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REQUESTED: ACTION	**For information** **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 is planned at Oxford, United Kingdom, 2005-09-26/29.**
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To: IEEE 802.3 Bob Grow
copy to Brad Booth, Alan Flatman
From: IEC/JTC1/SC25/WG 3 Secretariat
Date: 2005-01-21
Venue: Ixtapa, Mexico, 10/14 January 2005

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 Ixtapa, Mexico, 2005-01-10/14

SC 25/WG 3 thankfully received your liaison report distributed as SC 25/WG 3 N 730, started work on the subject and approved an answer that is forwarded as SC 25/WG 3. The report provided by Alan Flatman on 10GBASE-T where helpful input on the new work on a technical report on the qualification of installed cabling for 10GBASE-T and on an amendment to ISO/IEC 11801 that will include channel as specified up to 500 MHz and up to 1 GHz. A more detailed report on the subject is being developed during the next weeks. We will keep you informed on the progress on the two subjects also before our next meeting in autumn.

The findings on **electromagnetic performance** that where forwarded to IEEE 802.3 as attachment to SC 25/WG 3 N 711 have been updated as attached to this letter.

As a Convenor of WG 3 I kindly ask IEEE 802.3 not to hesitate to provide WG 3 with its own findings on all the subjects mentioned above even before our next meeting as we plan intensive work by correspondence during the next months.

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

ISO/IEC JOINT TECHNICAL COMMITTEE 1

SUBCOMMITTEE No.25: INTERCONNECTION OF
INFORMATION TECHNOLOGY EQUIPMENT
WORKING GROUP 3: CUSTOMER PREMISES CABLING

38th Meeting of WG 3
Ixtapa Mexico, January 2005

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

Table of contents

1 Summary

This document describes the necessary electromagnetic performance, expressed as coupling attenuation, for a cabling system to comply with EMC limits. The required coupling attenuation is dependent of the application specifications, 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 for the applications (see reference 1) and guess work where information is not available. At last practical measurements are reported and the results are compared with the developed theory.

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

5. CLC TC215 WG 1 25/33 IEEE 802.3 Meetings, Ottawa, ON: 27 Sep-01 Oct 2004, San Antonio, TX: 15-18 Nov2004. Alan Flatman

3 Document history

Version	Changes	Date
3Bor48a	New	27 February 2004
3Chi016	Results from measured spectra included. 10 dB correction for traffic rate taken out	17 May 2004
3Chi16a	Corrections from Joseph Babanezhad's comments	16 June 2004
3IXT025	Results from practical measurements included	3 January 2005

4 Electromagnetic performance

The electromagnetic performance of cabling is defined by parameters which determine 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 analysis independent of the cabling technology.

5 Radiated emission

5.1.1 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 formula

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

P Power density [W/m^2]
V Field strength [V/m]
R Impedance of free 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

5.1.2 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 5.1.1

5.1.3 Power of transmitted signal

The power of the transmitted signal is dependent on the application, the rate of traffic (see clause 8) and any low pass filtering applied in the transmitter circuit. The power is a pseudo noise signal, which shall be measured in a bandwidth of 120 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.

5.1.4 Required coupling attenuation

If we ignore the radiation from 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)

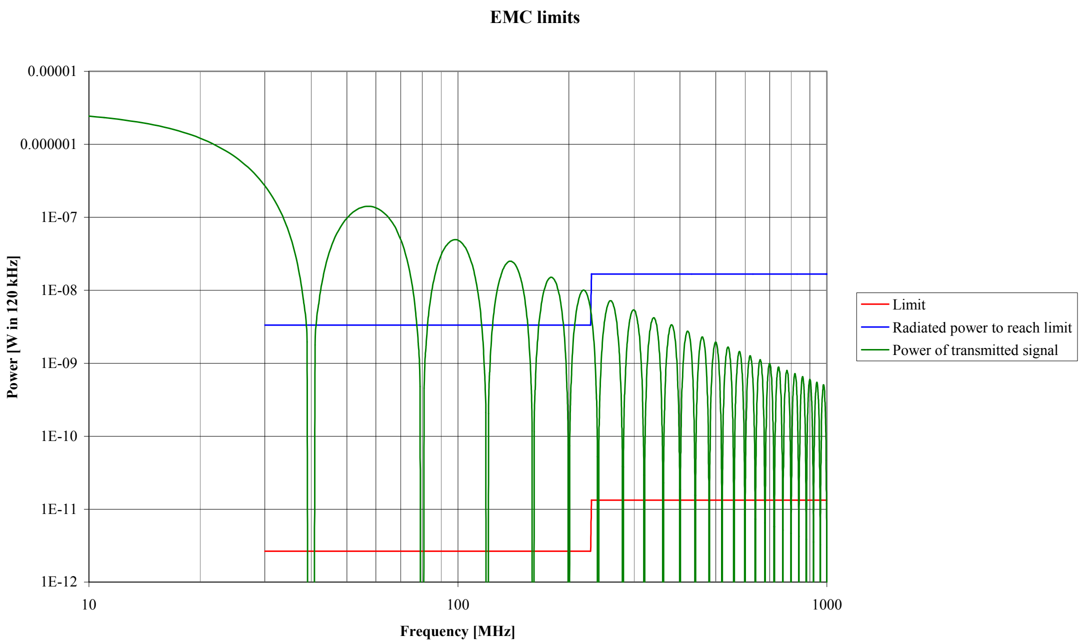

Figure 1. Limit for radiation, required radiated power and transmitted power.
The required coupling attenuation is the ratio between the blue and the green graph.

6 Immunity

6.1.1 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 free 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

6.1.2 Received power in cabling

The cabling can be viewed as an antenna in an electromagnetic 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]

6.1.3 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
C_{att}	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 (100 Ω 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.

7 Calculations for popular applications

7.1 Ethernet 10 BASE-T

7.1.1 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).

7.1.2 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:

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

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:

$$P_d = \frac{0.0784}{5 \cdot 10^6} = 0.0156\,\mu\text{W/Hz}$$

As the measurement bandwidth is 120 KHz, the power in this bandwidth is:

$$P_{120} = 0.0156 \cdot 120000 = 1872 \ \mu\text{W}$$

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.

