Report

EMC Test (Electromagnetic Emission and Immunity) of a Sample Data System Using Shielded and Unshielded Cabling Systems at 1000BaseT Operation

No.

Report 746 / 01

based on EN 45001 – test report 746 / 01

Customer ID

ZVEKE011

This report comprises 36 pages plus annex.

Table of Contents

1 General Information

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1.2 Test Date

9 January 2001 to 24 January 2001

1.3 Test Site

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1.4 Test Conducted by:

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2 Customers

The test series were conducted at the instigation of the following companies (in alphabetical order), who also covered the cost incurred:

Albert Ackermann GmbH + Co. KG
BTR Blumberger Telefon und Relais Vertriebs GmbH
Corning Cable Systems GmbH & Co.KG
Dätwyler Kabel + Systeme GmbH
Draka Multimedia Cable GmbH
Kerpenwerk GmbH & Co.
LEONI Kabel GmbH & Co. KG
Nexans Deutschland Industries AG & Co. KG
Telegärtner Karl Gärtner GmbH

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3 Subject matter and objective of the tests

The Electromagnetic Compatibility of equipment and systems depends on several factors, which cannot always be discussed separately. The interaction between devices and their cable connections exerts a major influence on a system's EMC behaviour.

The purpose of the tests documented in this report was to investigate the effects of shielded and unshielded cabling systems of the same performance class (link performance class E) on the EMC behaviour of a data system. Accordingly, identical active systems (switch, personal computers with network adapters) and test conditions (workload, hardware and software configuration) were used in both test set-ups.

Despite recent revision, current standards leave some scope in terms of the test set-up for conducting laboratory tests on information technology equipment (ITE). The set-up used for these tests was specified in consultation with all the companies involved in the project, and was designed to include as many influencing factors as possible that are relevant in practice. These considerations were reflected, for example, in the lengths of cable used (10m and 90m), in the cable rack and in the way the active components were connected.

The results obtained in the test and the comments contained in this report relate to the EUT (Equipment Under Test) used and the test set-up described.

To ensure that system performance be assessed as objectively as possible, all passive components were ordered from resellers via third parties. The shielded cabling system was ordered as a mix&match system (cables and components from various manufacturers) according to the customers' specifications, whereas the unshielded cabling system was ordered as a complete system (all components supplied by one manufacturer).

The systems were installed by the GHMT laboratory staff according to the specifications provided by the manufacturer. A conventional field test instrument (Fluke DSP 4000) was used to conduct the standard check for the correct installation of the cabling links (10m and 90m) used in the test set-up prior to starting the EMC test.

In the year 2000, both cabling systems underwent a link performance laboratory test for their adherence to Class E limits and were found to meet these requirements. The results obtained in the measurements are documented in the test reports 615- / 99 A and B.

At the customers' request, this report uses wildcard characters for the manufacturers of the cabling systems and the part numbers in order to avoid any distorted competition between the companies involved in the project. The results listed in the following report refer to the EUT described completely in original test report 746/ 01. In addition, the report includes a more detailed description of the error patterns obtained.

4 Equipment Under Test

Definition of the terms UTP and STP, which are used in the report:
UTP stands for Unshielded Twisted-Pair Cabling (100Ω)
STP stands for Shielded Twisted-Pair Cabling (100Ω)

4.1 Description of EUT (Equipment Under Test)

Information technology equipment (ITE), data system in 1000BaseT client/server operation

System/distributor side (identical for equipment with shielded and unshielded cabling systems):

- 1 x 43U **Schroff proline, LAN closet**, 0.8m x 0.8m x 2.05m with hinged 19″ frame and vertical grounding kit, glazed door

Active systems (identical for equipment with shielded and unshielded cabling systems):

- 1 x **Routing Switch 480T**
  Intel Net Structure
  serial number: 0031M-02874
- 2 x **IBM Netfinity 7000 –** 8651-THO model, high-performance server with
- 2 x **Network- Interface Card Intelpro/1000** Server Adapter (copper)
  serial number: 1B523143013A19845003, serial number: 1B54C043013A19845003
- 2 x **Siemens- Nixdorf** MCM 1404, low-emission colour monitor, CE 95 marking, serial numbers BZ 053787 and BZ 061526

Cabling system of system 1 (shielded):

- STP patch cord (4 x 4.5m) from **supplier A, 600 MHz, FR/LS0H** (please refer to test report 614/99 for the part numbers), 4 twisted pairs, both ends pre-assembled with one RJ45 plug (**supplier A)** and one blanking grommet each.

- 1 x shielded patch panel from **supplier A Cat. 6** (please refer to test report 614/99 for the part numbers), 19" assembly, 1 U, 24 x shielded RJ 45.

- STP installation cable (1 x 90m) from **supplier B** (please refer to test report 614/99 for the part numbers), J-02YS(C)H 4x2x23/1AWG PimF, zero-halogen, installed on patch panel and telecommunications outlet according to TIA/EIA 568-A, version B, and terminated on installation simulation rack as proposed by CENELEC TC46X WG3.

- STP installation cable (1 x 10m) from **supplier B** (please refer to test report 614/99 for the part numbers), J-02YS(C)H 4x2x23/1AWG PimF, zero-halogen, installed on patch panel and telecommunications outlet according to TIA/EIA 568-A, version B, and terminated on installation simulation rack as proposed by CENELEC TC46X WG3.

- 2 x telecommunications outlets from **supplier C** (please refer to test report 614/99 for the part numbers), 2 x RJ45 each.

Cabling system of system 2 (unshielded):

- UTP patch cord (4 x 4.5m) from **supplier D Cat. 6** (please refer to test report 614/99 for type & Comcode), 4 twisted pairs, both ends pre-assembled with one RJ45 plug each.

- 1 x unshielded patch panel from **supplier D Cat. 6** (please refer to test report 614/99 for type & Comcode)**,** 24 x RJ 45 according to TIA/-EIA 568-A, version B.

- Unshielded installation cable (1 x 90m) from **supplier D Cat. 6** (please refer to test report 614/99 for type & Comcode), 4 twisted pairs, zero-halogen, installed on patch panel and telecommunications outlet according to TIA/EIA 568-A, version B, and terminated on installation simulation rack as proposed by CENELEC TC46X WG3.

- Unshielded installation cable (1 x 10m) from **supplier D Cat. 6** (please refer to test report 614/99 for type & Comcode), 4 twisted pairs, zero-halogen, installed on patch panel and telecommunications outlet according to TIA/EIA 568-A, version B, and terminated on installation simulation rack as proposed by CENELEC TC46X WG3.

- 2 x telecommunications outlets from **supplier D Cat. 6** (please refer to test report 614/99 for type & Comcode), 1 x RJ45 each for mounting outlets in **single surface-mount outlets** (please refer to test report 614/99 for type & Comcode).

4.2 Arrival of EUT

Active components: calendar week 51/00
Passive components: calendar weeks 01/01 as well as 40/99 and 45/99.
All passive components were ordered from resellers via third parties.

4.3 Condition of EUT at the Time of Test

The individual components described under 4.1 were combined to form a (sample) data system. The switch and the relevant patch panel were installed in the data closet. The rear connection of the shielded patch panel to earth was linked to the vertical grounding kit within the closet. The pin assignment of the RJ 45 installation was based on TIA/EIA568-A version B.

4.3.1 Basic Configuration of the Data System

Both servers were equipped with the Windows2000 operating system and connected to each other via a Gigabit Ethernet 1000 BaseT IEEE802.3ab.

4.3.2 Integration of the Protocol Analyser in the Test Set-Up

The sample data system was linked to the IntelNetStructure 480T RoutingSwitch by means of a fibre optic connection, which ensured that for the entire measurement duration any interference in the sample data system was prevented from affecting the test set-up and distorting the test results.

