high surge repetition rate: 1 /s.
Note 3. Reference to 1 MHz pulse test (IEC 255-4).
Note 4. Special method defined.
Note 5. Surge test is proposed for inclusion in the standard.

Common mode disturbance voltages are normally higher than differential mode voltages. That is why the test levels are different. On the other hand, a differential mode disturbance source on a cable, like an inductive load on the same cable, may generate a more powerful transient. A common mode test is therefore performed with a lower impedance generator than a differential mode test.

4.6.2 Considerations

Two different methods must be used to test immunity to transients on the power supply.

IEC publ 801-4 Fast transient/burst test has been used for several years, and it is an effective tool for testing digital and microprocessor controlled equipment. This test is performed on each part in the power cable (line to ground testing) and on each other cable as a common mode test.

IEC publ. 801-5 Surge test is not yet approved, but is proposed to be performed on each cable connected to wide spread cable systems and between earth connections in systems. Application to interconnection lines shall be limited to such lines that can be judged to be exposed to high energy transients. In the overview above it should be noticed that there is no difference in requirements for ac and dc power line except in the proposed generic standard. It seems that a 1 kV diff mode transient on a battery powered 24 V emergency supply is unrealistic (unless in fault conditions) and a relaxation will be proposed.

Although surge immunity testing is still not a basic standard method, it is recommended to use it as a mandatory test for type approval in order to reach immunity to primarily atmospheric lightning.

If those two methods are used, it is judged unnecessary to use other methods as well.

4.6.3 Proposal

The proposed unified requirement would be:

Test	Severity type of cable			Notes
	mains, DC>48 V, process/control	DC<48 V	data/signal	
IEC 801-4	2 kV	2 kV	1 kV	
IEC 801-5	2 kV CM 1 kV DM	1 kV CM 0,5 kV DM	1 kV CM	Note 1

Note 1: Reduce test level to half the value on short (10-30 m) process/control and signal/data lines. No test on shorter lines.

The rationale to have different surge immunity requirements for high and low supply voltage lines is that the generation of disturbances from loads are dependent on supply voltage.

4.7 Immunity to supply voltage variations

4.7.1 Overview

Under this heading different kinds of phenomena on the power supply could be collected. The approval rules from most classification societies contain requirements on performance when supply voltage and/or frequency steadily and for short time (a few seconds) deviate from nominal by a certain amount (see also IEC 92-504).

Specification	AC-supply variation (%)				DC-supply variation(%)		Transient time	
	Steady state		Transient		Steady state	Transient	AC	DC
	Voltage	Frequency	Voltage	Frequency	Voltage	Voltage	(s)	(s)
LR	±10	±5	±20	±5	+30/-20		1,5/5	
DnV	+10/-15	±5	±20	±15	±17	±20	2	2
GL	±10	±5	±20	±10	+30/-25		3	

Specification	AC-supply variation (%)				DC-supply variation(%)		Transient time	
	Steady state		Transient		Steady state	Transient	AC	DC
	Voltage	Frequency	Voltage	Frequency	Voltage	Voltage	(s)	(s)
BV	±10	±5	±20	±10	±20		3	
RINA	+6/-10	±5						
IACS	±10	±5	±20	±10	+30/-20		1,5/5	
IEC 945	±10	±6			+10/-20 (mains) +30/-10 (battery)			
EN 50082-2	±10				±20			

4.7.2 Considerations

Since the mains on a ship is so much weaker than the general mains, comparison with industrial requirements is not very useful. No international standard for this test exists and no known work is going on. It seems quite natural to unite around IACS unified requirement.