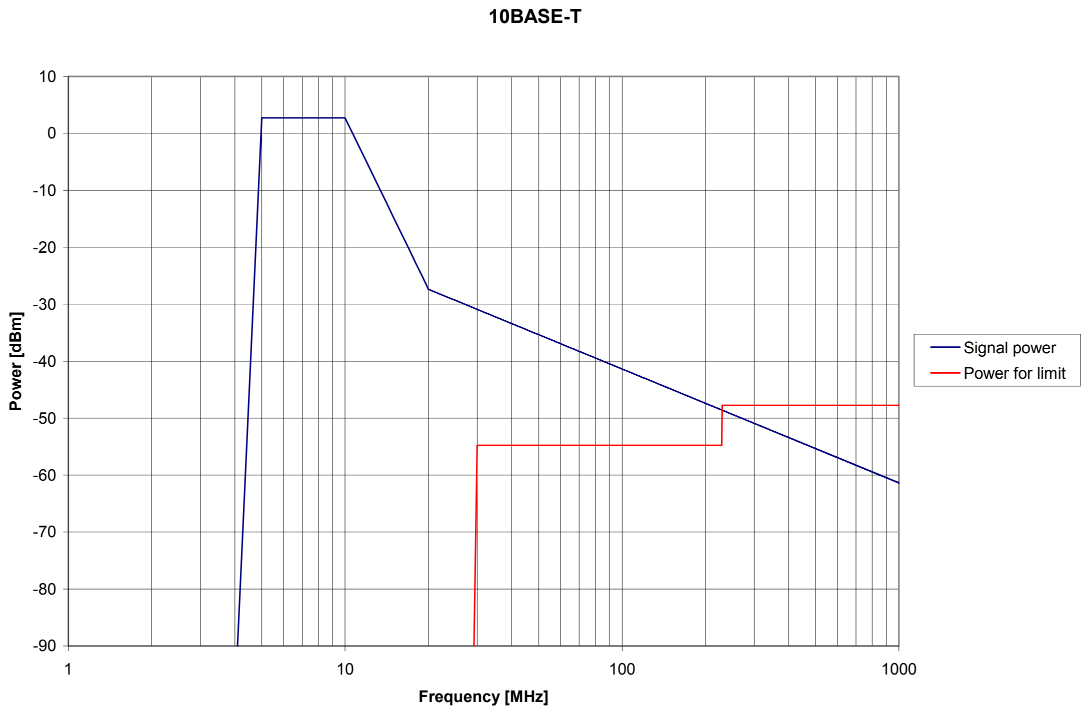

Figure 2. Estimated spectrum for Ethernet 10 Base-T

In figure 2 the blue graph is the estimated power spectrum measured in a bandwidth of 120 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 23 dB or better at 30 MHz is enough. For this application cabling is not the limiting factor.

7.1.3 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.

7.2 Ethernet 100 BASE-T

7.2.1 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, MLT-3 code, 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.

7.2.2 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 62.5 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)
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:

$$P_d = \frac{0.005}{17.5 \cdot 10^6} = 0.00029 \,\mu\text{W/Hz}$$

As the measurement bandwidth is 120 KHz, the power in this bandwidth is:

$$P_{120} = 0.00029 \cdot 120000 = 35 \;\mu\text{W or -14.6 dBm}$$

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

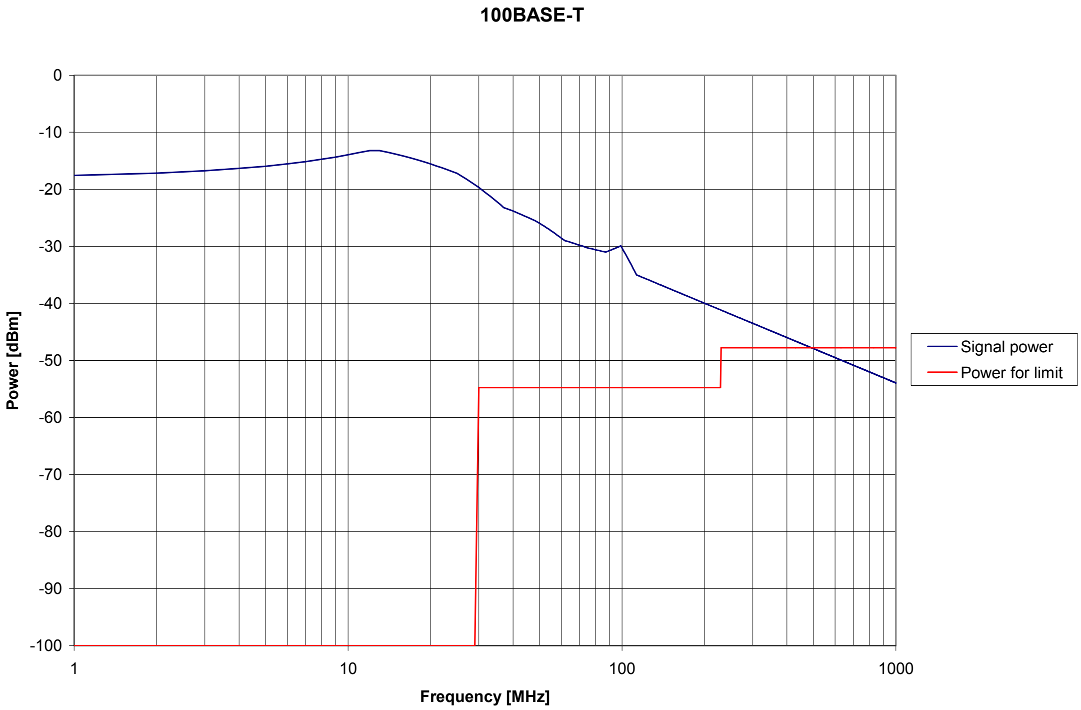

Figure 3. Estimated power spectrum for 100BASE-T

In figure 3 the blue graph is the estimated power spectrum measured in a bandwidth of 120 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 35 dB or better at 30 MHz is adequate.

7.2.3 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 6, 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.

7.3 Ethernet 1000 BASE-T

7.3.1 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

7.3.2 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.

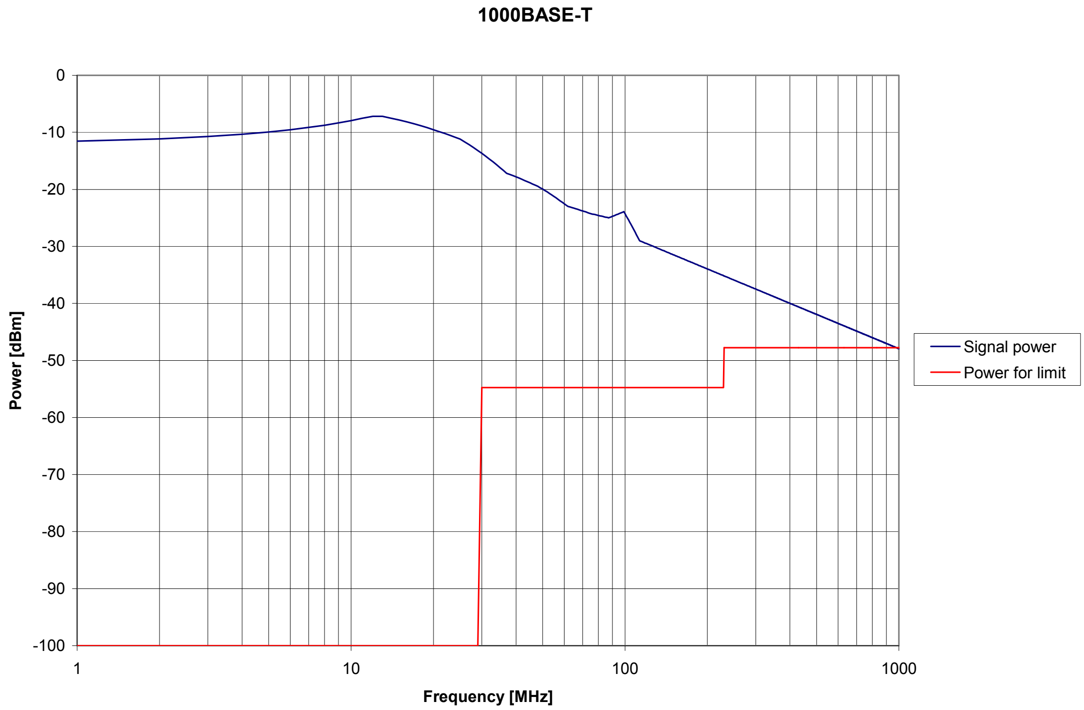

Figure 4. Estimated power spectrum for 1000BASE-T

For explanation of the figure, see figure 3. The required coupling attenuation is 42 dB at 30 MHz. This is not impossible for modern cabling. Good 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.