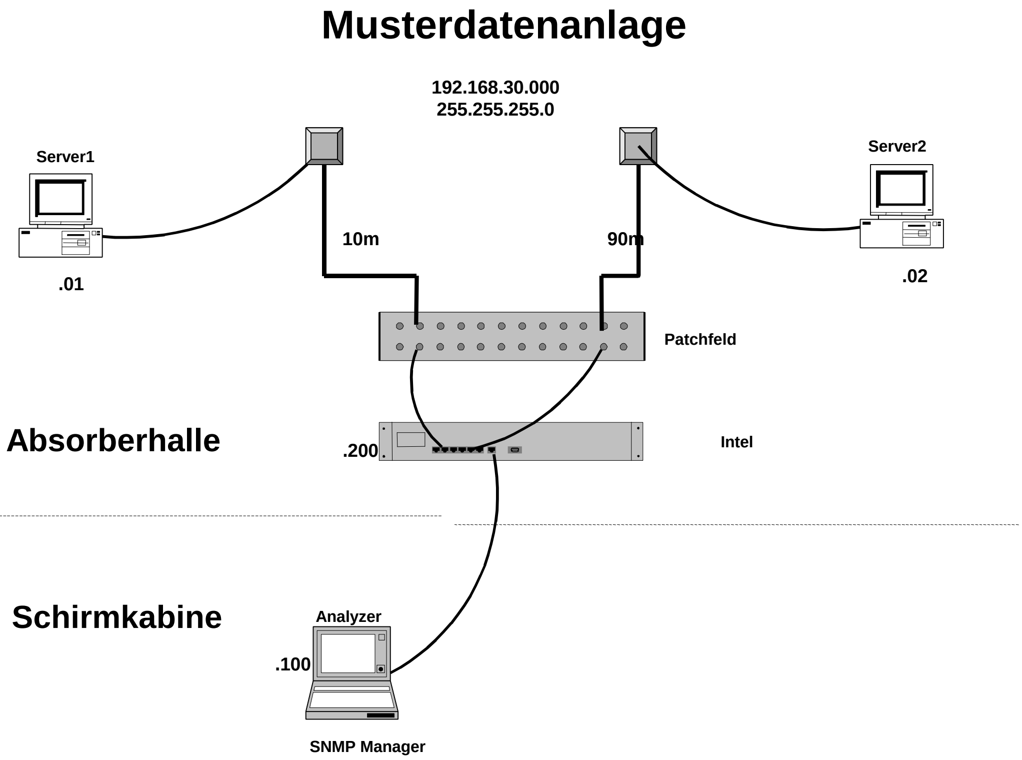


Figure 1: System configuration diagram

Grafikbeschriftung: Musterdatenanlage = sample data system / Server1 = server1/ Server2= server2/ Patchfeld = patch panel / Absorberhalle = absorber-lined chamber / Schirmkabine = shield cubicle / Analyzer = Analyser / SNMP Manager = SNMP Manager

The parameters described in the following section were evaluated with the Triticom LAN Decoder SNMP Manager. It permits a readout of the RMON-MIB of the Intel switch by means of the SNMP protocol. Since the dwell time per application frequency was three seconds during the interference measurements, the values were read out every second and then processed graphically. It was thus possible to allocate detected error conditions to specific frequencies. The parameter readout will be described in greater detail in the next chapter.

4.3.3 Ethernet Frame Format

For a better understanding of the measuring data analysis, this section briefly describes the Ethernet frame format:

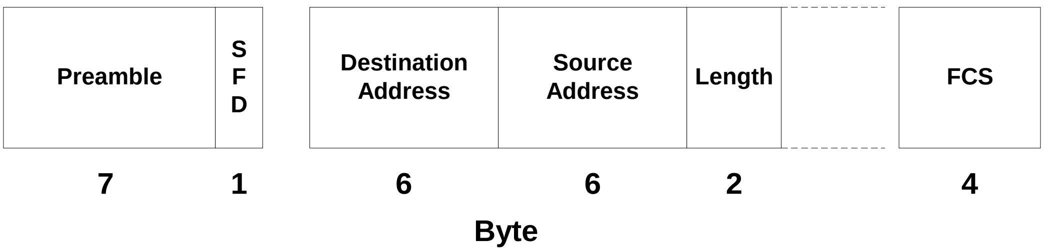


Figure 2: Ethernet frame format according to IEEE 802.3

Preamble	The preamble is required for the synchronisation of the receiver. Each packet is preceded by a 7-Byte sequence of 10101010 combinations.
SFD	The Start Frame Delimiter serves as a signal indicating the beginning of the frame to the receiver. It is transmitted upon completion of the preamble and contains the bit combination 10101011.
Destination Address	6-Byte destination address
Source Address	6-Byte source address
Length	2-Byte length field
FCS	The Frame Check Sequence is a 4-Byte character (CRC 32, 32 bit long Cyclic Redundancy Check) which is appended to the frame. The check is carried out in bit mode. Incomplete bytes (alignment error) therefore do not necessarily have to include an FCS error.

According to the RMON MIB definition (RFC 1757), Ethernet frames are classified as *good packets* or *bad packets*:

Good Packets:
Good packets are error-free packets of a valid frame length (between 64 and 1,518 bytes). This corresponds to the definition laid down in IEEE 802.3.

Bad Packets:
Bad packets show a correct framing (preamble + SFD) but include errors such as invalid length or FCS errors.

4.3.4 Ethernet Parameters

The following parameters form part of the RMON-MIB of the Intel switch, which was used to analyse the measuring results:

- Ethernet Octets
- Ethernet Packets
- Drop Events
- CRC/Alignment Error
- Undersize
- Oversize
- Fragments
- Jabbers
- Collisions

Ethernet Octets Total number of bytes (including those in faulty packets) received per port (excluding preamble/SFD but including FCS bytes).

Ethernet Packets Total number of packets received per port (including broadcasts, multicasts and faulty packets).

Drop Events Total number of events in which the switch drops packets due to a lack of resources. This figure is not equivalent to the number of lost packets. It is merely a measure of the number of events in which the disposal of packets was recognised.

CRC/Alignment Total number of packets found to have a length between 64 and 1,518 bytes and a CRC/alignment error (including FCS bytes). The figure also includes packets with either a faulty FCS and a multiple of 8 bits (FCS error) or with a poor FCS and no multiple of 8 bits (alignment error).

UnderSize Total number of packets found to fall short of a length of 64 bytes (including FCS bytes) but which otherwise do not include any errors.

OverSize Total number of packets found to exceed a length of 1,518 bytes (including FCS bytes) but which otherwise do not include any errors.

Fragment Total number of faulty packets which have a length of under 64 bytes (including FCS bytes). The figure also includes packets with either a faulty FCS and a multiple of 8 bits (FCS error) or with a poor FCS and no multiple of 8 bits (alignment error).

Jabber Total number of faulty packets which exceed a length of 1,518 bytes (including FCS bytes). The figure also includes packets with either a faulty FCS and a multiple of 8 bits (FCS error) or with a poor FCS and no multiple of 8 bits (alignment error).

Collisions The best possible estimate of the number of collisions per port.

4.3.5 Analysis of the Measuring Results

Port 1 (10 m link) and Port 2 (90 m link) were used for data transmission during all measurements. The following figure shows a record of the characteristic data measured. The LAN Decoder provided the evaluation of the Ethernet parameters initially in the form of a table by way of reading out the Ethernet statistics table in the switch. The values shown were updated every second. To ensure a clear overview during the monitoring procedure, the parameters Octets (bytes), CRC/Alignment Errors, and Jabber were depicted graphically:

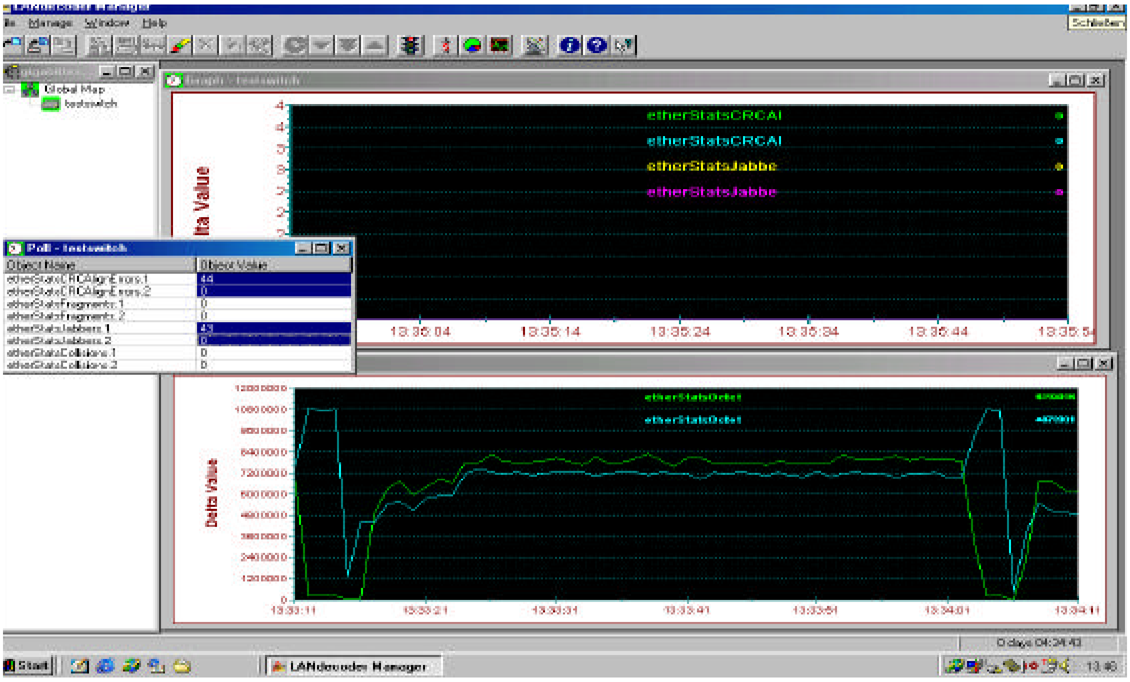


Figure 3: Bytes per second during data transmission in normal condition

Undisturbed data transmission was in the range of approximately 7,200,000 bytes per second. The peak values that occurred at a regular interval of roughly 50 seconds were caused by the type of load generation. A file sized c. 330Mbytes was copied from server1 to server2 and vice versa, which was controlled by a batch file. In addition, the two switch ports (ports 1 and 2) were constantly monitored so as to permit immediate detection of any deviation from normal conditions (identical values resulted in a superimposition of the graphs). The measuring parameter used for identifying a drop in utilisation was the number of bytes transmitted per second. The number of bytes transmitted per second and utilisation are directly proportional, which explains why it is possible to identify a drop in utilisation on the basis of a drop in the number of bytes per second. This becomes clear from the following figure:

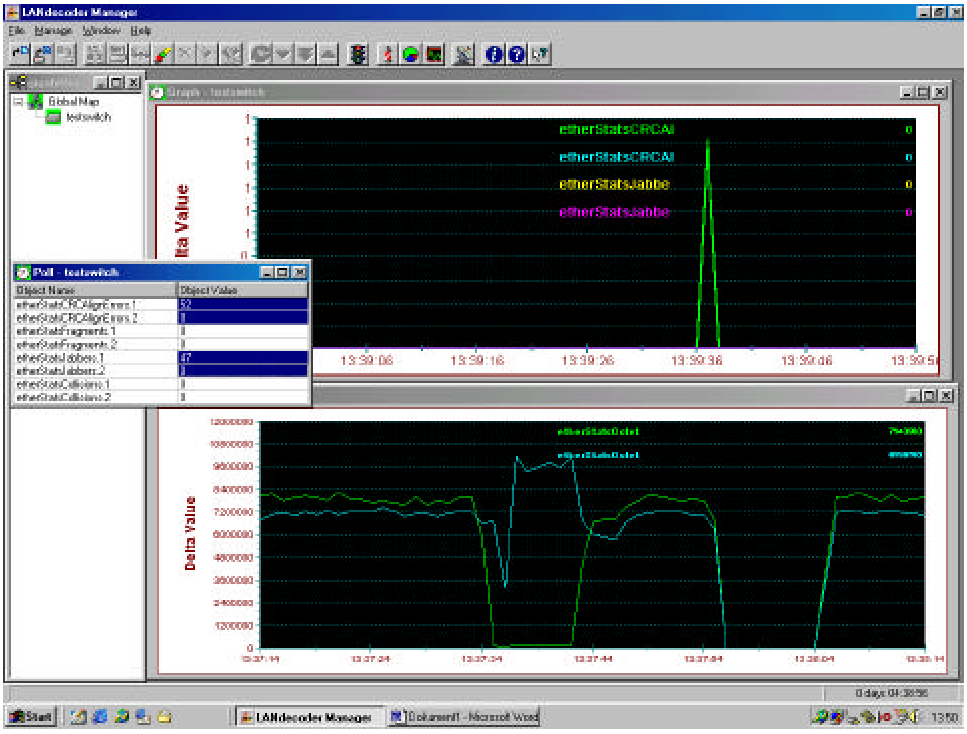


Figure 4: Drop in the number of bytes per second due to an application failure, self-healing

It is an inherent feature of full-duplex transmission that collisions do not occur. It will only be possible to detect the simultaneous occurrence of a CRC/alignment error and a drop in utilisation if a faulty packet initially shows a valid framing (see definition of good/bad packets) so that a bit error may be recognised within the packet. In the case of interference that has a stronger impact on the transmission, the switch is no longer able to identify the framing and thus the entire packet. This led to a rapid decrease in utilisation without further Ethernet errors occurring.

5 Test

5.1 Test Type

Electromagnetic compatibility test.

5.2 Rules and Regulations

5.2.1 Rules and Regulations Applied

Electromagnetic emission:
DIN EN 55022 (VDE 0878 part 22): 1998-04: limit class B

EN 61000-3-2 (VDE 0838 part 2): 1998-10
Electromagnetic compatibility (EMC) part 3-2: Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)

EN 61000-3-3 (VDE 0838 part 3): 1996-03
Electromagnetic compatibility (EMC) part 3-3: Limitation of voltage fluctuation and flicker in low-voltage supply systems for equipment with rated current of 16 A

Additional Tests:
DIN VDE 0878 part 1: 1986-12: limit according to communication of 01/99
in the Official Journal No. 1, 1999

Electromagnetic immunity:
DIN EN 50082-2 (VDE 0839 part 82-2):1996-02
DIN EN 55024 with more stringent requirements according to DIN EN 50082-2
(Immunity standard: Industrial environment)

DIN VDE 0847 part 4-2:1996-03	(EN 61000-4-2:1995)
DIN VDE 0847 part 4-3:1997-08	(EN 61000-4-3:1996)
DIN VDE 0847 part 4-4:1996-03	(EN 61000-4-4:1995)
DIN VDE 0847 part 4-5:1996-09	(EN 61000-4-5:1995)
DIN VDE 0847 part 4-6:1997-04	(EN 61000-4-6:1996)
Additional Tests:	
DIN VDE 0847 part 4-8:1997-04	(EN 61000-4-8:1996)
DIN VDE 0847 part 4-9:1997-04	(EN 61000-4-9:1996)

5.2.2 Deviations from Standardised Test Procedures

5.2.2.1 Electromagnetic Emission

In addition to the requirements specified in EN 55022, the (magnetic) radio noise field strength was examined in the frequency ranges from 9 kHz to 30 MHz and from 1 GHz to 2 GHz.

(Magnetic) Radio Noise Field Strength in the Range from 9 kHz to 30 MHz:
Procedure according to DIN VDE 0878 part 1: 1986-12, however, with limit based on communication 01/99 in the Official Journal No. 1, 1999, for the protection of primarily allocated radio communication services (utilisation provision No. 30)

Radio Noise Strength in the Range from 1 to 2 GHz:
Procedure according to DIN EN 55022, however, extension of the measuring frequency range up to 2GHz. Limit derived from DIN VDE 0875, part 11:1992-07, table 6 "Grenzwerte für die Funkstörstrahlung zum Schutz besonderer Sicherheits-Funkdienste in bestimmten Gebieten"[1] (47 dBµV/m in 3 m up to 2 GHz instead of up to 1.215 GHz)

5.2.2.2 Electromagnetic Immunity

Besides the requirements specified in EN 50082-2, additional parameters were checked. Besides the requirements specified in EN 55024, additional parameters were checked and more stringent test severity levels were applied. Test criterion A was applied to all parameters.

Power Frequency Magnetic Field Immunity Test at 50 Hz:
Instead of applying power-frequency magnetic fields as described in EN 61000-4-8, interference current was supplied to the shield of the data transmission cabling used. The disturbance is generated by means of a variable-voltage isolating transformer with a current-limiting protective resistor. The output terminals of this interference unit were connected on the one hand to the earth tag of the patch panel and on the other hand to the shield of the installation cable to be tested, in the proximity of the telecommunications outlet. The corresponding data terminal was supplied with current by means of an isolating transformer in order to avoid parasitic currents via the mains leads (PE) of the active components. A clamp-on probe was used for determining the r. m. s. value of the 50 Hz parasitic current supplied.

