ISO/IEC JTC 1/SC 25/WG 3 N 685

Date: 2004-03-14

Replaces ISO/IEC JTC 1/SC 25/WG 3 N n/a

ISO/IEC JTC 1/SC 25/WG 3
Customer Premises Cabling
Secretariat: Germany (DIN)

DOC TYPE:	**Liaison document**
TITLE:	**Report on SC 25 WG 3 meeting Bordeaux 2004-02-23/27; Liaison report to IEEE 802.3 on electromagnetic performance**
SOURCE:	**WG 3 Secretariat** (Bordeaux 48A, 72A, 78)
PROJECT:	**25.03.02.xx: Generic cabling for customer premises**
STATUS:	**Forwarding of the Bordeaux 48A and 72A was approved by WG 3 at its meeting at Bordeaux, France, 2004-02-23/27.**
ACTION ID:	**FYI**
DUE DATE:	**n/a**
REQUESTED:	**For information**
ACTION	**IEEE 802 is requested to consider the attached information, provide feedback to SC 25/WG 3 and to expect further contributions to be developed at the next meeting of SC 25/WG 3.** **The next meeting of WG 3 planned at Chitose, Japan, 2004-06-21/24.**
MEDIUM:	**Def**
No of Pages:	**15 (including cover)**

DISTRIBUTION:

Members of JTC 1/SC 25/WG 3, see N 680
JTC 1 Secretariat, Mrs Rajchel
JTC 1/SC 25 Chair Dr. Zeidler
Conv/Sec Mr Robinson
IEEE 802 Chair/Liaison Mr. Nikolich/Mr. Flatman

IEC Central Office, Mr Barta
DKE, Hr Wegmann
JTC 1/SC 25 Sec Dr. von Pattay JTC 1/SC 25/WG 4
JTC 1/SC 25/PT SOHO Conv/Sec Prof. Halme/Ms Menou
IEEE 802.3 Chair/Liaison Mr Grow/Mr Flatman

Secretary - ISO/IEC JTC 1 / SC 25/WG 3 - Dr.-Ing. Walter P. von Pattay
ZVEI FV 7 & FV 8, Gotthelfstraße 24, D- 81677 München, Germany
Tel.: +49/89/923 967 57, Tfx,: +49/89/923 967 59 (on request only)
EM: Walter@Pattay.com

Ftp address SC 25: "ftp.iec.ch", login: "sc25mem", password: see SC 25 N 791
Home page SC 25: "http:/www.iec.ch/sc25"

To: IEEE 802.3 Bob Grow

copy to Brad Booth, Alan Flatman

From: IEC/JTC1/SC25/WG 3

Date: 2004-02-27

Venue: Bordeaux, France, 23/27 February 2004

Report from the convener of ISO/IEC JTC 1/SC 25/WG 3 to the chairman of IEEE 802.3 on SC 25/WG 3 meeting at Bordeaux, 2004-02-23/27

SC 25/WG 3 thankfully received the answer from IEEE 802.3 to the liaison report SC 25 N 912 and the tutorials provided on electromagnetic performance and10GBASE-T. in addition the explanations provided by Bradley Booth and Alan Flatman where most helpful.

The working group advanced both topics during its Bordeaux meeting, 2004-02-23/27.

The preliminary findings on **electromagnetic performance** are forwarded to IEEE 802.3 with the following letter and attachments that where endorsed by SC 25/WG 3.

The discussions on the **minimum channel performance** needed **for 10GBASE-T** and the possibilities to meet this moving target with different kinds of installed and new cabling did not come to conclusions during the meeting that where found ripe enough to be forwarded to IEEE 802.3. Homework was allocated in order to be able to provide IEEE 802.3 with helpful input after the next meeting of WG 3, Chitose, Japan, 2004-06-21/24.

As a Convenor of WG 3 I kindly ask IEEE 802.3 not to hesitate to provide WG 3 with its own findings even before our next meeting. Further information on the channel performance requirements, the distances to be covered and the significance of installed park could be helpful to focus the discussions in WG 3 on those points that are most important to IEEE 802.3.