7.3.3 Immunity

The noise specification (from ref. 1) is the same as for 100BASE-T (see clause 7.2.3). The requirements are therefore the same, although it is known that a 5 level code is more susceptible to noise disturbances than a 3 level code. With the same specification a higher burden is put on the 1000BASE-T receiver design.

7.4 Ethernet 10G BASE-T

7.4.1 Radiated emission

The signalling scheme adopted in the November 2004 meeting of IEEE 802.3an is 128-DSQ (128 constellation with Double-SQuare coding). Peak differential output voltage is ±1 to ±1.25 V. Transmission on all four pairs. The Nyquist frequency is 400 MHz. (see ref. 5 for further information).

7.4.2 Signal spectrum

The proposed PSD mask is -78 dBm/Hz up to 330 MHz. Measured in a bandwidth of 120 kHz this is -27.2 dBm. As power is transmitted on all four pairs the resulting power density is -21.2 dBm. In ref. 5 it is shown that the PSD of 10GBASE-T is 6.6 dB lower than the PSD of 1000BASE-T at 10 MHz. A PSD of -21.2 dBm therefore

relates to a PSD of -14.6 dBm for 1000BASE-T. My estimate for the PSD of 1000BASE-T is -7.2 dBm. This value is supported by the measured value using an EMC receiver (figure 12). The discrepancy between these two figures, 7.4 dB, may be due to the fact that an EMC receiver measures the peak power. The PSD therefore has to be calculated for 100 % duty cycle of the data signals. I do not know if this has been done. (Please also see the difference between peak and average detector measurements figure 9 and figure 11)
In figure 5 I have used a PSD value of -13.8 dBm for 10GBASE-T.

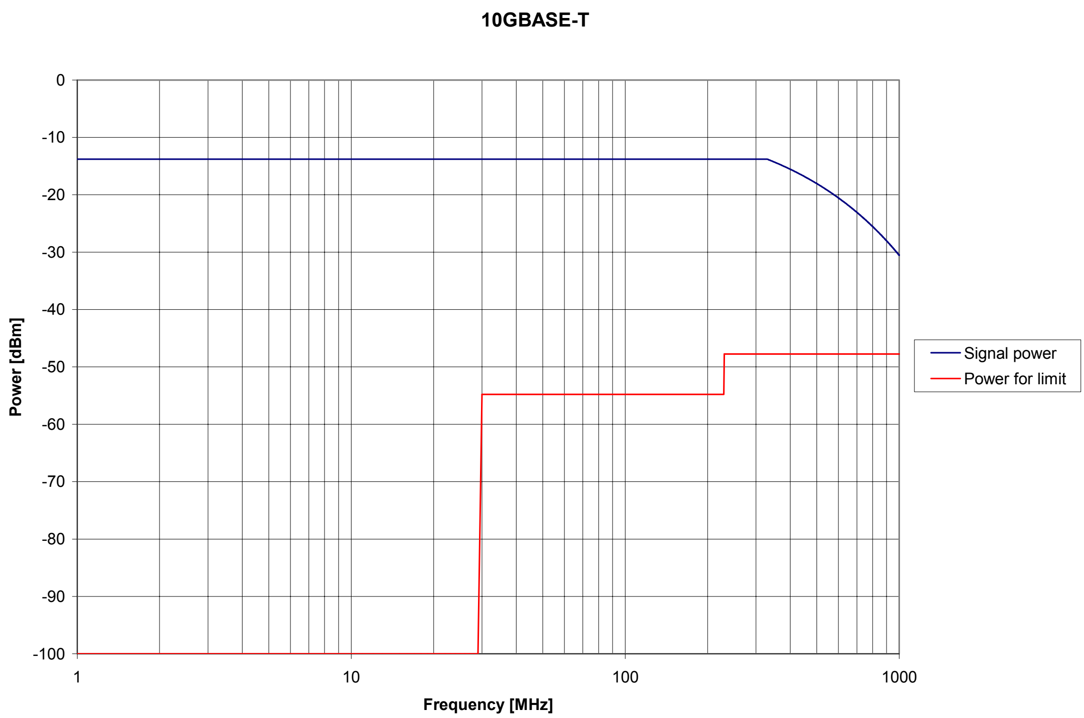

Figure 5. Estimated power spectrum for 10GBASE-T

For explanation of the figure, see figure 3. The required coupling attenuation is 41 dB up to 230 MHz for compliance with the class B level.

7.4.3 Immunity

No information yet

8 Measured spectrum for 100 BASE-T

In order to verify the theoretical calculation in clause 7.2.2, the signal spectrum for a 100 BASE-T LAN was measured using an EMI receiver.
Two computers were connected by a short link. The LAN was either kept in idle state or in a state where the one computer was transmitting large files to the other. The signal was picked up by a directional coupler, with an attenuation of 20 dB.

Graphs were obtained in the frequency range of 20 MHz to 200 MHz. Quasi peak, peak and average detectors were used, and the LAN was in the idle or heavy traffic state.

The signal strength recorded by the receiver is in dB over 1 μV. This was converted to dBm and the attenuation of the baluns and directional coupler was accounted for.

The results are shown in the graphs below:

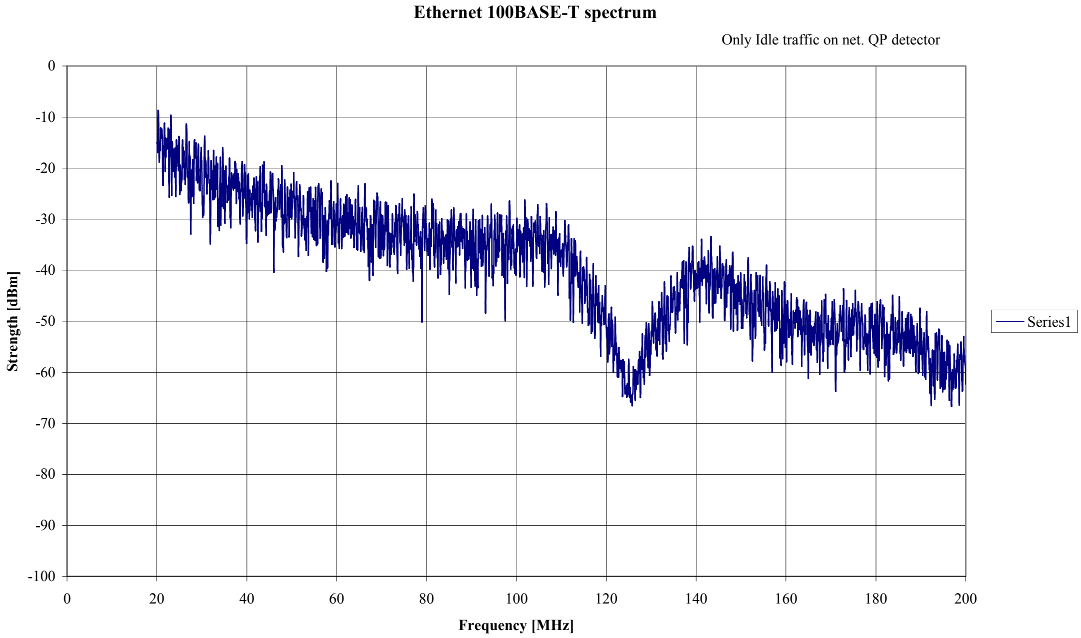

Figure 6. 100BASE-T spectrum. Idle traffic, QP detector.