Pulse Magnetic Fields:
The EUT is surrounded by a single-turn coil which apart from its inductive resistance constitutes a generator short circuit. EN 61000-4-9 specifies coil sizes of 1 m x 1 m and 1 m x 2.6 m. The field-generating coils described were replaced by a coil of size 2.5 x 2.5 m in order to embrace the overall set-up. The conductor forming the single-turn coil was accommodated in a pivoted plastic tube attached to the cable rack.

5.2.3 Non-standardised Test Procedures

None.

[1] *Limits of radio disturbance for the protection of special security radio communication services in specific environments*

5.3 Characteristic Values and Test Severity Levels

Electromagnetic Emission:
DIN EN 55022: limit class B (VDE 0878 part 22, 05/1995)
DIN VDE 0878 part 1: 1986-12: limit according to communication of 01/99
in the Official Journal No. 1 of the year 1999
EN 61000-3-2 (VDE 0838 Teil 2): 1998-10
EN 61000-3-3 (VDE 0838 Teil 3): 1996-02

Parameter	**Test severity level**	**Frequency**	**Measuring point**
Radio noise voltage	Quasi peak, class B 66 to 56 dBµV, linear decr. log f 56 dBµV 60 dBµV	 0.15 – 0.5 MHz 0.5 – 5 MHz 5 – 30 MHz	Mains lead of all active components
Radio noise field strength	Quasi peak 3m, class B 40 dBµV/m 47 dBµV/m 47 dBµV/m	 30- 230 MHz 230 – 1,000 MHz (1,000-2,000) MH	Overall system
Flicker	Limits Short-term flicker Pst = 1 Long-term flicker Plt = 0.65		Mains lead of all active components

Harmonics	Limits for equipment class A Order n	Max. current in A	Mains lead of all active components
	2	1.08	
	3	2.30	
	4	0.43	
	5	1.14	
	6	0.30	
	7	0.77	
	9	0.40	
	11	0.33	
	13	0.21	
	uneven 15-39	0.15*15/n	
	even 8-40	0.23*8/n	
Additional tests			
(Magnetic) radio noise field strength	Peak 3m, RegTP 1/99 40- 20 log (f/MHz) dBµV/m 40- 8.8 log (f/MHz) dBµV/m	 0.009 – 1 MHz 1 – 30 MHz	Overall system

Electromagnetic Immunity:
DIN EN 50082-2 (VDE 0839 part 82-2):1996-02 with additional tests
DIN EN 55024 with more stringent requirements according to DIN EN 50082-2
(Immunity standard: Industrial environment)

Parameter	**Test Severity Level**	**Characteristic value**	**Coupling point**	**Standard**
Electrostatic discharge (ESD)	Contact: 4 kV Air: 8 kV Coupling 4 kV	t_r = 0.7- 1 ns	Any tangible metallic parts in the case of "contact discharge"; any insulated "air", system vertical or horizontal coupling plane	EN 61000-4-2:1995
Radiated, radio-frequency, electromagnetic field immunity	10 V/m	80-1,000 MHz, AM: 80% AF: 1 kHz 900 ±5 MHz, PM: 50% duty cycle AF : 200 Hz	application to the entire system	EN 61000-4-3:1996
Electrical fast transient/ burst immunity	data t. c.: 1 kV mains l.: 2 kV	5/50 ns, 5 kHz	Data transmission cables in the vicinity telecommunications outlets and panels; mains lead of all active components	EN 61000-4-4:1995
Surge immunity	2/4 kV	1.2/50 µs	mains lead of all active components	EN 61000-4-5:1995
Conducted disturbance induced by radio frequency fields immunity	e.m.f. 10 V	0.15-80 MHz AM: 80 % AF: 1 kHz	Data transmission cables in the vicinity telecommunications outlets and panels; mains lead of all active components	EN 61000-4-6:1996
Additional tests				
Compensating currents Power frequency magnetic field immunity	$I_{eff.}$ = 1 A	50 Hz	Data transmission cables (only possible with shielded system)	adapted from EN 61000-4-8:1996
Pulse magnetic fields	up to 300 A/m	rise time 10 µs	overall system	adapted from EN 61000-4-9:1996

5.4 Description of the Measuring Parameters

5.4.1 Electromagnetic Emission

The limitation of the electromagnetic emission values serves primarily to protect radio communication services, such as the reception of TV broadcasts, police radio or aeronautical radio service, etc.
The choice of method will depend on the frequency range and on the properties of the EUT. Various measuring methods are used for assessing electromagnetic emission. These methods will be described briefly in the following section.

Radio noise voltage, mains terminals, 0.15 MHz-30 MHz
Limit class B

For data systems, radio noise voltage is measured on the mains lead of the active components. What is generally referred to as V-AMN (Artificial Mains Networks) are used for measuring the radio noise voltage. These artificial mains networks define a specific network impedance in the test set-up, protect the network against disturbance, since these must not be included in the measurements, and also shut off the line voltage from the measuring receiver input.

Apart from the quasi peak value, an average limiting value that is lower by 10 to 13 dB is specified for the radio noise voltage values which are to be determined in the frequency range between 150 kHz and 30 MHz. Both limits have to be adhered to.
The distinction between limit class A and limit class B (more stringent) corresponds to the distinction between industrial environments and residential environments.
The measuring results are thus largely independent of the EMC quality of the data transmission cable connections.

Radio noise field strength at a measuring distance of 3 m, 30 – 1,000 (2,000) MHz
Limit class B

The electrical component of the radio noise field strength is measured by means of plane-polarised antennae. This requires measuring runs with horizontal and vertical polarisation. The entire sample system is mounted on a turntable since with the antenna being stationary, the system's emissions will have to measured from various positions. The measuring distance between antenna and EUT is 3 m.
In order to take the new mobile communications services (DECT and GSM) into account, the standard frequency range currently specified in the EN 55022 standard was extended in the test to include frequencies up to 2,000 MHz.
The distinction between limit class A and limit class B (more stringent) corresponds to the distinction between industrial environments and residential environments.
The strength of the field radiated is affected by the EMC quality of the data transmission cable connections and by the active components in the measuring room.

Harmonic current emissions according to IEC 61000-3-2 Class A

Harmonic current emissions are caused by the non-linear input current consumption of active components. Limits applicable to the harmonic components of the input current have been specified in order to avoid interference with or even the destruction of other equipment and cabling. Active components (equipment) have to adhere to these limits.
Harmonic current emissions are generated by power supplies and do not depend on the data transmission cable connections.

Flicker according to IEC 61000-3-3

Flicker is described as voltage fluctuations caused by equipment connected to the mains networks. The human eye detects flicker due to the luminance fluctuations of lamps (luminance flicker). Under normal operating conditions, the severity of flicker caused by voltage fluctuations should not exceed the value of P = 1 during 95% of any period of time.
Reactions to flicker are subjective and may vary greatly depending on the cause and duration of flicker. In some cases, P = 1 may already be regarded as annoying whereas in other cases higher P values are not perceived as disturbing.
Flicker emissions represent a disturbance introduced by active components in the mains. This disturbance is independent of the EMC quality of the data transmission cable connections.

(Magnetic) radio noise field strength at a measuring distance of 3 m, 9 kHz – 30 MHz Limit: RegTP[2] recommendation from 1/99

Hitherto, matters have been simplified by assuming that radiated emission from housings and wiring is negligible below 30 MHz and that only conducted disturbance (radio noise voltage), as dominant variable, need be tested.
Current disturbance reports from aeronautical radio and amateur radio services, however, contradict this definition and clearly show the necessity of defining radio noise voltage limits from 9 kHz to 30 MHz. The ever-increasing use of ADSL, XDSL and LAN networks has thus prompted a renewed discussion about the limits of measuring parameters for magnetic field strength (9 kHz – 30 MHz). National and international standardisation bodies are now striving to define field strength limits even below 30 MHz. In January 1999, the German regulatory authority RegTP introduced a stringent limit into the discussion in order to ensure coverage of the long, medium and short wave ranges.
The strength of the field radiated is affected by the EMC quality of the data transmission cable connections and by the active components in the measuring room.

[2] German regulatory authority responsible for telecommunications and mail services

5.4.2 Electromagnetic Immunity

The immunity tests currently prescribed by the generic standards applicable to residential and industrial environments are described in the generic standards IEC 1000-4-x and EN 61000-4-x. The electromagnetic immunity of the sample system in a representative operating condition is tested by way of simulating disturbances characteristic of the individual environment. The system's working order is monitored through appropriate measuring instruments (in this case a protocol analyser). The minimum operating quality was specified by the customers in the run-up to the test. Due to the stringent availability requirements laid down by the network operators in most applications (fail-safe mode, error-free system operation under any conditions if possible), the test criterion chosen for all test parameters was "A". This means that no impairment of the utilisation will be tolerated during the exposure stage. The occurrence of individual CRC errors was only permitted if there was no reproducibility at a specific frequency, and if no concomitant decrease in utilisation was detected.