Best regards

Dr Walter v. Pattay
Convenor ISO/IEC JTC 1/SC 25/WG 3

Liaison letter from SC25/WG 3 to IEEE 802.3 on electromagnetic performance of generic cabling

During the meeting of JTC 1/SC 25/WG 3 in Bordeaux, February 2004, the following documents were presented and developed:

Bor048A, Establishment of the needed electromagnetic performance of generic cabling for compliance with EMC requirements.

Bor072A, Parameters, which influences immunity of IT systems utilizing generic cabling.

WG 3 kindly requests you to consider these documents and provide input for the modeling proposed in the first document.

Our next meting will take place on 21-24 June 2004 in Chitose, Japan.

Best regards

Dr Walter v. Pattay
Convenor ISO/IEC JTC 1/SC 25/WG 3

Establishment of the needed electromagnetic performance of generic cabling for compliance with EMC requirements.

Table of contents

1 Summary 1
2 References 2
3 Electromagnetic performance 2
4 Radiated emission 2
4.1.1 Limits 2
4.1.2 Required power for emission to limit 3
4.1.3 Power of transmitted signal 3
4.1.4 Required coupling attenuation 3
5 Immunity 4
5.1.1 Limits 4
5.1.2 Received power in cabling 5
5.1.3 Received power in the inner symmetrical circuit 5
6 Calculations for popular applications 6
6.1 Ethernet 10 Base-T 6
6.1.1 Radiated emission 6
6.1.2 Signal spectrum 6
6.1.3 Immunity 7
6.2 Ethernet 100 BASE-T 8
6.2.1 Radiated emission 8
6.2.2 Signal spectrum 8
6.2.3 Immunity 9
6.3 Ethernet 1000 BASE-T 10
6.3.1 Radiated emission 10
6.3.2 Signal spectrum 10
6.3.3 Immunity 11
6.4 Ethernet 10G BASE-T 11
7 Conclusion 11

1 Summary

This document describes the necessary electromagnetic performance, here expressed as coupling attenuation, for a cabling system for compliance with EMC limits. The necessary coupling attenuation is dependant of the specifications for the application in use and the EMC limits. A cabling system for which coupling attenuation is equal to or better than calculated, is a necessary but not sufficient condition for a system to comply. The active equipment must also in it self comply with the EMC requirements.
The calculations are approximate. They do not give a guarantee for compliance, but they may be used as a guideline for design. The document firstly gives the basis for the calculations, and then calculations are performed for known popular applications. These calculations are based on knowledge given in the standards and reference 1 for the applications and guess work where information is not available.

2 References

References are the information given in:

1. ISO/IEC JTC 1/SC 25/WG 3(Bordeaux/Flatman)045 10/100/1000BASE-T Electromagnetic Noise Requirements

2. New Pseudo ternary line code for high speed Twisted Pair Data Lines. Alistair Coles. Network Technology Department, HP Laboratories Bristol. HPL-95-103, Sept. 1995

3. Gigabit 1000BASE-T. White paper. Gigabit Ethernet alliance, 1997

4. Evaluation of proposed generic cabling set-up to be included in EMC testing of information technology equipment based on radiation emission tests. JTC 1/SC 25/WG 3N447B

3 Electromagnetic performance

The electromagnetic performance of cabling is here defined as the performance parameters, which determines how cabling influences EMC performance of systems. This is balance for unscreened and screened cabling and in addition screening attenuation for screened cabling. The modern definition of these parameters relates to the ratio of power transmitted in the system to the power radiated from the system. A convenient parameter, which adds the balance and screening (if applicable), is coupling attenuation. Coupling attenuation is used in this paper in order to make the rationales independent of the cabling technology.

4 Radiated emission

4.1.1 Limits

There are mainly two classes of limits, which has to be used: Class A for industrial environments and class B for residential environments.

The field is measured at a bandwidth of 120 kHz.