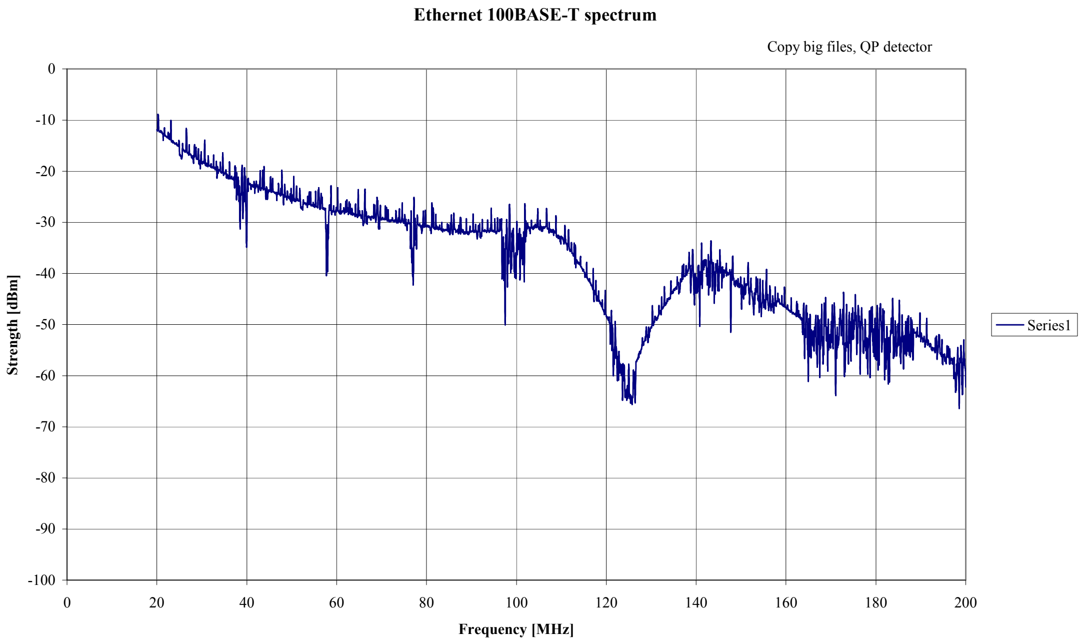

Figure 7. 100BASE-T spectrum. Copy big files, QP detector.

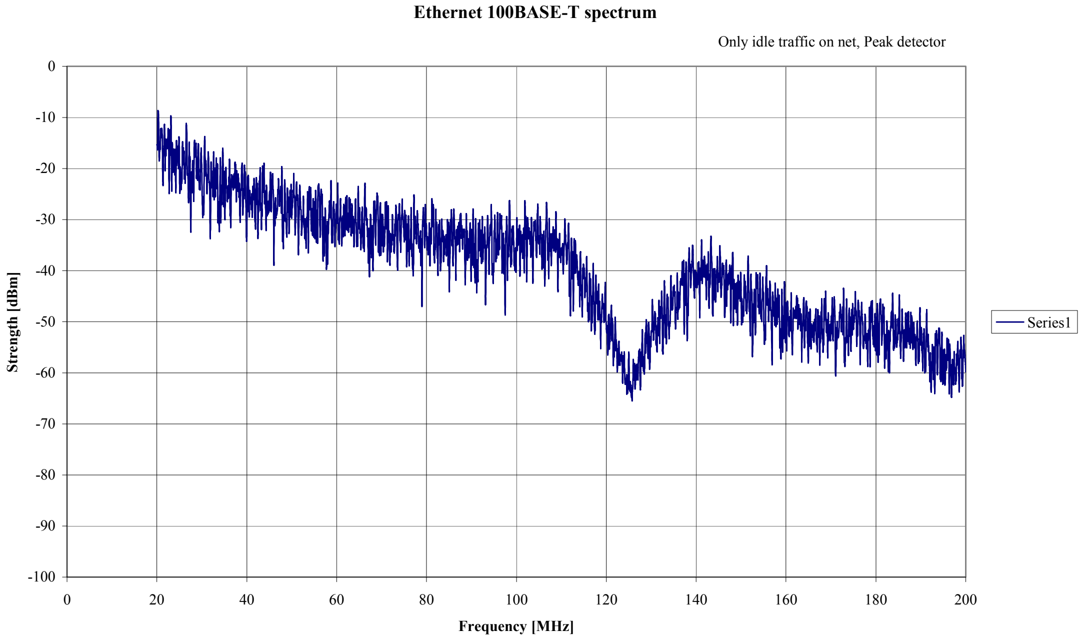

Figure 8. 100BASE-T spectrum. Idle traffic, Peak detector.

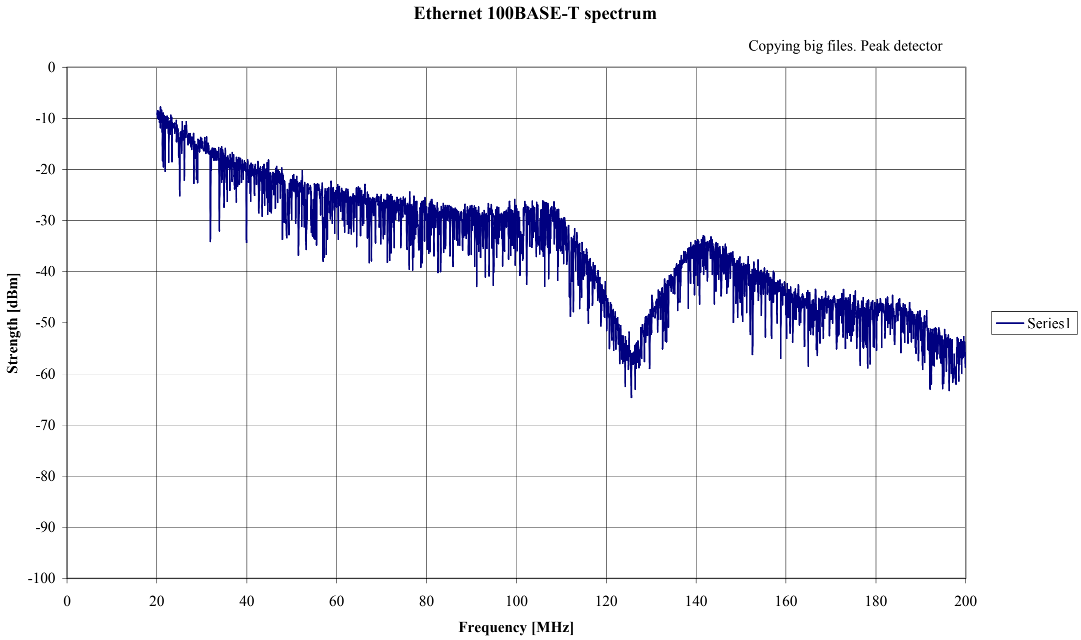

Figure 9. 100BASE-T spectrum. Copy big files, Peak detector.