As test severity level, the more stringent requirements to be met by industrial environments were chosen, since a large number of disturbing phenomena exceed the less stringent residential and commercial requirements (for instance 2W GSM mobile phones)

For every phenomenon to be simulated, there is a corresponding generic standard.

Electrostatic discharge
Test severity level: contact discharge 4 kV, air discharge 8 kV, coupling plane 4 kV
Test criterion: A

The growing use of electrostatically sensitive semiconductor devices increases the importance of protection against transient currents and fields generated during electrostatic discharge. This development was taken into consideration in test specification EN 61000-4-2.
As regards the selection of test points, all those parts of the EUT will qualify that are accessible to the service staff in the usual handling of the device, including maintenance. At least 10 pulses per polarity must be applied to every point, with the minimum time between two subsequent pulses not falling below one second.
Immunity to this phenomenon is affected by the EMC quality of the data transmission cable connections and by the active components, which are likewise exposed to electrostatic discharge.

Radiated, radio frequency, electromagnetic field immunity, 80- 1000 MHz
Test severity level: 10 V/m
Test criterion: A

The sample system was positioned in front of the field-generating antenna in the absorber-lined chamber (ALC). The test signals used are sinusoidal carrier signals in the frequency range from 80 MHz to 1 GHz, which are amplitude-modulated with a low-

frequency sinusoidal voltage (80% swing) (see section EN 61000-4-6). In addition mobile radio communications is simulated by means of pulse modulation at 900 MHz.
Earlier specifications (IEC 801-3) merely prescribed examination of the frequency range from 26 to 500 MHz, without amplitude modulation. This standard is listed in a generic standard on electromagnetic immunity in the residential environment, etc. The latter standard has been revised but will continue to be valid until the middle of 2001 (EN 50081-2:1992). However, since it has been found that the AM test puts more stringent requirements on the EUT, qualification according to the outdated standard will be dispensed with.
Based on the finding that most electronic equipment is affected by electromagnetic fields, potential sources of interference also include hand-held walkie-talkies, stationary radio or TV stations or even industrial RF sources. In addition, tests are carried out at around 900 MHz (D network) for frequencies that are typical of mobile radio communications.
Immunity to this phenomenon is affected by the EMC quality of the data transmission cable connections and by the active components, which are likewise exposed to electromagnetic radiation.

Exposure to fast transient currents (burst)
Test severity level: data transmission cables 1 kV, mains leads 2 kV
Test criterion: A

If the switch in a circuit that contains inductive loads (relay, contactor, fluorescent lamps) is opened, the entire voltage induced in the coil by means of the fast change in the current and thus in the flux acts across the switch contacts and ignites the relatively small air gap. As the flow of current resumes, the voltage across the switch contacts decreases, and the spark is extinguished. This process is repeated several times and gives rise to pulse packets which represent a potential disturbance due to their high-frequency components (up to several hundred MHz) and their high voltages (up to several kV). This phenomenon, which is generally known as burst, is simulated in the laboratory with what is usually referred to as a burst generator. The procedure is described in EN 61000-4-4.
The individual pulse was defined as a 5/50 ns pulse voltage, with the pulse packets being generated at a repetition rate of 5 kHz.
As far as mains leads are concerned, the disturbance is introduced by means of a coupling/decoupling network with a maximum of seven coupling variants (L, N, PE, L+PE, N+PE, L+N, L+N+PE). Mains leads which run parallel to the data transmission cables and which are subject to such burst potentials are simulated by way of placing the data transmission cable in a capacitive clamp-on coupling, to which the generator feeds its pulse packets.
Immunity to this phenomenon is affected by the EMC quality of the data transmission cable connections and by the active components, which are likewise subjected to transient currents.

Exposure to surges
Test severity level: mains leads 2/4 kV
Test criterion: A

Atmospheric discharges and even the actuation of switches in the power supply system generate high-energy overvoltages of various wave shapes. These can cause interference in electrical devices or, in the worst of cases, even destroy electrical devices. Since not all types of overvoltage encountered in practice can be used when testing immunity to surge pulses, the authors of the EN 61000-4-5 standard agreed on the use of the lightning impulse wave shape of 1.2/50 µs. The laboratory simulation uses a combination-wave generator.

Coupling into mains conductors is effected in a capacitive manner in order to decouple the generator output from the mains voltage. The power supply network is kept free from test pulses by means of additional series inductors in the coupling/decoupling network. Surges were not applied to fast data transmission cables since coupling networks of this type have a strong impact on the transmission properties of such cables. For the aforementioned reasons, immunity with this type of test does not depend on the EMC quality of the data transmission cable connections. However, the pulse magnetic field immunity test (EN 61000-4-9) takes this condition into account, since here the entire system is subjected to surges.

Introduction of conducted RF disturbance
Test severity level: data transmission cables e.m.f. = 10 V, mains leads e.m.f. = 10 V
Test criterion: A

One assumes that the RF energy radiation in the lower frequency range is mainly absorbed by means of the EUT wiring connections. For this reason, radiation below 80 MHz is forgone and the interference signal is fed directly into the mains conductor and the data transmission cable connections of the EUT via coupling-decoupling networks or clamp-on probes. The main sources of interference in this frequency range include radio and TV stations, walkie-talkies and ISM devices.

The test signal consists of a sinusoidal RF signal (f = 0.15 - 80 MHz; amplitude modulation: 80% in depth by a 1 kHz signal) at the test. The listed e. m. f. value of 10 V is the no-load r.m.s. value of the amplifier output voltage. This is applied to the clamp-on input device in which the data transmission cable is placed, so that the cable is directly subjected to the disturbance.

Immunity to phenomenon is affected by the EMC quality of the data transmission cable connections and by the active components, which are likewise subjected to the disturbance.

Power frequency magnetic field
Test severity level: 1A on shielded data transmission cables
Test criterion: A

Instead of applying power-frequency magnetic fields as described in EN 61000-4-8, interference current was supplied to the shield of the data transmission cabling used. This simulates the shield currents generated locally in installations whenever the magnetic fields of utility installations (for example transformers, primary distributors, conductor-rail systems) permeate installation loops formed by shielded data cabling in conjunction with the mains leads. The test also simulates equipotential currents between two points connected by the cable shield.

The disturbance is generated by means of a variable-voltage isolating transformer with a current-limiting protective resistor. The output terminals of this interference unit were connected on the one hand to the earth tag of the patch panel and on the other hand to the shield of the installation cable to be tested, in the proximity of the telecommunications outlet. The corresponding data terminal was supplied with current by means of an isolating transformer in order to avoid parasitic currents via the mains leads (PE) of the active components. A clamp-on probe was used for determining the r. m. s. value of the 50 Hz parasitic current supplied.

Immunity to phenomenon is affected by the EMC quality of the data transmission cable connections and by the active components, which are likewise subjected to the disturbance.

Pulsed magnetic fields
Test severity level: 300 A/m
Test criterion: A

The test simulates interference encountered in medium-voltage and high-voltage switchplants. However, the findings obtained in this test are also of great importance when it comes to planning a lightning protection zone. To ascertain the required efficiency of the room shields to be employed, one has to know the immunity of the devices to be used in the individual lightning protection zones against the transient fields of the lightning channel and of the current-carrying components of the external lightning protection.
The EUT is surrounded by a single-turn coil which apart from its inductive resistance constitutes a generator short circuit. The standard specifies coil sizes of 1 m x 1 m and 1 m x 2.6 m. To test a minimum but representative set-up, e. g. a data system, larger coils of a suitable size will be required.
The field-generating coils described in EN 61000-4-9 were replaced by a coil of size 2.5 x 2.5 m in order to embrace the overall set-up. The conductor forming the single-turn coil was accommodated in a pivoted plastic tube attached to the cable rack. This facilitates the generation of horizontally and vertically aligned magnetic fields. The coil is fed by a combination-wave generator supplying a current of 8/20 µs with positive and negative amplitudes. The current or magnetic field pulse of 8/20 µs serves to simulate the rising edge of the initial lightning pulse, which has a wave shape of 10/350 µs (f_{max} = 25 kHz).
Immunity to phenomenon is affected by the EMC quality of the data transmission cable connections and by the active components, which are likewise subjected to the interference.