4.7.3 Dips and interruptions

International standardisation has prepared a basic standard for immunity to short dips and interruption on the mains, IEC 1000-4-11, and provisions are taken for a rapid incorporation in the requirement for CEmarking of equipment connected to the mains. Such tests have not been adopted by any of the classification societies as a mandatory requirement for equipment installed in ships. This is a severe lack since it is known that program controlled equipment often inhibit the program execution when exposed to such disturbances. A power supply system on a ship is expected to be more unsafe and generate more disturbances of that kind than the public mains. A somewhat modified test is adopted by some societies. This consists of a repeated "power on"-test consisting of 3 power interruptions within 5 minutes with 30 second's power off time. The main difference between this test and the standardised one, is that a '30 second' break is long enough for most systems to perform a complete "power-off" programme cycle, while a shorter break may disturb the programme running.

4.7.4 Proposal

Thus it is proposed that the unified requirements, in addition to the test specified by IACS above, should include tests according to the standard for voltage dips and interruption, IEC 1000-4-11 with the following specification:

Normal or only acceptable degradation of performance is required when the supply voltage dips 30% to 100% during 0.005 to 30 seconds with an interval of at least 10 s between each dip. If not stated otherwise in the test plan, the standardized test conditions

in the reference shall be used. Acceptable degradation has to be judged from what the user may reasonably expect from the apparatus if used as intended. It is adequate to require that the tested equipment be self recoverable with no loss of data or operating state when tested with the shortest dips. Systems, which control safety related functions, must not become unsafe for any type of dips. This implies that full performance shall be restored within a reasonable short time automatically or by operator action. Other systems may comply with the requirement if full performance may be restored by the operator after the test.

4.8 Immunity to other disturbances

4.8.1 50 Hz disturbance

Some types of disturbances have not been covered above. The most important environmental factor is mains frequency disturbance that may be induced on all cables. It is known to superimpose on low level signals to a degree that may affect measurement or control accuracy. However, the basic international standard is still missing and it could be argued that equipment not working properly in its installation (where the mains frequency disturbance is continuously present) would be claimed within short and corrections must be taken by the manufacturer. During certain fault conditions, (earthfault, short circuit) a considerable increase of main frequency disturbance may occur, so the problem is still there and should be reconsidered when a standard has been approved.

4.8.2 Magnetic field

Magnetic field will normally appear with the power mains frequency and announce itself as a disturbance voltage in cables as mentioned above. Direct interaction on equipment is not very frequent, but some sensitive devices have been recognised like CRT´s. hall sensors and audio circuits. It is not believed that magnetic field test will be a general test on all equipment but a special test used on certain products. Thus it is essential that reference to product standards is used in the approval requirements.

4.8.3 RF-current in metalwork

Only RINA is specifying a test where RF-current is injected in the metallic case of the equipment under test. Such disturbances are of coarse present in environments with RF-transmitters, but a special test is not necessary. RF currents in the metallic case of the equipment will be generated when performing tests according to IEC 801-3 and IEC 801-6 either by the influence of the field from an antenna or by direct injection in cable screens and earth points. The execution of the test is not identical with RINA's specification, but it is rather probable that the same aim is reached.

4.9 Emission requirements

No classification society has included emission requirements in its approval requirements. However, IEC 945 has adopted limits for permitted RF-emission in the range 10 kHz-300 MHz and it is expected that it will be mandatory for equipment within its scope. The

limits are shown in fig 5 and 6 which also present international accepted limits for industrial equipment according to generic standard EN 50081-1[3] and 50081-2[4].
The radiated limits are converted to approximately correspond with the method envisaged in IEC 945. (An inverse proportionality factor of 20 dB/decade measurement distance has been used.)

As can be seen a requirement according to international standard would be rather in line with IEC 945. The class B limit is suitable for areas where radio reception protection is needed and class A is relevant in other areas. The special limit between 156 and 165 MHz in IEC 945 is probably motivated by the very close proximity between navigation equipment and marine radio communication equipment. To require such low limits for all equipment is not recommended due to the costs and difficulties that it would cause the manufacturers.

Emission requirements at lower frequency, primary harmonics to the mains' frequency and voltage fluctuations, are discussed internationally and limits are given in IEC 555-2 and -3. Those are applied to household equipment, but limits for industrial equipment will probably be accepted in the near future. The applicability of industrial limits must be investigated considering the special power system on ships. Thus, no proposal on limiting the generation of harmonics will be given here.