Class A	40 dB/µV/m, 30 - 230 MHz	47 dB/µV/m, 230 – 1000 MHz
Class B	30 dB/µV/m, 30 - 230 MHz	37 dB/µV/m, 230 – 1000 MHz

Table 1. EMC limits expressed in V/m

These limits can be expressed in power density [W/m^2] by using the formul

$$P = \frac{V^2}{R}$$

P	Power density [W/m^2]
V	Field strength [V/m]
R	Impedance of empty space, 377 Ω

Class A	2.65E-11 W/m^2, 30 - 230 MHz	1.33E-10 W/m^2, 230 – 1000 MHz
Class B	2.65E-12 W/m^2, 30 - 230 MHz	1.33E-11 W/m^2, 230 – 1000 MHz

Table 2. EMC limits expressed in W/m^2

4.1.2 Required power for emission to limit.

Under the assumption that all power is radiated from a point source, the power required for generating a field strength equal to the limit can be calculated as:

$$P_r = 4\pi r^2 P_L$$

P_r	Radiated power to get the limit [W]
P_L	Limit power density [W/m^2]
r	measurement distance [m]

The measurement distance, r, is equal to 10 m for the limits in section 4.1.1

4.1.3 Power of transmitted signal

The power of the transmitted signal is dependent of the application, on the rate of traffic and on any low pass filtering applied in the transmitter circuit. The power is a pseudo noise signal, which shall be measured in a bandwidth of 200 kHz for EMC calculations. The rate of traffic is specified to 10 % in CISPR 22:1997. The power function is dependent of frequency. The signal power for the different applications can be gained either by measurements or by examination of the standards. The power will normally follow a sin(x)/x function up to the first null. At higher frequencies filtering will normally limit the power.

4.1.4 Required coupling attenuation

If we look away from radiation from the electronic equipment and only take radiation from the cabling into account, the required coupling attenuation can be calculated as the ratio (expressed in difference in dB) between the power required to get the limit and the transmitted power. This is a conservative assumption as it is calculated as if the power is radiated from a point source. The power is actually radiated along the cabling. The power is therefore distributed so that the intensity is lower than calculated based on the assumption.

In figure 1 it is shown how the calculation may be performed (the power of the transmitted signal is just a calculation example)

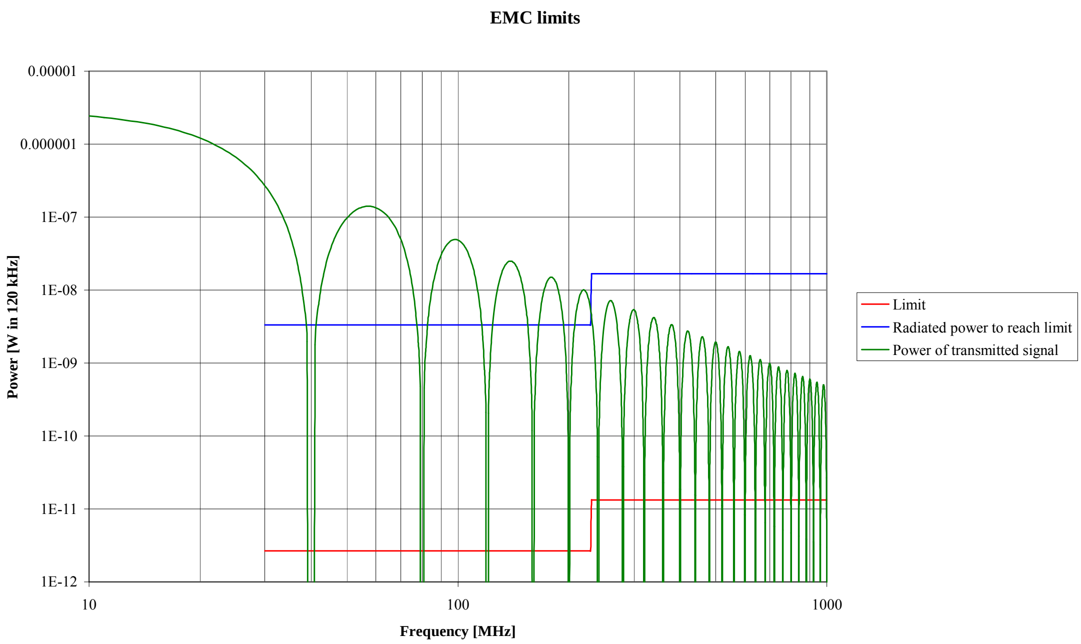

Figure 1. Limit for radiation, required radiated power and transmitted power.
The required coupling attenuation is the ratio between the blue and the green graph.

5 Immunity

5.1.1 Limits

There are mainly two classes of limits, which has to be used: 10V/m for industrial environments and 3V/m for residential environments.