6 Test Equipment

Device	Description	Manufacturer	Technical data
Measuring room	BIC	Lindgren Rayproof	14 m x 12.20 m x 7.50 m
Shield cubicle	BIC	Lindgren Rayproof	7.10 m x 3.40 m x 2.45 m
Turntable	DS425	Ing.-Büro H. Deisel	∅ 2.5 m
Turntable controller	HD100	Ing.-Büro H. Deisel	
Antenna mast	2071-2	EMCO	6 m
Mast controller	2090	EMCO	
Ground absorber	CRAM SFC 24	Cuming Corp.	
Magnetic field antenna	6502	EMCO	0.9 MHz ...30 MHz
Log.-period. antenna	3146	EMCO	200 MHz ...1 GHz, max. 1 kW
Bilog.-period. antenna	VULB 9168	Schwarzbeck	20 MHz ...2 GHz, 10 W
Bilog.-period. antenna	VULB 9167	Schwarzbeck	30 MHz ... 2 GHz, 500 W
Biconic antenna	3110	EMCO	30 MHz ... 300 MHz
Prism antenna	VHBC 9133	Schwarzbeck	25 MHz ... 200 MHz, 1 kW
Amplifier	BSA0122-100	Bonn	9 kHz ... 220 MHz 100 W CW
Amplifier	BLWA0810-500	Bonn	80 MHz ... 1 GHz 500 W CW
Signal generator	SMY 01	Rohde&Schwarz	10 kHz ... 1 GHz
Signal generator	SMY 02	Rohde&Schwarz	10 kHz ... 2 GHz
Signal generator	SMGL-B4	Rohde&Schwarz	10 kHz ... 1 GHz
ESD generator	ESD 30	EM-Test	16 kV
Ultra compact test system	UCS 500	EM-Test	Burst / Surge / Powerfail
Burst generator	EFT 500	EM-Test	4,4 kV
Surge generator	VCS 500	EM-Test	4kV
Coupling network	CNI 503	EM-Test	3 x 32 A r.m.s. / 400 V
DC power supply	PS-2403D	Conrad Electronic	0 ... 40 V, 0,01 ... 3 A
AC power sources	5001i-400-4725	California Instruments	3 pcs 18,5 A max each
Three-phase precision power meter	LMG310	ZES Zimmer Electronic Systems	f = 0.1 Hz ... 1 MHz I = 3 mA ... 30 A, U = 1 ... 1,000 V
Reference impedance	NI2415	ZES Zimmer Electronic Systems	3-phase
Power meter	NRVD	Rohde&Schwarz	
Field strength meter	HI4400	Holaday	10 kHz ... 1 GHz, max. 300 V/m
RF probe	ESH2-Z3	Rohde&Schwarz	
Spectrum analyser/ measuring receiver	ESMI	Rohde&Schwarz	20 Hz ... 26,5 GHz
Measuring receiver	ESHS	Rohde&Schwarz	9 kHz ... 30 MHz
Spectrum analyser	HP8594	Hewlett Packard	9 kHz ... 1.8 GHz
Oscilloscope	9370 M	LeCroy	Analog bandwidth 600 MHz
Nearfield probe		Hewlett Packard	10 kHz ... 1 GHz
Precision dipole	VHAP	Schwarzbeck	30 MHz ... 300 MHz
Precision dipole	UHAP	Schwarzbeck	300 MHz ... 1 GHz
Calibration system for the definition of measuring chamber factors	RefRad	Forschungszentrum Seibersdorf	30 MHz ... 1 GHz
Capacitive Coupling Clamp	HFK	EM-Test	
Artificial mains network	NSLK8128	Schwarzbeck	3 x 32 A
Artificial mains network	NNBM8125	Schwarzbeck	50 A, 0 Hz ... 400 Hz
Artificial mains network	NTFM8135	Schwarzbeck	T-network
Coupling-decoupling network	CDN (M2, M3,S2,AF3)		
Absorbing clamp	MDS21	Lüthi	**30.... 1000 MHz**
Injection clamp	EM101	Lüthi	0,15....1000 MHz
Current clamp	EZ 17	Rohde&Schwarz	20 Hz ... 100 MHz
Camera system	ACL 155	Pontis	
Ethernet analyser	LAN Decoder SNMP Manager	Triticom	10/100 Mbit/s Ethernet

Table 1: Test equipment

7 Test Set-ups

7.1 Overall Set-up

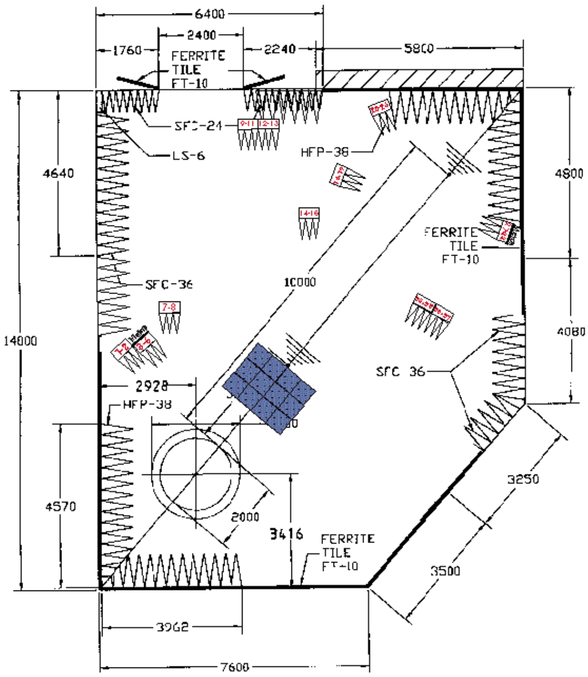


Figure 5: Overview of 10m measuring chamber used for conducting immunity tests according to EN 61000-4-3

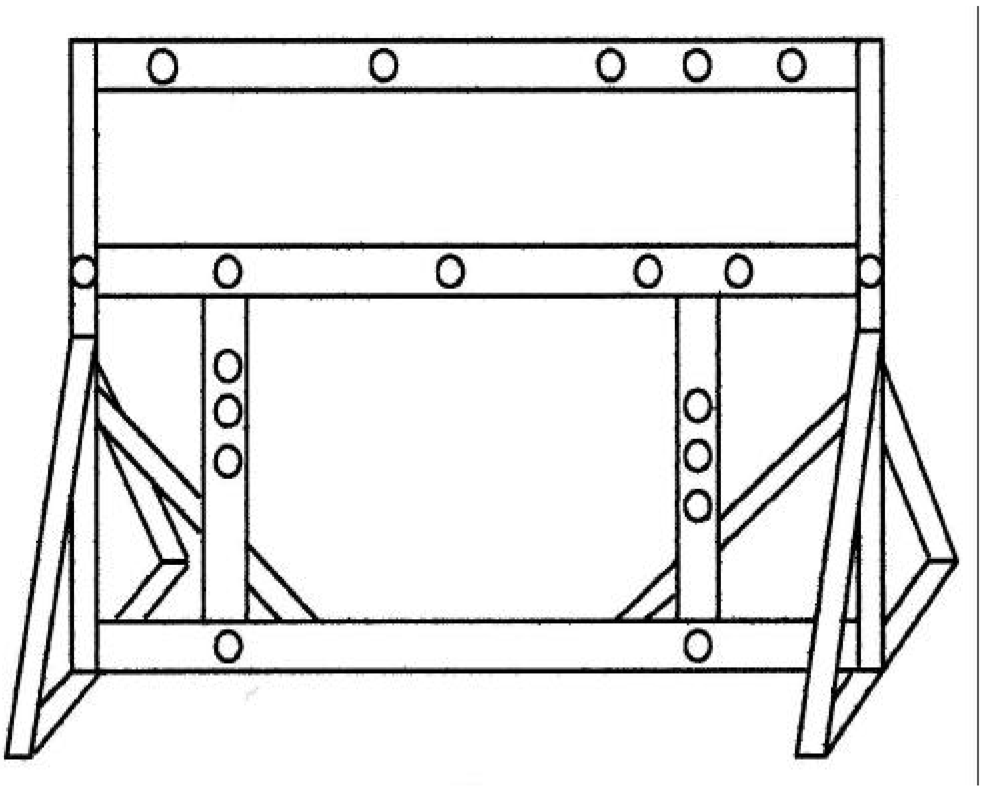


Figure 6: Cable rack

Before the measurement series was started, the installation cables were arranged on a cable rack as proposed by CENELEC TC 46X WG3 (see documentation photos) in order to achieve a high degree of reproducibility. The unshielded and the shielded cabling systems were each arranged on a separate rack. A 10 m link and a 90 m link were installed for each cabling system in order to simulate the critical cases encountered in practice. Both devices are identical in terms of their mechanical structure and the material used.