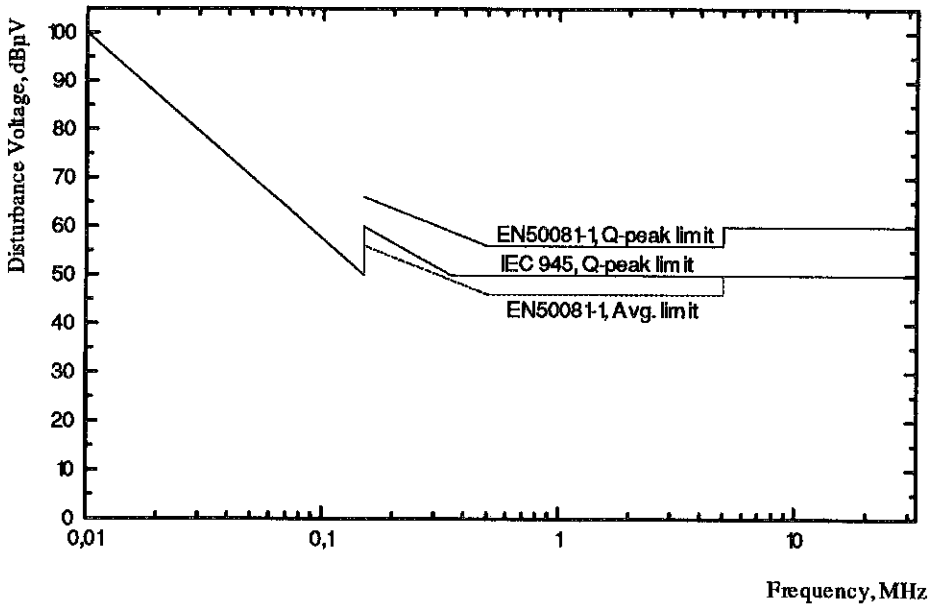

Figure 5.

[3]Generic emission standard for residential, commercial and light industry environment.
[4]Generic emission standard for industrial environment.

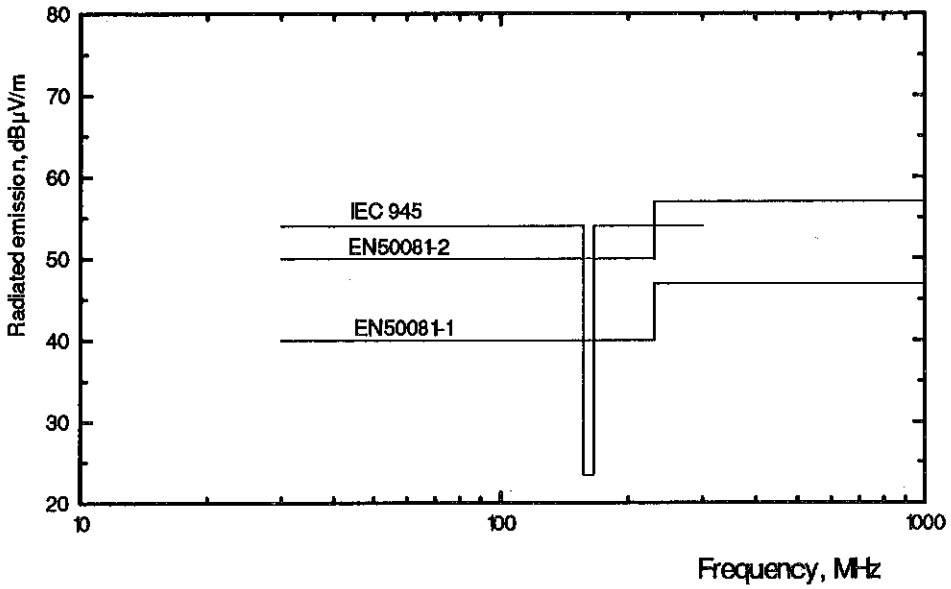
80
70
60
50
40
30
20
Radiated emission, dBµV/m
IEC 945
EN50081-2
EN50081-1
10
100
1000
Frequency, MHz

Figure 6

Annex 1

Worst case test program

In order to fulfill the EMC requirements of all the classification societies, the following test program should be applied.