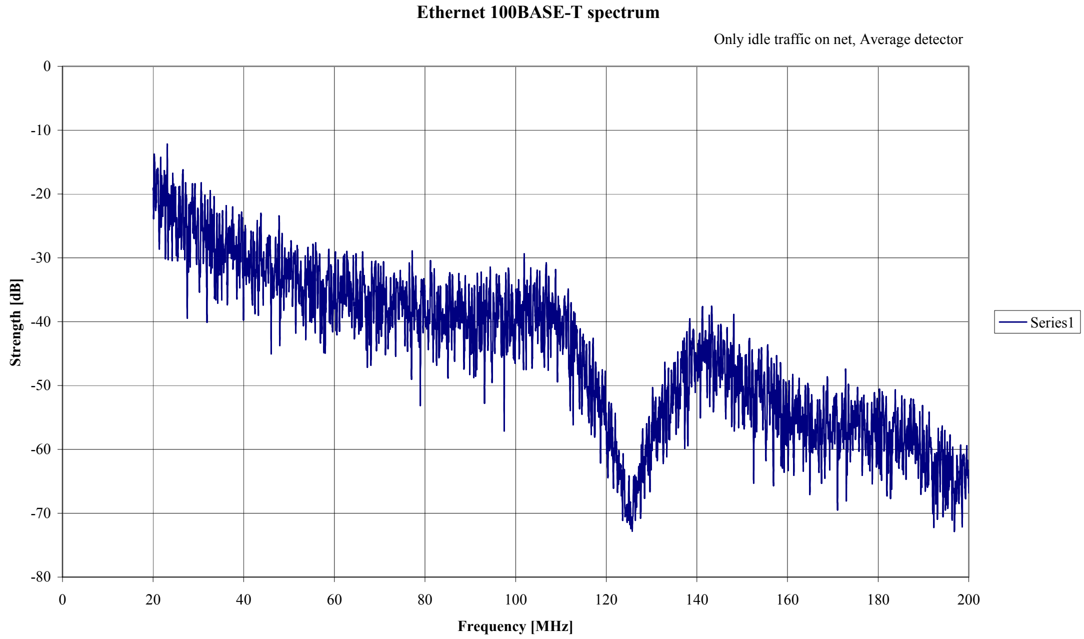

Figure 10. 100BASE-T spectrum. Idle traffic, Average detector.

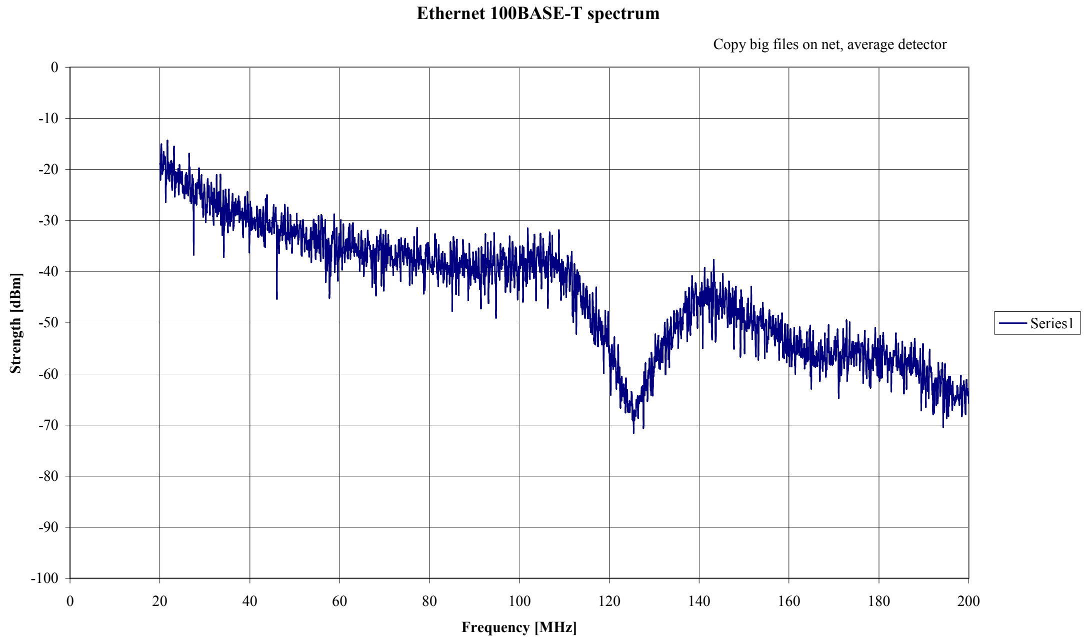

Figure 11. 100BASE-T spectrum. Copy big files, Average detector.

It is seen from the graphs that the measured peak emissions show very little dependency on the rate of traffic. This is true for all the detectors. The reference detector for EMI measurements is the quasi peak detector. This detector gives the same results as the peak detector for these kinds of signals. It can also be seen that the measured spectrum is very close to the theoretical spectrum of fig. 3.
In the first version of this document, 3Bor048a, I made a correction for 10 % traffic rate of 10 dB. The results show that this is not true. This correction has therefore been taken out of this version of the document.

9 Measured spectrum for 1000 BASE-T

The spectrum for 1000 BASE-T was measured in the same way as shown in clause 8. Two network interface cards from Intel was used[1]
The signal on one pair was measured. As there are signals on all four pairs, 6 dB's was added to the result. The measurement was performed with the peak detector with only idle traffic and with transmission of signals. The results are not dependant of the rate of traffic. For this reason only one graph is shown here.

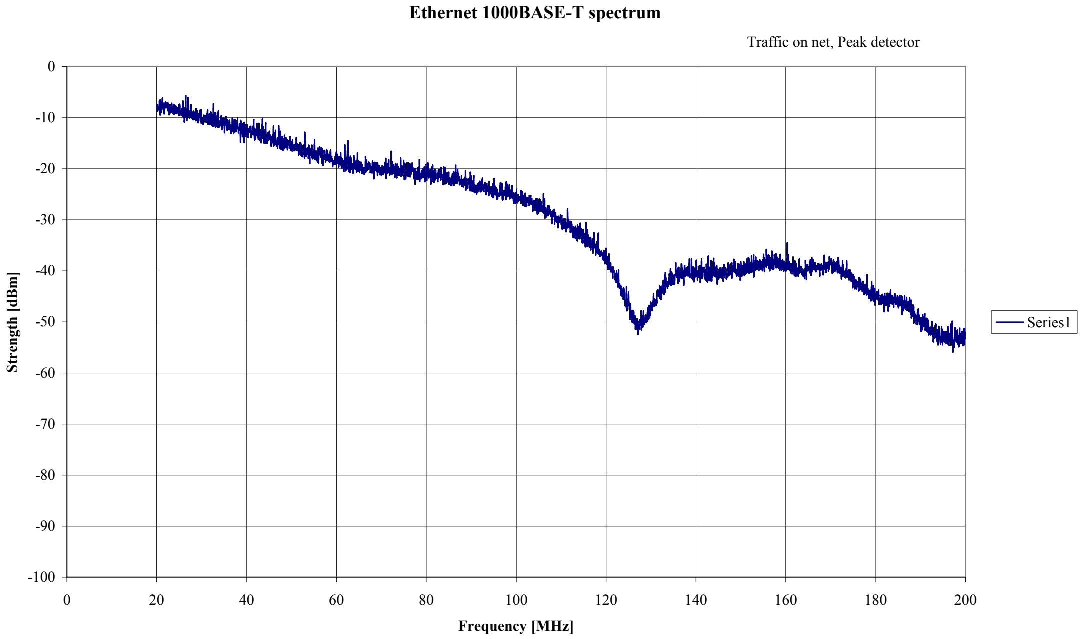

Figure 12. Signal spectrum for 1000 BASE-T. Traffic on net. Peak detector.