The power density can be calculated using the formula:

$$P = \frac{F^2}{R}$$

P Power density [W/m^2]
F Field strength [V/m]
R Impedance of empty space, 377 Ω

This is shown in the table below:

Environment	Field strength	Power density
Residential	3 V/m	0.024 W/m^2
Industrial	10 V/m	0.26 W/m^2

Table 3. EMC immunity limits

5.1.2 Received power in cabling

The cabling can be viewed as an antenna in an electrical field. If the gain of the antenna is one, the antenna is isotropic and it receives the power equally from all directions. An isotropic antenna is not possible, but it is a good estimate, that a cabling system will have a performance as an antenna, which is equal to an isotropic antenna plus minus some dB.

The received power from an isotropic antenna is:

$$P_r = \frac{\lambda^2}{4\pi} \cdot P_D$$

P_r	Received power [W]
λ	Wavelength [m]
P_D	Power density [W/m^2]

The wavelength is:

$$\lambda = \frac{c}{f}$$

c	velocity of light 3e8 m/s
f	frequency [Hz]

5.1.3 Received power in the inner symmetrical circuit

The power in the inner symmetrical system is dependent of the coupling attenuation of the cabling. We can express the power in the inner system by:

$$P_i = P_r \cdot \frac{1}{C_{att}}$$

P_r	Received power [W]
Pi	Power in inner system
Catt	Coupling attenuation

The power in the inner system, generated from outside noise, determines the signal to noise ratio. The tolerable signal to noise ratio is very dependant of the character of the noise. For many applications a requirement for the tolerable voltage at the input of the receiving circuit is defined. The voltage generated by the noise in the inner system can be calculated, bearing in mind that the impedance for the signal is 50 Ω (100 Ω from the receiver in parallel with 100 Ω from the transmitter):

$$V_i = \sqrt{P_i \cdot Z}$$

Vi	Noise voltage in inner system from the external field.
Z	Impedance in inner system, 50 Ω (100Ω in parallel with 100 Ω).

Some examples can be calculated to investigate the usefulness of these considerations:

Outer field strength	Frequency	Coupling attenuation	Noise voltage, Vi
10 V/m	30 MHz	40 dB	0.1 V
10 V/m	100 MHz	40 dB	0.03 V
10 V/m	1000 MHz	40 dB	0.003 V

Table 4 . Calculated noise voltage.

The figures from the table are well aligned with the results presented in ref. 4.

6 Calculations for popular applications

6.1 *Ethernet 10 Base-T*

6.1.1 Radiated emission

Specification (ref. 1)
Peak differential output voltage ±2.2 V to ±2.8 V with any harmonic at least 27 dB below fundamental for an all-one code sequence (i.e. 10 MHz).

6.1.2 Signal spectrum

The lowest frequency of 5 MHz is obtained when a sequence of 1-0-1 is sent; 10 MHz is obtained for an all one code sequence. The maximum power is:

$$P = \frac{2.8^2}{100} = 0.0784 \text{ W}$$

Radiation is measured for a duty cycle of 10 %. Therefore the power is 0.0078 W[1]. For a random signal of zeroes and ones this is a noise signal, where the main power is between 5 and 10 MHz. If we make a rough estimation that the power is evenly distributed between 5 and 10 MHz the power density will be:

$$P_d = \frac{0.00784}{5 \cdot 10^6} = 0.00156 \, \mu\text{W/Hz}$$

As the measurement bandwidth is 200 KHz, the power in this bandwidth is:

$$P_{200} = 0.00156 \cdot 200000 = 312 \ \mu\text{W}$$

[1] Noise is measured with a quasi-peak detector. The detector response for this signal has to be evaluated in order to establish the correct level of the power spectrum.

At harmonic frequencies the signal is attenuated at least 27 dB, and it is estimated that the spectrum is at least attenuated 20 dB pr. Decade at higher frequencies. In a graph this estimated power spectrum is shown in figure 2.