1. The test program and the methods for performance control shall, prior to the test, be approved by the classification society(ies). The manufacturer's choise of test laboratory shall also be annonced. The classification society may demand that the test shall be supervised by an inspector.

2. The equipment to be tested shall be fully identified by the type and serial number and relevant drawings. Program versions shall be noted and interconnecting cables shall be noted by type and length. Before the test commence, the equipment should be checked to ensure that it is operating normally.

3. Except if stated otherwise in the test program, the power supply shall be of nominal voltage and frequency.

4. Except if stated otherwise in the test program, the default conditions as stated in the refered test methods shall apply.

5. All the immunity test according to below shall be performed on one test object.

Test method	**Severity**	**Requirements**
draft rev IEC801-3, Radiated immunity test. Below 27 MHz a transverse electric field may be used (planparallel cell or beam or long wire antenna).	27 kHz-500 (1000) MHz, 10 V/m, AM 30(80)% at 1 kHz. Test to 1000 MHz with 80 % modulation is recommended	Normal performance required
IEC 801-2, 1st ed, ESD immunity test	8 kV on operator accessible parts. 10 discharges on each selected point	Normal performance required after the test. Permitted influence during the test is dependent on intended function of EUT

Test method	Severity	Requirements
IEC 801-2, 2nd ed, ESD immunity test	6 kV contact discharge, 8 kV air discharge. 10 discharges of each polarity on each selected point	Normal performance required after the test. Permitted influence during the test is dependent on intended function of EUT
draft IEC 801-6, Conducted RF-immunity test. Below 150 kHz the test is not specified	10 kHz-50(80) MHz, 3 V_{rms} AM-modulated to 30(80) % at 1 kHz	Normal performance required
Immunity to circulating RF-current in metalwork and screen of interconnecting cables acc. to RINA	10 kHz-30 MHz, 100 mA passing from one corner of equipment case to all other in turn and through inter-connecting cable screens.	Normal performance required
Immunity to AF disturbance on power lines acc to IEC 945	50 Hz-10 kHz, 3 V_{rms} or 10% of supply voltage up to 15^{th} harmonics of supply frequency reducing to 1 % at 100^{th} whichever is highest.	Normal performance required
IEC 801-4, Fast transient/burst test	Level 3 (2 kV on mains power, 1 kV on other cables)	Insignificant interferences are accepted during the test
draft IEC 801-5, Surge test	Class 3 (2 kV CM, 1 kV DM) on power mains. 0.1 Hz pulse repetition rate in 10 minutes (note 1)	Insignificant interferences are accepted during the test
1 MHz-test specified according to DnV. The test generator specified in IEC 255-4.	1 kV in CM and DM on power supply line during 2 s.	Insignificant interferences are accepted during the test
Power supply test, AC steady state	(volt dev. % / freq dev %) 10/6, -15/6, -15/-6, 10/-6	Normal performance during at least 15 min

Test method	Severity	Requirements
Power supply test, AC transient	(volt dev % / freq dev %) 20/15, -20/-15	Normal performance during 2 s volt dev. and 5 s freq. dev. and after the test
Power supply test, DC steady state	(volt dev. %) 30, -20	Normal performance during 15 min
Power supply test, DC transient	(volt dev %) 20, -20	Normal performance during 2 s and after the test
Power supply interruption	3 interruptions à 30 seconds within 5 minutes	Normal performance within specified time after each interruption

Note 1. LR normally accept 0.1 Hz PRF although they specify 1 Hz. Commercially, no disturbance generator for IEC 801-5 is available with 1 Hz PRF.