This result is very close to the prediction in clause 7.3.2

10 Measurements in anechoic chamber

10.1 Overview

A series of measurements were performed in an anechoic chamber on a 1000 BASE-T system in order to get some practical experience and see if the theory can be used.
A system was build with two computers, which were programmed for data transmission via a 1000 BASE-T Channel. These computers were placed outside the test chamber. The signals were fed into the chamber by well screened data cables, the screens of which were bonded to the screen of the chamber. In the chamber a channel was mounted on the cabling set-up, which was developed in the standardisation group ISO/IEC JTC 1/SC 25/WG 3.

Radiation and immunity performance was measured for one unscreened and one screened channel.

[1] Intel PRO/1000 MT Server Adapter

The unscreened channel was a class E channel, build with category 6 components. The channel consisted of one horizontal cable, two flexible cables, one patch panel and one wall outlet.
The screened channel configuration was the same as the unscreened channel. The cables were individually foil screened pairs with an overall braid screen.

A picture of the set-up is shown in figure 13.


Figure 13. Channel in anechoic chamber.

10.2 Radiated emission

The radiated emission was measured in the frequency range of 30 MHz to 1000 MHz. The results are shown in figure 14, 15 and 16. The shown graphs are for the worst case orientation of the receiving antenna, polarization vertical, height 1 m. The two graphs for the unscreened channel are one (fig. 13) where the unscreened cords are connected directly to the screened feeding cables and the other (fig. 14) where ferrite absorbers were inserted on the cords in order to suppress the influence of signal unbalance on the measurements. This is done because the goal of this document is to investigate the contribution on EMC from the cabling system alone.
The configuration with the absorbers is shown in figure 14.

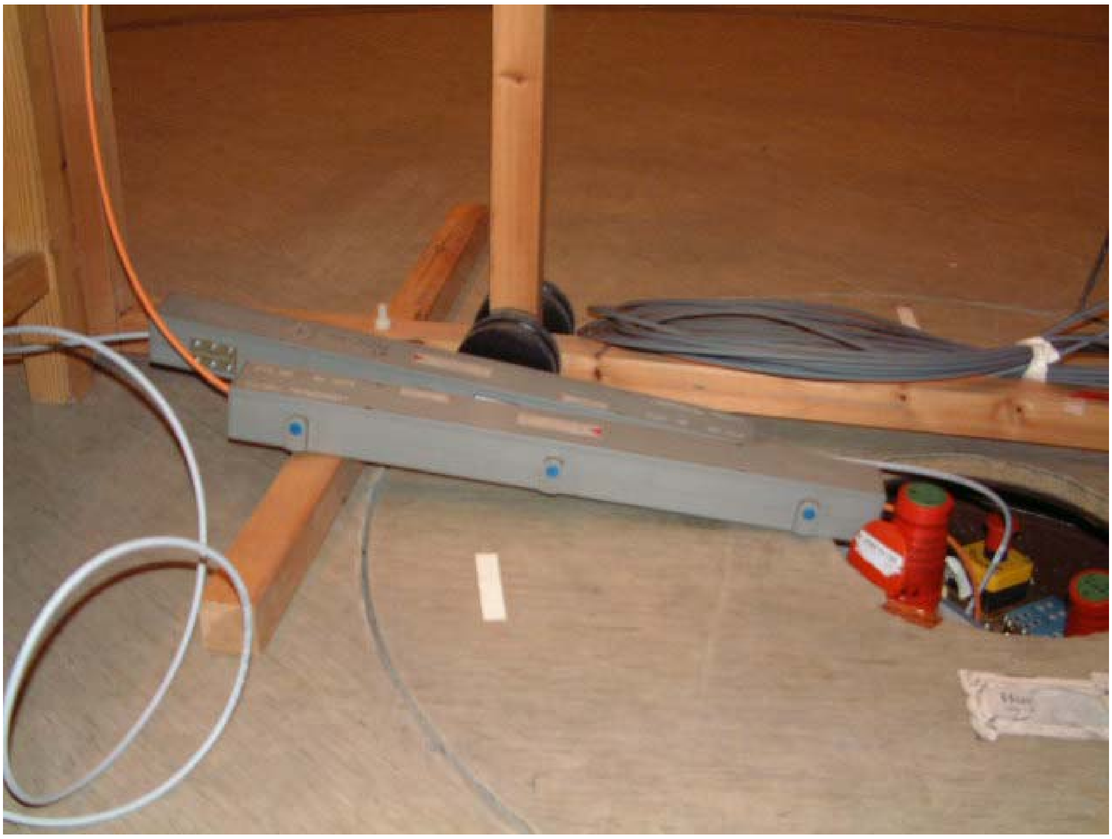

Figure 14. Ferrite absorbers.

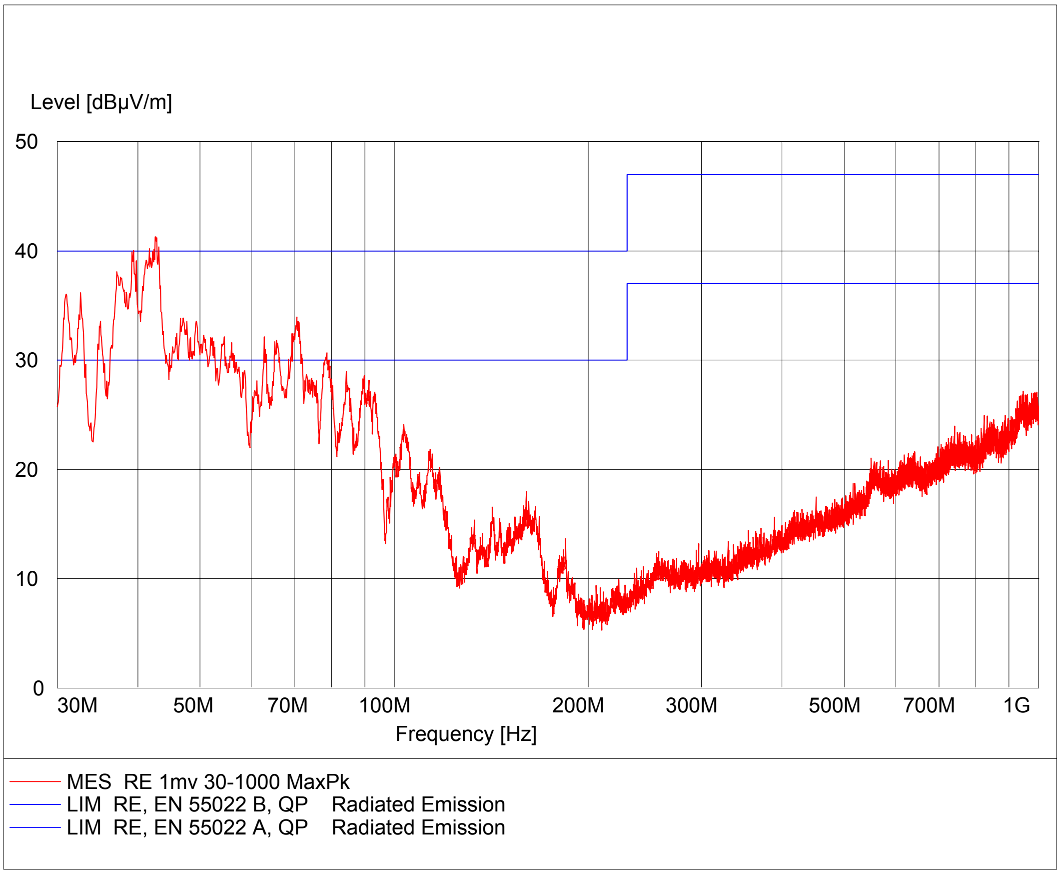

Figure 15. Radiated emission for UTP channel. Without ferrite absorbers.