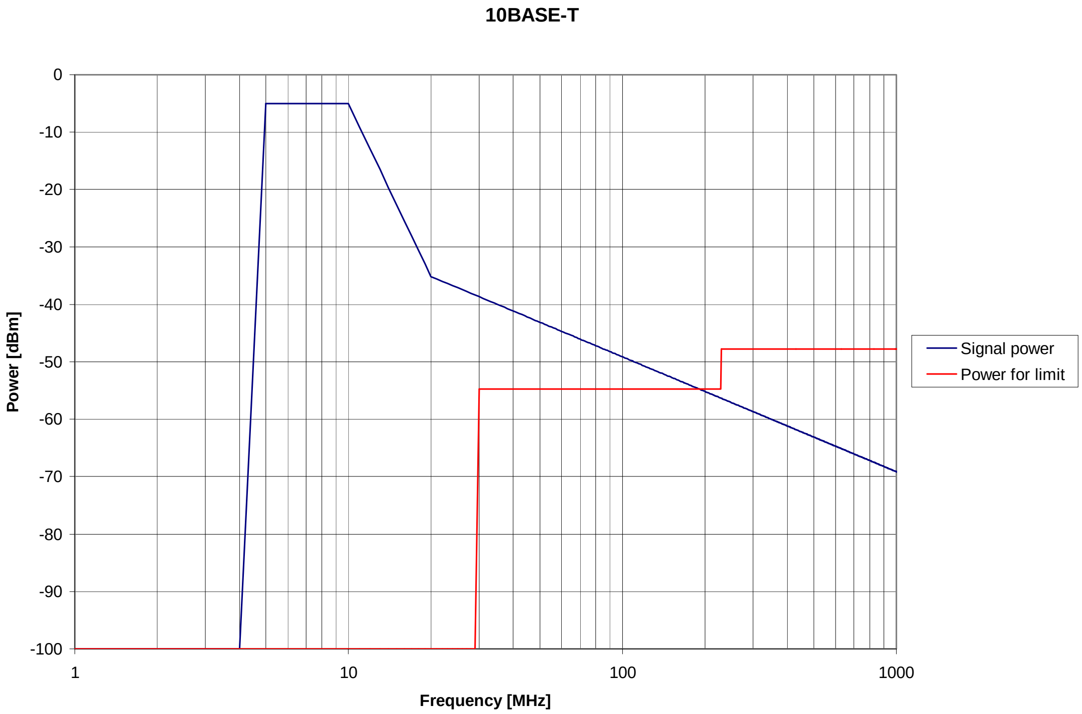

Figure 2. Estimated spectrum for Ethernet 10 Base-T

In figure 2 the blue graph is the estimated power spectrum for 10 % duty cycle measured in a bandwidth of 200 kHz. The red graph is the power, which will generate field strength at the limit (class B), if it is radiated by an isotropic antenna. The difference between the blue and red graph is the required coupling attenuation for the cabling system, in order to comply with the radiation limit. From this figure it is seen that a coupling attenuation of 15 dB or better at 30 MHz is enough. For this application cabling is not the limiting factor.

6.1.3 Immunity

Common mode rejection specification (from ref. 1):
The receiver must operate as specified (process data with a BER of no worse that 10^{-8}*) when a common mode voltage of 25V peak-to-peak, 500 kHz or lower in frequency is applied to the input signal.*

This specification applies to the receiver. It cannot be translated to requirements for cabling unless tolerance of the receiver for differential noise is known.

The Receiver Differential Input Signals are specified at

± 585mV (minimum) with a BER of no worse that 10-8.

If we calculate with a required S/N ratio of 15 dB, then the differential noise voltage at the receiver input shall be below ±104 mV. The required common mode ratio is then:

$$CMR = \frac{25}{0.104} = 240 \text{ or } 48 \text{ dB}$$

If the receiver and the cabling contribute equally to the common mode rejection, then the balance of the cabling should be better than 54 dB up to 500 KHz. There is no information on requirements for higher frequencies.

6.2 Ethernet 100 BASE-T

6.2.1 Radiated emission

Peak differential output voltage ±0.95 V to ±1.05 V. The symbol rate is 125 MB/s. The signal is a 3-level signal, where ones are transmitted as alternative -1 and +1 V, and zeroes are transmitted as 0 V. Coding and scrambling ensures that long lengths of ones and zeroes does not happen.