6. Emission tests according to IEC 945, clause 4.5.3 and 4.5.4 shall be performed if the equipment may be installed in locations where protection of radio reception is important or otherwise if the classification society(ies) so demands.

7. A test report containing a specification of the tested equipment, the tests performed and the results of the functional tests shall be submitted to the classification society(ies).

Annex 2

Unified approval rules for EMC-tests on marine electronics

0. General

Type approval of marine electronics is obtained by following the administrative procedures announced by the different classification societies. This standard presents the unified technical requirements adapted[5] by most of them and ensures that multiple EMC testing is avoided. Type approval will,however, be received only by the formal application to the societies observing the special procedures stated by each of them.

1. Scope

The purpose of this standard is to present unified EMC requirements on equipment covered by the classification rules of ships. Fulfilling of the requirements shows that an adequate degree of compatibility with the electromagnetic environment on ships exists.

2. Field of application

This standard for EMC requirements applies to electrical and electronic apparatus intended for use in all locations on ships.

Equipment designed to radiate electromagnetic energy for radio communication purpose are excluded from this standard.

Where a relevant dedicated product standard exists, this EMC standard shall be used to adapt the requirements in the product standard to the ship environment (if this is not foreseen in the product standard).

3. References

ENV 50140, 1993	Radiated, radio-frequency electromagnetic field-Immunity test
ENV 50141, 1993	Conducted disturbances induced by radio-frequency fields-Immunity test
IEC 801-2, 1991	Electromagnetic compatibility ..- Part 2: Electrostatic discharge requirements
IEC 801-4, 1988	Electromagnetic compatibility..- Part 4: Electrical fast transient/burst test
IEC 1000-4-5, draft	Electromagnetic compatibility - Section 5: Surge immunity test; Draft international standard 65A/77B(CO)41/25

[5]At the time of finishing this report, this is only an intention.

IEC 1000-4-11	Electromagnetic compatibility - Section 11: Voltage dips, short interruptions and voltage variations - Immunity tests
CISPR 22, 1993	Limits and methods of measurement of radio disturbance characteristics of information technology equipment

4. Definitions

Port:	Particular interface of the EUT with the external electromagnetic environment.
Enclosure port:	The physical boundary of the EUT through which electromagnetic fields may radiate or impigne
Cable port:	A point at which a conductor or a cable is connected to the apparatus. Examples are signal, control and power ports.
EUT	Equipment under test

5. Sampling and operation conditions

Tests are normally made on one test sample (type testing), but different identical samples may be chosen for convience. Prototype testing is encouraged, since EMC tests are a valuable tool in the developement of new constructions, but cannot supersede the final test on a sample from the production.

The immunity tests shall be made in the most susceptible operating mode consistent with normal applications. The configuration of the test sample shall be varied to achieve maximum susceptibility.

If the equipment is part of a system, or can be connected to auxiliary equipment, then the equipment shall be tested while connected to at least the minimum configuration of auxiliary equipment necessery to adequatly exercise the tested equipment. The performance of the auxiliary equipment must not be disturbed by the test environment nor must the auxiliary equipment contribute to the measured emission level. Auxiliary equipment may be simulated if that is deemed a possible way to simulate a normal installation.

A test program shall be specified (in collaboration with the test laboratory) and, prior to the test, be approved by the classification societies.

The test sample, its test set-up and mode of operation shall be precisely noted in the test report by technical documentation, photos and/or drawings. If the technical specification of the test sample cannot be fully verified during the EMC tests, an adequat selection of the parameters to be checked shall be chosen or a test circuit exposing any influences from the test environment shall be used.

6. Test methods

The EMC characterisation of an equipment has to be subdivided into a number of tests which evaluates the performance of the EUT in normal use - emission of radio frequency disturbances - and under exposure of electromagnetic disturbances - immunity. The emission may radiate from the case or the cables of the equipment or conduct along the cables. The disturbances may originate from a transient or a continuous source and may be entering the equipment by the cables or the case. The EMC characterisation is thus a sum of tests measuring or simulating all these situations.