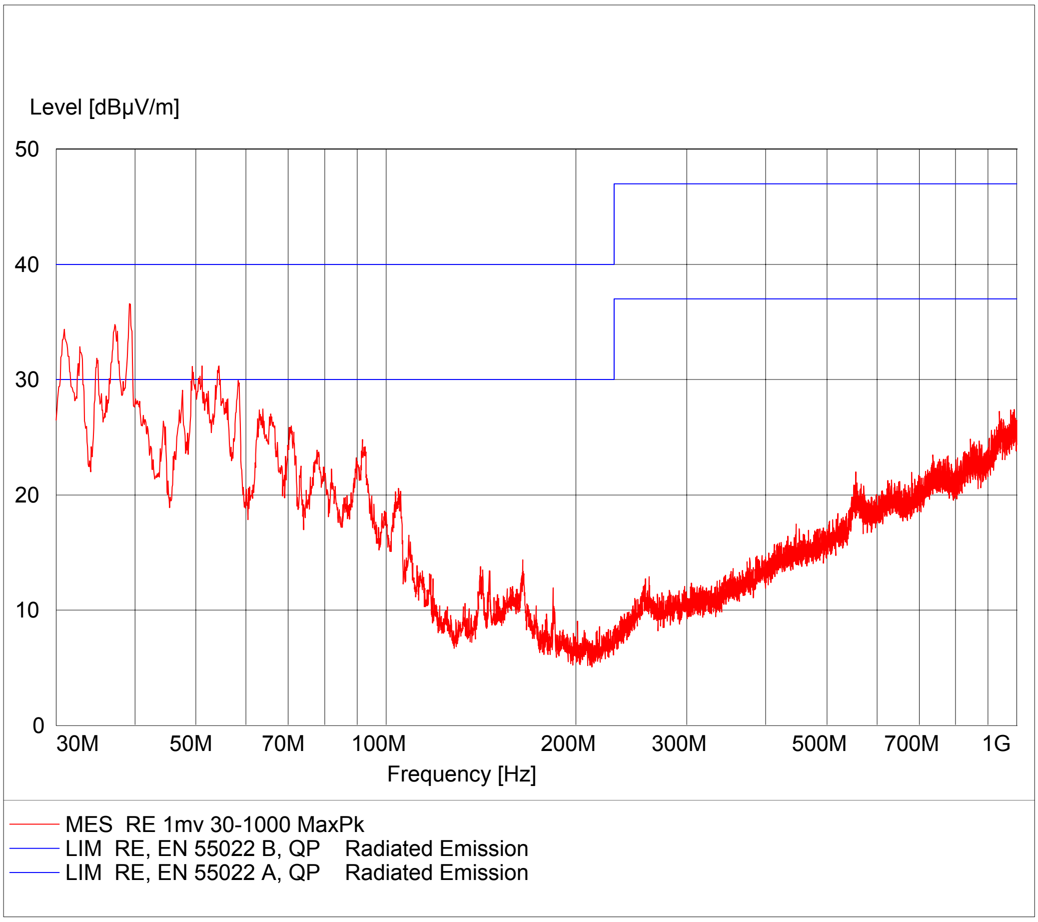

Figure 16. Radiated emission for UTP channel. With ferrite absorbers.

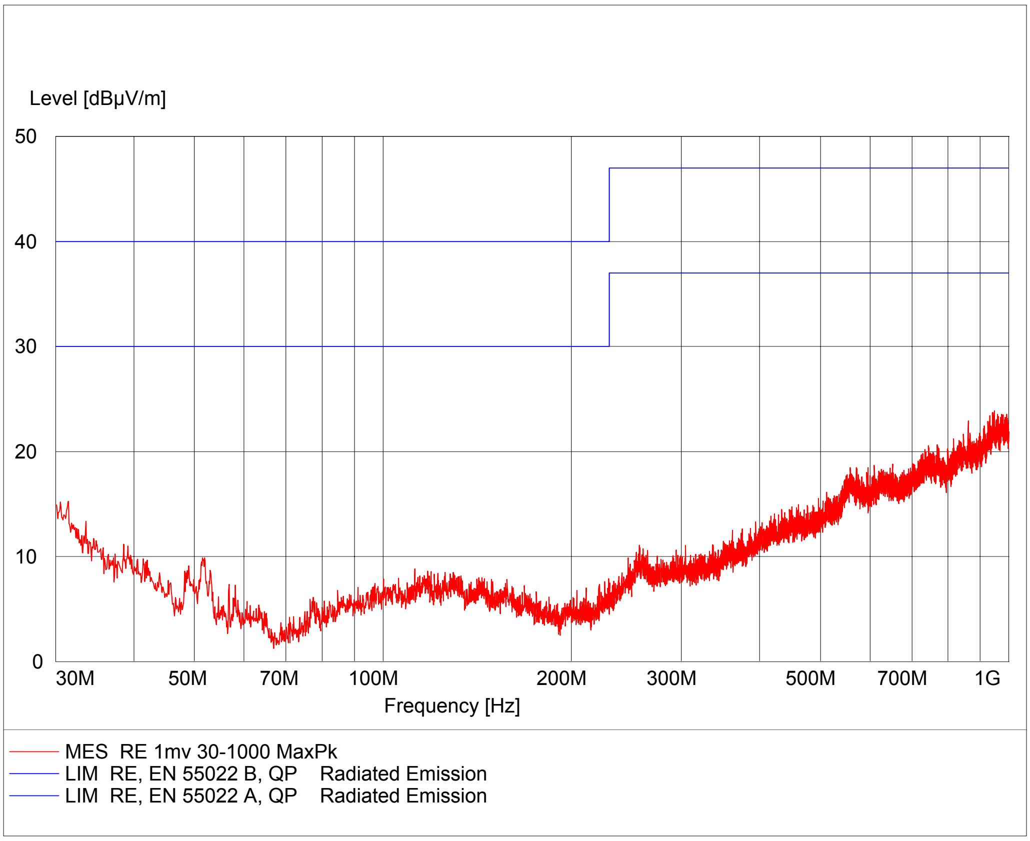

Figure 17. Radiated emission for FTP channel

The results show that the unscreened channel exceeds the class B limit by 11 dB at 35 MHz (figure 15) and 6 dB when absorbers are inserted (figure 16). The screened channel complies with the limit. For the screened channel most of the radiated noise is hidden by the noise floor of the test set-up. Around 50 MHz a peak may be seen. From this it can be concluded that the radiation from the screened channel is about 22 dB attenuated in respect to the radiation from the unscreened channel.

10.3 Radiated immunity

The channels were tested for radiated immunity in the frequency range of 80 MHz to 200 MHz.

It was found that the unscreened channel passed the requirement for 3 V/m field at all the frequencies from 80 MHz to 200 MHz, and the requirement for 10 V/m at frequencies from 90 MHz to 200 MHz. In the frequency range between 80 MHz and 90 MHz, the communication link stopped functioning at some frequencies for higher field strengths than 3 V/m.

The screened channel passed the requirement for 10 V/m at all frequencies in the tested range.