6.2.2 Signal spectrum

The signal has some energy at low frequencies, because a zero is transmitted as 0 V. The highest frequency is for all ones transmission. This frequency is 62.25 MHz. The maximum power is:

$$P = \frac{1^2}{2 \cdot 100} = 0.005 \text{ W}$$

(the factor 2 is because the voltage is zero half of the time for the MLT-3 code)
Radiation is measured for a duty cycle of 10 %. Therefore the power is 0.0005 W. For a random signal of zeroes and ones this is a noise signal, where the main power is between 0.06 and 0.2 times the symbol rate (Ref. 2, figure 3). This is between 7.5 MHz. and 25 MHz. If we make a rough estimation that the power is evenly distributed between 7.5 and 25 MHz the power density will be:

$$P_d = \frac{0.0005}{17.5 \cdot 10^6} = 0.000029 \, \mu\text{W/Hz}$$

As the measurement bandwidth is 200 KHz, the power in this bandwidth is:

$$P_{200} = 0.000029 \cdot 200000 = 5.7 \ \mu\text{W or -22.4 dBm}$$

The estimated power spectrum is shown in figure 3, using information from Ref. 2, figure 3.

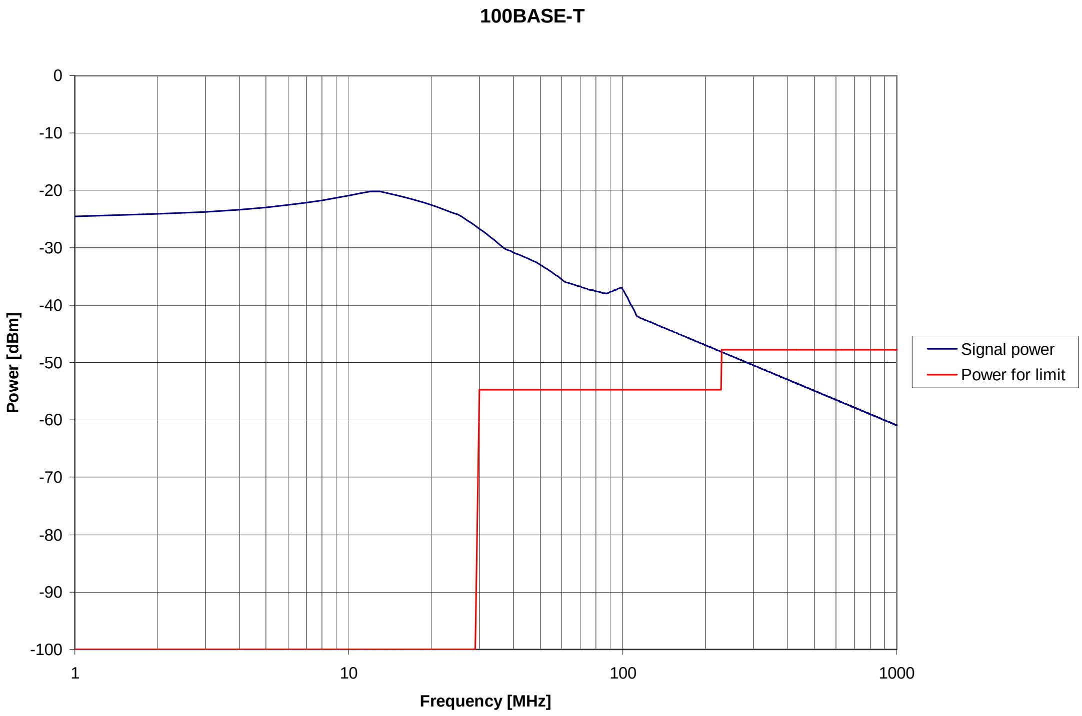

Figure 3. Estimated power spectrum for 100BASE-T

In figure 3 the blue graph is the estimated power spectrum for 10 % duty cycle measured in a bandwidth of 200 kHz. The red graph is the power, which will generate field strength at the limit (class B), if it is radiated by an isotropic antenna. The difference between the blue and red graph is the required coupling attenuation for the cabling system, in order to comply with the radiation limit. From this figure it is seen that a coupling attenuation of 30 dB or better at 30 MHz is adequate.

6.2.3 Immunity

Noise specification (from ref. 1):

The noise coupled from external sources measured at the output of a filter attached to the output of the near end of a disturbed channel should not exceed 40mV peak-to-peak. The measurement filter is a 5th order Butterworth filter with a 3 dB cutoff @ 100 MHz.