System configurations 1 (shielded) and 2 (unshielded) were tested one after the other. There was thus only one cabling system with 10 m and 90 m installation cable links in the test room during a test.

As soon as the test series for the unshielded system were completed, the cable rack was removed from the test room and replaced by the device that carried the shielded system. The same active systems (switch, servers and network adapters) were used in both test series, so that here, too, both cabling systems were tested under the same conditions.

All data system components underwent the tests on a turntable (d = 2,5m), which was situated in the absorber-lined chamber. The data closet was placed in the centre of the turntable. The upper half of the hinged 19" frame contained the switch and the patch panel used in each case. The switch and the patch panel were connected to each other by means of the appropriate patch cables (unshielded or shielded) of approx. 4.5 m in length. The installation cables routed through the base panel into the closet were connected to the reverse side of the patch panel. The cable rack was positioned at the rear of the data closet. The two high performance servers and their network adapters were positioned on standard spacers mounted at the side of the LAN closet.
The installation cables were attached to data outlets on the data terminal side. The outlets and the servers were linked by means of flexible unshielded or shielded patch cables, which were about 4.5 m long.

7.2 Front View of the EUT

See documentation photos

7.3 Rear View of the EUT

See documentation photos

8 Test Points

DIN VDE 0847-4-2 (ESD):

E1: Door of closed data closet, lock
E2: Closed data closet, side wall screw
E3: Data closet inside, 19" mounting bracket for patch panel
E4: Data closet inside, patch panel cover, not painted
E5: Patch panel port "10m", RJ45 plug*
E6: Patch panel port "90m", RJ45 plug*
E7: Data closet inside, 19" mounting bracket for switch
E8: Switch port "10m", RJ45 plug*
E9: Switch port „90m“, RJ45 plug*
E10: Telecommunications outlet (TO) "10m", RJ45 plug*
E11: Telecommunications outlet (TO) "90m", RJ45 plug*
E12: Switch rear panel

* Shielded system: contact/air discharge on the shield
* Unshielded system: air discharge on the plug body

DIN VDE 0847-4-4 (Burst):

B1: Data transmission cable, in the vicinity of the telecommunications outlet, "10m"
B2: Data transmission cable, in the vicinity of the telecommunications outlet, "90m"
B3: Data transmission cable, in the vicinity of the patch panel, "10m"
B4: Data transmission cable, in the vicinity of the patch panel, "90m"
B5: Switch power supply
B6: Server 1 power supply

DIN VDE 0847-4-5 (Surge):

S5: Switch power supply*
S6: Server power supply*

* The test was conducted in one system configuration only.

DIN VDE 0843-6 (conducted RF disturbances):

H1: Data transmission cable in TO direction, in the vicinity of the TO, "10m"
H2: Data transmission cable in TO direction, in the vicinity of the TO, "90m"
H3: Data transmission cable in patch panel direction, in the vicinity of the patch panel, "10m"
H4: Data transmission cable in patch panel direction, in the vicinity of the patch panel, "90m"
H5: Switch power supply
H6: Server 1 power supply