The difficulties of translating the results or transposing the test parameters from one test to another makes it very important that everybody use the same methods. This has been recogniced by IEC and CENELEC in their ongoing activities to support the EMC directive from the EU commission with suitable EMC test methods and requirements. The technical committees TC 77 in IEC and TC 110 in CENELEC are thus coordinating their activities to create a number of "basic standards" that always shall be referred to when establishing EMC requirements on an equipment. Product committees are urged to use those standards in their product specifications.

In this method only basic standards or basic standard proposals have been referred to except for one test simulating the power generation system on ships where no such standard exists.

The contents of the basic standards are not given here. It is the intention of this standard that the basic standard referred to shall be applied to the full. However, when this is not possible or suitable, all modifications shall be noted in the test report.

7. Requirements

Tests are applied to the relevant ports of the equipment according to tables 1 to 7. Tests shall only be carried out where the relevant ports exist.

It may be determined from consideration of the electrical characteristics and usage of a particular equipment that some of the tests are inappropriate and therefore unnecessary. In such a case it is required that this is noted in the test program and approved by the classification society.

In cases where the manufacturer specifically calls for external protection or measures in the installation, the tests may be applied on a test set-up with such protections installed. This shall be noted in the test report.

Performance criteria

The variety and diversity of the equipment within the scope of this standard makes it impossible to define precise criteria for the evaluation of the immunity test results.

Common requirements for all immunity tests: Equipment shall not become dangerous or unsafe as a result of the application of the tests defined in this standard. The judgement

of fulfilling this requirement must include possible activities of auxiliary equipment controlled by the disturbed EUT.

Performance criterion A: The equipment shall continue to operate as intended during and after the test. No degradation below the minimum performance level specified by the classification society or loss of function is allowed. If no minimum performance level is specified then the manufacturer may specify the performance loss during exposure to disturbances assuming this loss will not unduly affect the function of the equipment.

Performance criterion B: The equipment shall continue to operate as intended after the test. No degradation of performance or loss of function is allowed. This implies that no change of operating state or stored data is allowed and that the correct function shall be self recoverable within a time short enough to be consistent with the intended use of the equipment and insignificant to the operator.

Performance criterion C: Temporary loss of function is allowed, provided the loss of function is self recoverable or can be restored by the operator. If this temporary loss of function is inconsistent with the requirement of safe operation, either performance criterion B is required or other methods to preserve the function ("fail-safe" techniques) should be used.

Table 1: Immunity-Enclosure port

	Environmental phenomena	Units	Test specification	Test standard	Remarks	Performance criteria
1.1	Radio frequency electromagnetic field. Amplitude modulated	MHz V/m (unmod) %AM(1 kHz)	26-1000 10 80	ENV 50140		A
1.2	Radio frequency electromagnetic field. Pulse modulated	MHz V/m(unmod) duty cycle % Rep freq Hz	900 3 50 200	ENV 50140		A
1.3	Electrostatic discharge	kV	6 contact 8 air discharge	IEC 801-2: 1991		B

Table 2. Immunity for signal lines and data buses not connected to supply voltage >48 V.

	Environmental phenomena	Units	Test specification	Test standard	Remarks	Performance criteria
2.1	Radio frequency common mode. Amplitude modulated	MHz V (unmod) %AM(1 kHz) Source imp, ohm	0,15-80 3 80 150	ENV 50141		A
2.2	Fast transients	kV (peak) Tr/Th ns PRF kHz	1 5/50 5	IEC 801-4		B
2.3	Surge	kV Tr/Th µs	0.5 (line to ground) 1,2/50	IEC 1000-4-5 draft		B