The noise power, which can be tolerated, is then:

$$P_N = \frac{0.04^2}{8 \cdot 100} = 2 \ \mu\text{W}$$

Using the information in clause 5, the required coupling attenuation can be found.

$$C_{att} = \frac{P_D}{P_N} \cdot \frac{\lambda^2}{4\pi}$$

P_D Power density of disturbing field

P_N Tolerable noise power
λ Wavelength of noise signal

In the table below this is calculated for a noise field of 10 V/m

Frequency	Required coupling attenuation
30 MHz	60 dB
50 MHz	56 dB
100 MHz	50 dB

Table 5. Required coupling attenuation for 100 BASE-T, Industrial environment

For residential environment the required coupling attenuation is 10 dB less.

At higher frequencies than 100 MHz the requirements are less, due to the measurement filter required in the above specification. This is in practice only true if a filter is implemented in the receiver circuit.

6.3 Ethernet 1000 BASE-T

6.3.1 Radiated emission

Peak differential output voltage is ±1 V. The symbol rate is 125 MB/s. The signal is a 5-level signal, pulse amplitude modulation

6.3.2 Signal spectrum

The signal spectrum is essentially the same as for 100 BASE-T, but signals are transmitted simultaneously at all four pairs in order to achieve the high bit rate. This means that the total power transmitted is 4 times that of 100BASE-T (The transmission also allows for full duplex operation, but this is not taken into account here). The power spectrum is therefore 6 dB higher than that of 100BASE-T. This is shown in figure 4.

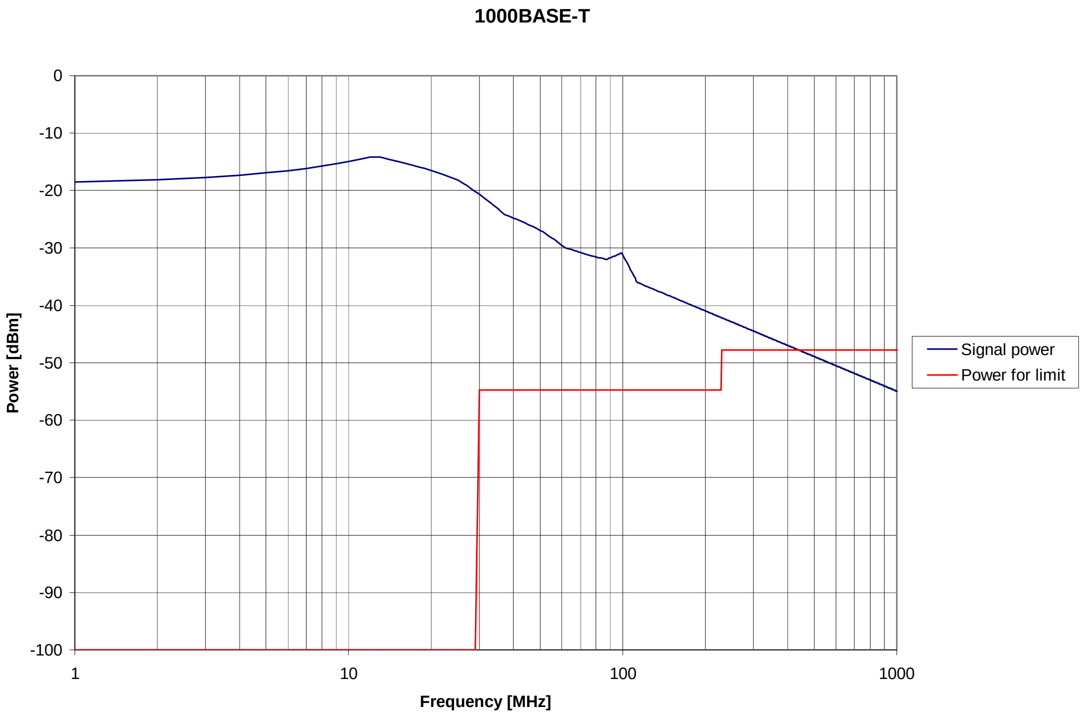

Figure 4. Estimated power spectrum for 1000BASE-T

For explanation of the figure, see figure 3. The required coupling attenuation is 36 dB at 30 MHz. This is not difficult for modern cabling. Normal UTP cabling will comply with this requirement. But is must be stressed that the calculation only comprises one cable to one work station. For a bundle of cables close to the distributor the radiation is worse, depending of the number of active channels and amount of traffic.