9 Documentation Photos

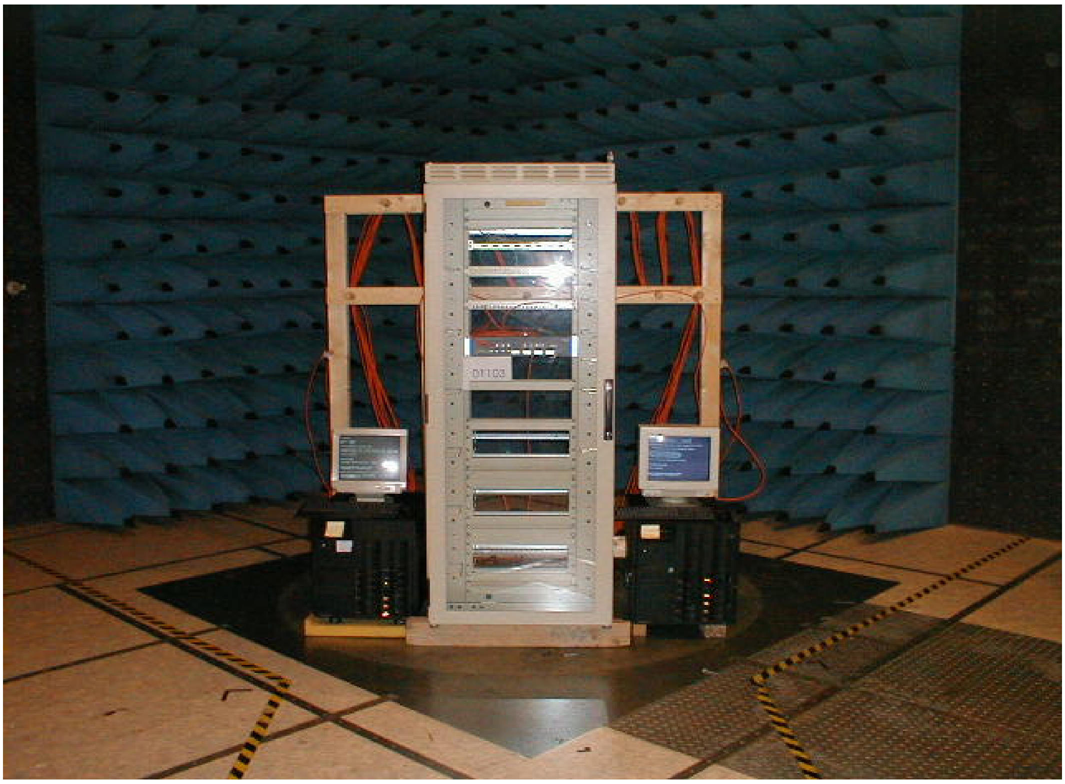


Figure 7: Sample data system, front view of system 2

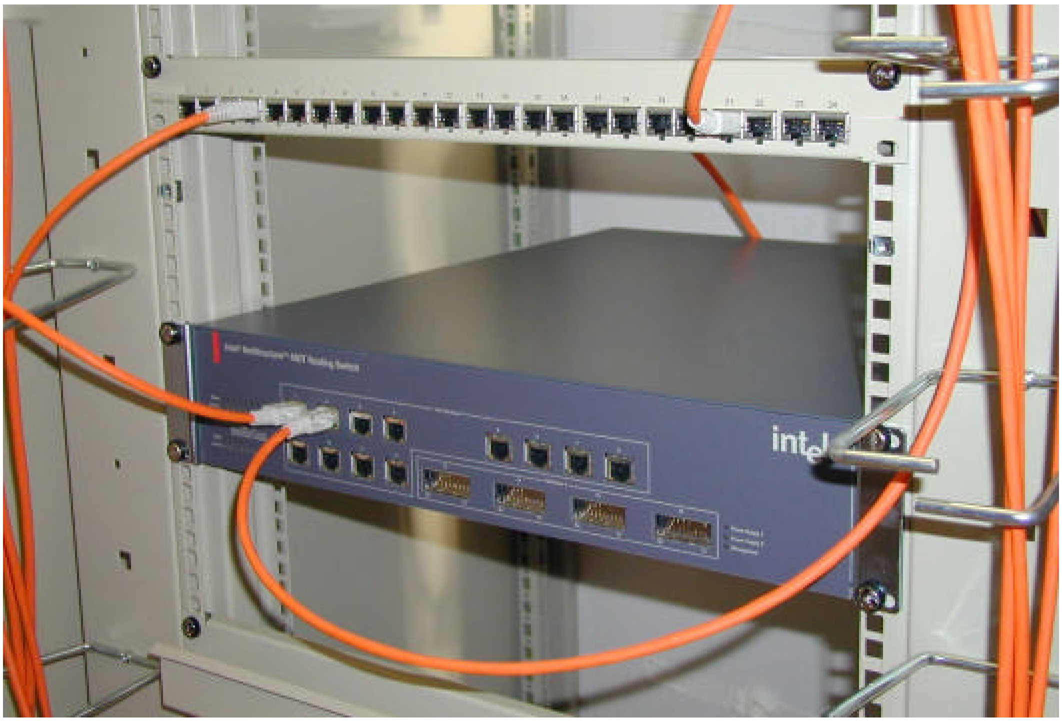


Figure 8: Data closet, front view showing switch and patch panel of system 2

Figure 9: Server 1, front view

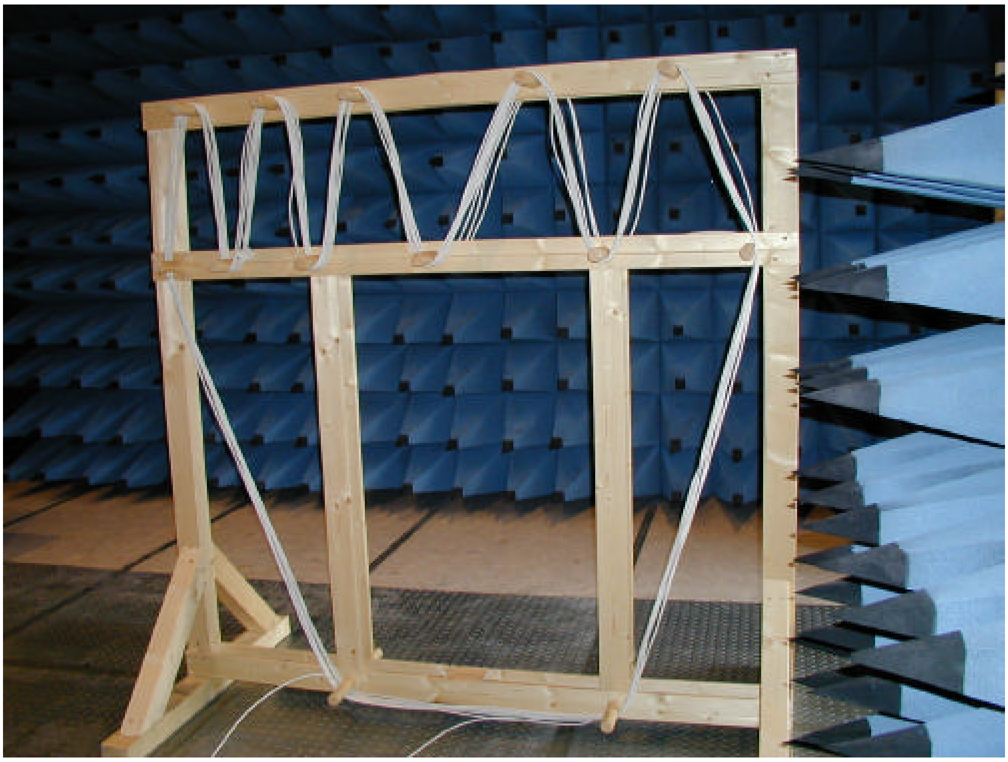


Figure 10: Device to accommodate cabling and EUT, system 2

10 Test Results

10.1 Overview

10.1.1 Electromagnetic Emission - EN 55022* and Additional Tests*

Standard*	Parameter	Limit	System 1 (shielded)	System 2 (unshielded)
EN 55022	Radio noise voltage	Class B	passed	passed
EN 55022	Radio noise field strength	Class B	passed	Failed
EN 61000-3-2	Audio frequency emissions Harmonic current emissions	Class A	passed	passed
EN 61000-3-3	Audio frequency emissions Flicker / voltage fluctuations		passed	passed
Additional Tests				
VDE 0878	(Magnetic) radio noise field strength	RegTP 01/99	passed	failed

10.1.2 Electromagnetic Immunity - EN 50082-2* and Additional Tests* (Criteria A)

Standard*	Parameter	Severity level	System 1 (shielded)	System 2 (unshielded)
EN 61000-4-2	Electrostatic Discharge (ESD)	Contact: 4 kV Air: 8 kV Coupling: 4 kV	passed passed passed	passed failed passed
EN 61000-4-3	Radiated, radio frequency, electromagnetic field immunity	01 V/m 03 V/m 10 V/m 15 V/m (i) 20 V/m (i)	not tested not tested passed passed passed	affected / passed failed
EN 61000-4-4	Exposure to fast transient/ burst	0,25kV 0,50kV 1,00kV 2,00kV(i) 4,00kV(i)	passed passed passed passed failed	affected / passed failed failed failed failed
EN 61000-4-5	Exposure to surges	2/4 kV	passed	passed

Standard*	**Parameter**	**Severity level**	**System 1 (shielded)**	**System 2 (unshielded)**
EN 61000-4-6	Conducted electromagnetic field immunity	01 V 03 V 10 V 20 V (i)	passed passed passed passed	affected / passed failed
		Additional Tests		
adapted from EN 61000-4-8	Compensating currents Power-frequency magnetic fields	$I_{eff.}$ = 1A	Passed	not tested since there was no shield
adapted from EN 61000-4-9	Pulsed magnetic fields	up to 300 A/m	Passed	passed

* Please refer to chapter 5.2, "Rules and Regulations" for detailed specification data and dates of issue

10.2 Comments

10.2.1 Electromagnetic Emission - EN 55022* and Additional Tests*

Radio noise voltage, mains leads – 0.15 MHz-30 MHz
Systems 1 and 2 meet the requirements of limit class B.

Radio noise field strength at a measuring distance of 3 m, 30 – 1000 (2000) MHz
System 1 (shielded) meets the requirements of limit class B.

Audio Frequency emissions (harmonic current emissions)
Systems 1 and 2 meet the requirements of limit class A.

Audio Frequency emissions (flicker, voltage fluctuations)
Systems 1 and 2 meet the requirements.

Magnetic radio noise field strength at a measuring distance of 3 m, 9 kHz – 30 MHz
System 1 (shielded) meets the RegTP requirements issued in 01/99.

System 2 (unshielded) does not meet the RegTP requirements issued in 01/99.

10.2.2 Electromagnetic Immunity - EN 50082-2*

Electrostatic Discharge (ESD)
DIN VDE 0847 part 4-2
System 1 (shielded) did not show any transmission errors or other effects with any of the coupling types.

System 2 (unshielded) experienced a drop in utilisation during the standard contact discharge of 8 kV. A 4 kV discharge did not have any impact on the system.

Radiated, radio frequency, electromagnetic field immunity, 80- 1000 MHz
DIN VDE 0847 part 4-3
System 1 (shielded) did not show any transmission errors or other effects even when the field strength was stepped up to 20 V/m (server immunity limit).

System 2 (unshielded) experienced a significant drop in utilisation (down to 0%) with interference over a broad frequency range, which even resulted in a total data transmission crash so that data transmission had to be restarted.

Exposure to fast transients (burst)
DIN VDE 0847 part 4-4
System 1 (shielded) did not show any transmission errors or other effects, even when the burst voltage was increased to 2 kV. A further increase to 4 kV led to utilisation fluctuations and to an increase in the number of CRC errors.

System 2 (unshielded) experienced utilisation fluctuations when the 90 m data transmission cables were subjected to a burst voltage of as low as 250 V. This error pattern did not change even when the exposure voltage was gradually increased to

2 kV. Only a further increase to 4 kV caused the utilisation to drop to 0% and led to the failure of the transmission process so that a restart was necessary.

Exposure to surges
DIN VDE 0847 part 4-5
Neither of the systems experienced any transmission errors or any other effects.

Exposure to conducted RF interference
DIN VDE 0847 part 4-6
System 1 (shielded) did not show any transmission errors or other effects even when the e. m. f. was increased to 20 V (server interference threshold).

System 2 (unshielded) experienced a significant drop in utilisation (down to 0 %) over a broad range of frequencies when the data transmission cables were subjected to conducted RF disturbance. This resulted in a total data transmission crash so that in some cases transmission had to be restarted.

Power-frequency magnetic fields
adapted from DIN VDE 0847 part 4-8
System 1 (unshielded) was not tested since there was no shield.

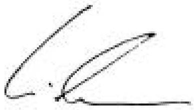
System 2 (shielded) did not show any transmission errors or other effects.

Pulsed magnetic fields
adapted from DIN VDE 0847 part 4-9
Neither of the systems experienced any transmission errors or any other effects.

* Please refer to chapter 5.2, "Rules and Regulations" for specification data and dates of issue.

11 Signature

Bexbach / Saar, 23 February 2001



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12 Test Records

Please refer to the original test report.