10.4 Conducted immunity

The theoretical analysis in this document does not cover conducted immunity, but for completeness this was measured. The test was performed in the frequency range of

0.15 MHz to 80 MHz. During the test a common mode signal was injected into the one flexible cord of the channel in the direction of the closest computer. The current was calibrated in order to simulate a field according to the relevant EMC standard.

The unscreened channel passed the test for signal strength of 1 V/m. At 3 V/m the transmission stopped at several frequencies between 6 MHz and 50 MHz. At 10 V/m the communication link stopped functioning at frequencies higher than 2.3 MHz

The screened channel passed the test for 10 V/m at all the test frequencies.

For both radiated and conducted immunity measurements the disturbing signal was a carrier with 80% amplitude modulation, 1000 Hz.

10.5 Coupling attenuation

The coupling attenuation of the two channels was measured in order to see if this parameter can explain the results.

The graphs presented here are the worst case results for the measurements at different positions in the channel.

The coupling attenuation of the unscreened channel is shown in figure 18 and of the screened channel in figure 19.

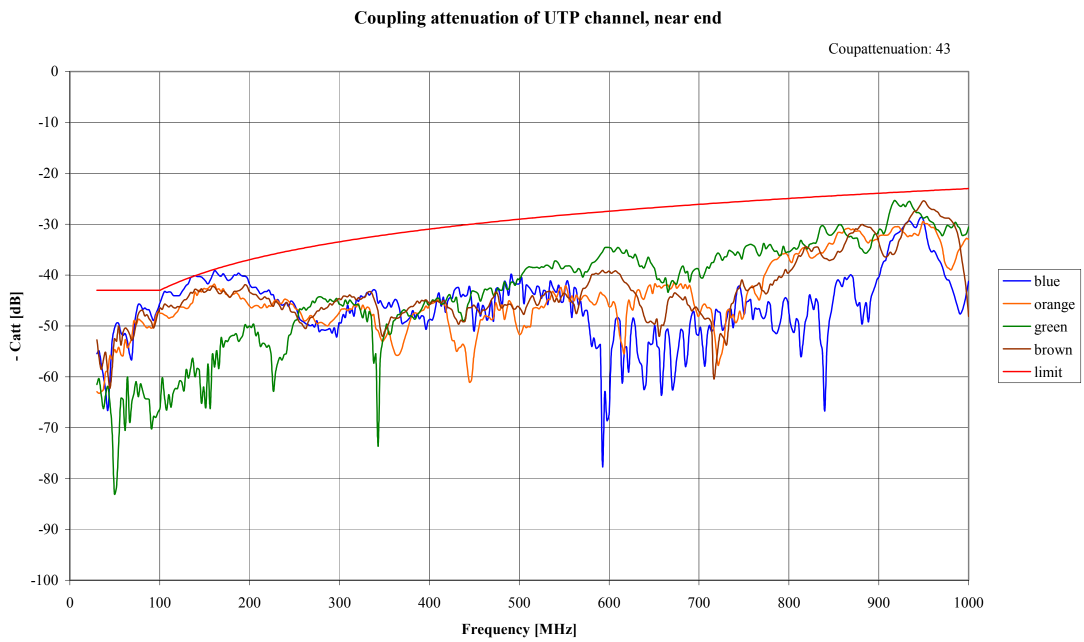

Figure 18. Coupling attenuation of UTP channel.

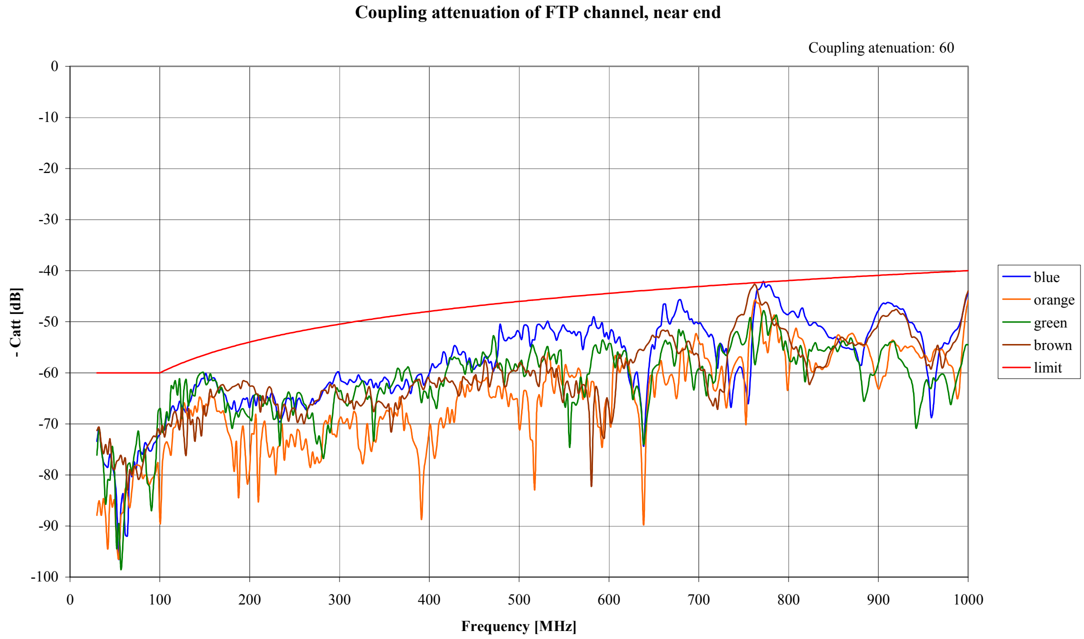

Figure 19. Coupling attenuation of S-FTP channel.

10.6 Comparison between radiated emission and coupling attenuation.

In clause 7.3.2 it is concluded that a coupling attenuation of 42 dB is required for compliance with the class B limit. The measured coupling attenuation of the UTP channel is 43 dB. Despite this, the limit is exceeded about 6 dB. This is within the expected accuracy of the prediction. The reason may be that coupling attenuation is measured under idealised conditions, while the channel in the test chamber is mounted on a support, which is not ideal. The assumptions for the calculations were that the set-up has a gain of 0 dB (act as a unidirectional antenna). In practice it will give gain at certain frequencies and attenuation at others. The prediction in clause 7.3.2 does not take the unbalance of the transmitter and receiver into account. This is because the goal of the document is to predict the influence from the cabling. During measurement of emission from the unscreened channel, ferrite absorbers were used to suppress influence from unbalance of the signal fed to the cabling.

For the screened channel the radiated emission is attenuated around 16 dB. The measured coupling attenuation for the screened channel is 60 dB, which is 17 dB better than the unscreened channel. The correlation between radiated emission and coupling attenuation is therefore clear.

10.7 Comparison between radiated immunity and coupling attenuation.

In clause 7.3.3 and clause 7.2.3 it was predicted that 50 dB coupling attenuation would be required at 30 MHz to comply with the 3V/m requirement. For the UTP channel the coupling attenuation is less and it is also shown that the requirement is not met. A coupling attenuation of 60 dB was predicted as needed for the 10 V/m

requirements. This is obtained for the screened channel. It is also shown that the screened channel comply with the 10 V/m limit.
The agreement between the prediction and measurement is very good and better than would be expected.

11 Conclusion

A convenient 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 to 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 compliance of cabling per se with the calculated EM requirements is a necessary but insufficient condition for system EMC compliance. It is also important that the active equipment is in compliance when tested in accordance with CISPR 22.

The comparison between the predicted and the measured results show excellent agreement.