6.3.3 Immunity

The noise specification (from ref. 1) is the same as for 100BASE-T (see clause 6.2.3). The requirements are therefore the same, although it is known that a 5 level code is more prone to noise disturbances as a 3 level code. With the same specification a higher burden is put on the 1000BASE-T receiver design.

6.4 Ethernet 10G BASE-T

No information yet.

7 Conclusion

A simple way to specify and calculate the necessary EM performance of cabling has been proposed. The method uses the parameter coupling attenuation for this characterization. This parameter is applicable in the frequency range of 30 MHz 1000 MHz. Radiation and immunity at lower frequencies should also be covered in the future. The method has been used to find the requirement for cabling for popular applications. Although the method is very simple it is found that the calculated results

are in line with expected results. It is also found that the results are in agreement with results found in anechoic chamber measurements.
It must be stressed that the fact that the cabling complies with the calculated EM requirements is a necessary but not sufficient condition for EMC compliance. It is also important that the active equipment is in compliance when it is tested according to CISPR 22.

An interesting result is that the requirement of immunity, especially in industrial environments, puts a higher requirement to cabling than radiation. This is true, especially when we have single channels.

Parameters, which influences immunity of IT systems utilising generic cabling

Electromagnetic performance of generic cabling systems, channels and links.

3Bor072

Reference is made to the minutes (3bor064) of the add hoc for the pre assumptions for the tabled values.

IS 11801: Sub-clause 6.4.14-6.4.15

2004-02-24 Bordeaux add hoc on EM performance.

			Balanced Cabling Channel		
			Typical construction		
			Unscreened	Screened	Screened
			U/UTP	F/UTP	S/FTP
Performance class	Crosstalk parameters	Alien crosstalk	≥ Channel PSNEXT (ffs)	≥ Channel PSNEXT (ffs)	≥ Channel PSNEXT (ffs)
	Unbalance attenuation	TCL	40-10log(f) 1-max f for Class	40-10log(f) 1-max f for Class	to be considered
		ELTCTL	30-20log(f) 1-30MHz	30-20log(f) 1-30MHz	to be considered
	Screen parameters	Screening attenuation	not applicable	not specified	40dB
		Coupling attenuation	not specified	40-20log(f/100) 30-1000MHz*	50-20log(f/100) 30-1000MHz
	Installation mitigation		not necessary	not necessary	not necessary
E1					
Performance class	Crosstalk parameters	Alien crosstalk	≥ Channel PSNEXT (ffs)	≥ Channel PSNEXT (ffs)	≥ Channel PSNEXT (ffs)
	Balance parameters	TCL	50-10log(f) 1-max f for Class	45-10log(f) 1-max f for Class	to be considered
		ELTCTL	40-20log(f) 1-30MHz	35-20log(f) 1-30MHz	to be considered
	Screen parameters	Screening attenuation	not applicable	not specified	50dB
		Coupling attenuation	not specified	50-20log(f/100) 30-1000MHz	60-20log(f/100) 30-1000MHz
	Installation mitigation		not necessary	not necessary	not necessary
E2					
Performance class	Crosstalk parameters	Alien crosstalk	≥ Channel PSNEXT (ffs)	≥ Channel PSNEXT (ffs)	≥ Channel PSNEXT (ffs)
	Balance parameters	TCL	60-10log(f) 1-max f for Class	45-10log(f) 1-max f for Class	to be considered
		ELTCTL	50-20log(f) 1-30MHz	35-20log(f) 1-30MHz	to be considered
	Screen parameters	Screening attenuation	not applicable	not specified	60dB
		Coupling attenuation	not specified	60-20log(f/100) 30-1000MHz	80-20log(f/100) 30-1000MHz
	Installation mitigation		not necessary	not necessary	not necessary
E3					
	Balance parameters	TCL	40-10 log (f) f.f.s.		
ISO/IEC 11801:2002		Coupling attenuation	No value		

* formula for coupling attenuation means: A constant value, 40 dB from 30 MHz to 100 MHz. Use the formula from 100 MHz to 1000 MHz

ISO/IEC 11801;2002 data for information only