Table 3. Immunity for signal and control lines connected to supply voltage >48 V

	Environmental phenomena	Units	Test specification	Test standard	Remarks	Performance criteria
3.1	Radio frequency common mode. Amplitude modulated	MHz V (unmod) %AM(1 kHz) Source imp, ohm	0,15-80 3 80 150	ENV 50141		A
3.2	Fast transients	kV (peak) Tr/Th ns PRF kHz	2 5/50 5	IEC 801-4		B
3.3	Surge	kV kV Tr/Th µs	1 (line to line) 2 (line to ground) 1,2/50	IEC 1000-4-5 draft		B

Table 4. Immunity Power supply ports not >48 V

	Environmental phenomena	Units	Test specification	Test standard	Re-marks	Performance criteria
4.1	Radio frequency common mode. Amplitude modulated	MHz V (unmod) %AM(1 kHz) Source imp, ohm	0,15-80 3 80 150	ENV 50141		A
4.2	Fast transients	kV (peak) Tr/Th ns PRF kHz	2 5/50 5	IEC 801-4		B
4.3	Surge	kV kV Tr/Th µs	1 (line to ground) 0.5 (line to line) 1,2/50	IEC 1000-4-5 draft		B
4.4	Supply voltage dips	% reduction ms	30-95 5-30000	IEC 1000-4-11		B for ≤300 %ms[6] C for >300 %ms
4.5	Supply var., continuous	% of nom vol % of nom freqt	DC:+30/-25 AC: ±10 ±5	under consideration		A
4.6	AC supply var., transient	% of nom volt % of nom freq	±20 /dur 1,5 s ±10 /dur 5 s	UC		A

[6]The number is the voltage reduction multiplied by reduction time. The limit is adapted to usual practice but should be considered when the power supply systems on ships are studied.

Table 5. Immunity for power supply ports >48 V.

	Environmental phenomena	Units	Test specification	Test standard	Re-marks	Performance criteria
5.1	Radio frequency common mode. Amplitude modulated	MHz V (unmod) %AM(1 kHz) Source imp, ohm	0,15-80 3 80 150	ENV 50141		A
5.2	Fast transients	kV (peak) Tr/Th ns PRF kHz	2 5/50 5	IEC 801-4		B
5.3	Surge	kV kV Tr/Th µs	2 (line to ground) 1 (line to line) 1,2/50	IEC 1000-4-5 draft		B
5.4	Supply voltage dips	% reduction ms	30,50,95 5,10,20,50,100, osv	under consideration		B for ≤300 %ms C for >300 %ms
5.5	Supply var., continuous	% of nom volt % of nom freq	±10 ±5	under consideration		A
5.6	Supply var., transient	% of nom volt % of nom freq	±20 / dur 1,5 s ±10 / dur 5 s	under consideration		A

Table 6 Emission limits in protected locations

	Port	Frequency range	Limits	Test standard	Remarks
6.1	Enclosure	30-230 MHz 230-1000 MHz	30 dBµV/m at 10 m (QP) 37 dBµV/m at 10 m (QP)	CISPR 22	At 3 m: increase limit by 10 dB
6.2	Power supply AC/DC	0,15-0,5 MHz 0,5-5 MHz 5-30 MHz	66-56 dBµV (QP) 56-46 dBµV (avg) 56 dBµV (QP) 46 dBµV (avg) 60 dBµV (QP) 50 dBµV(avg)	CISPR 22	
6.3	Signal/ control lines	0,15-30 MHz	under consideration	uc	

Table 7 Emission limits in non-protected locations

	Port	Frequency range	Limits	Test standard	Remarks
7.1	Enclosure	30-230 MHz 230-1000 MHz	40 dBm at 10 m (QP)	CISPR 22	At 3 m: increase limit by 10 dB
7.2	Power supply AC/DC	0,15-0,5 MHz 0,5-5 MHz 5-30 MHz	76-66 dBµV (QP) 66-56 dBµV (avg) 66 dBµV (QP) 56 dBµV (avg) 70 dBµV (QP) 60 dBµV(avg)	CISPR 22	
7.3	Signal/ control lines	0;15-30 MHz	uc	uc	