Evaluation of proposed generic cabling set-up to be included in EMC testing of information technology equipment based on radiation emission tests.

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1. Version January 1997
2. Version March 1997

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1. Introduction

In the Sydney meeting, Feb. 1996, of JTC 1/SC 25/WG 3, the work group responsible for the generic cabling standard ISO/IEC 11801it was noticed that many test results of EMC properties of cabling was published. These results were all obtained for different configurations of the cabling. It was therefor difficult to compare the results and difficult to use the conclusions for justifying compliance with the EMC standards for the tested cabling system. Firstly it was made clear that a cabling system, as a passive device, can not be stated as compliant with EMC standards. If compliance is proved for an active system communicating via the cabling system in question it can be stated that compliance is possible for a system using this cabling system for transmission of the LAN architecture, which was used for the test. Secondly it was proposed to define a standardised cabling set-up for future use in order to be able to get reproducible test results. It was also proposed to send a liaison letter to CISPR/G to propose the set-up for use when IT equipment is tested for EMC compliance.

In the London meeting, June 1996 of the work group, the set-up was defined and the liaison written. This report describes the first results using the set-up for measurements.

2. Scope

The scope of this report is to evaluate the feasibility of the proposed cabling set-up. At first the properties of the set-up as a radiating element is evaluated. The radiated emission, compared to the emission of a dipole antenna, is measured and it is investigated if the relative gain is approximately constant over the frequency range. Secondly the properties of the set-up connected to IT equipment under test for EMC compliance are evaluated. At last the voltage developed at the cabling interface caused by an interfering field is measured, and based on the results, the coupling attenuation of the cabling link calculated.

3. Document revision history

The first versions of this document were written in December 1996 and january 1997. IT was presented at the meeting of JTC 1/SC 25/WG 3 in Barcelona January 1997. In this meeting it was proposed to perform additional measurements in order to investigate the repeatability of the tests. The new tests regarding the properties of the set-up when it is subject to an electromagnetic field, was performed in February, and this report is based on the new results (for details see section 10).

4. Proposed generic cabling set-up

The proposed set-up is depicted in Fig. 1.

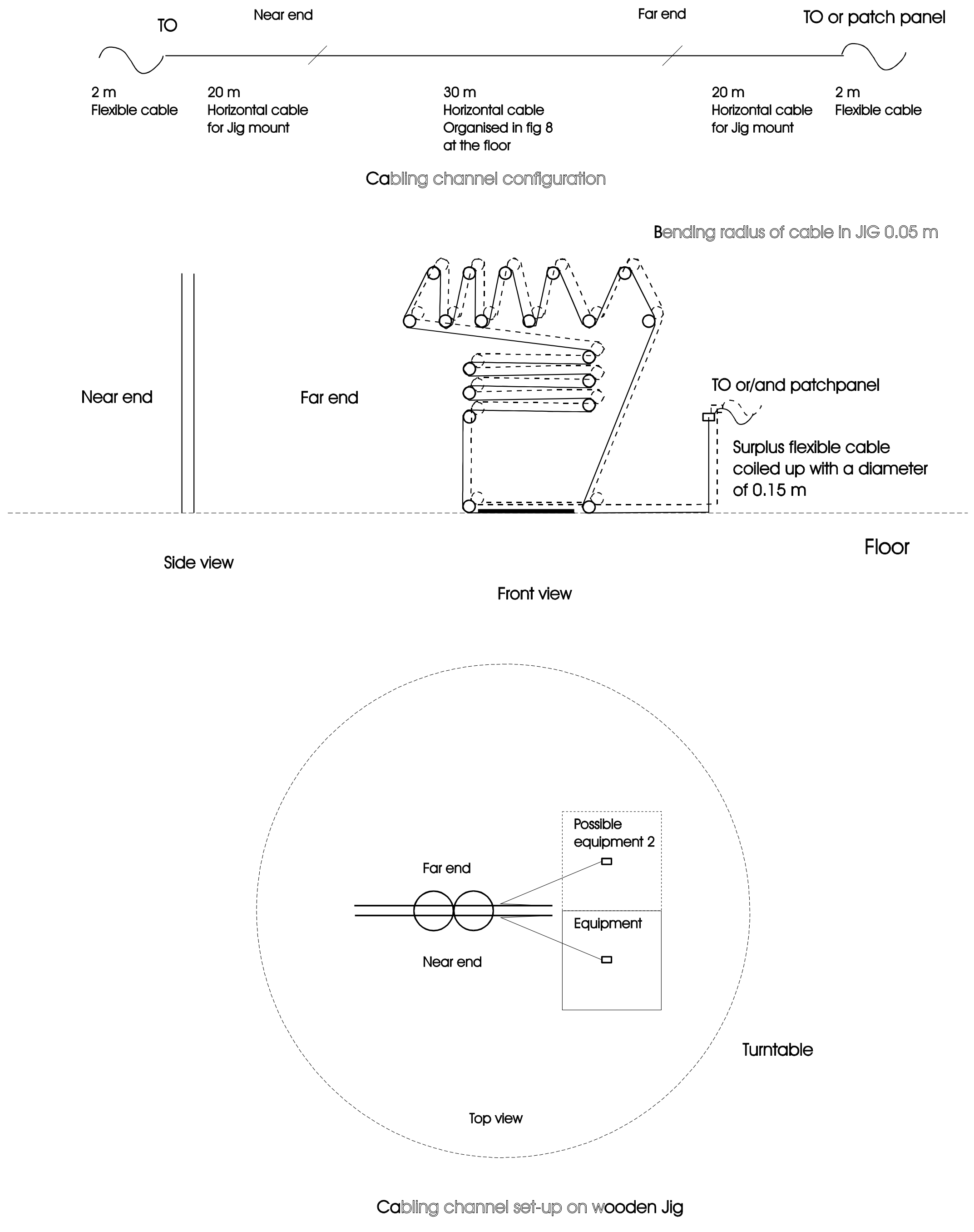

Fig. 1 Cabling set-up

A total of 70 m horizontal cable is wound up on a wooden support as shown. One half of the cable is on one side, while the other half is on the other side. The distance between the two sides is 10 cm. At a height of about 80 cm above the floor, telecommunication outlets or patch panels are terminating the cable. From this points flexible cables are connected to the equipment under test. If none or only one equipment is placed inside the test chamber, then cables under the floor are connected to the outlets. These cables provides the necessary signals for making the equipment operate. They are well screened and the screen is connected to the screen of the chamber, where they are fed through the wall. The reason for only using 70 instead of 90 m horizontal cable in the set-up, is to allow for some attenuation in the feeding cable's.

A photography of the proposed set-up is shown at Fig. 2

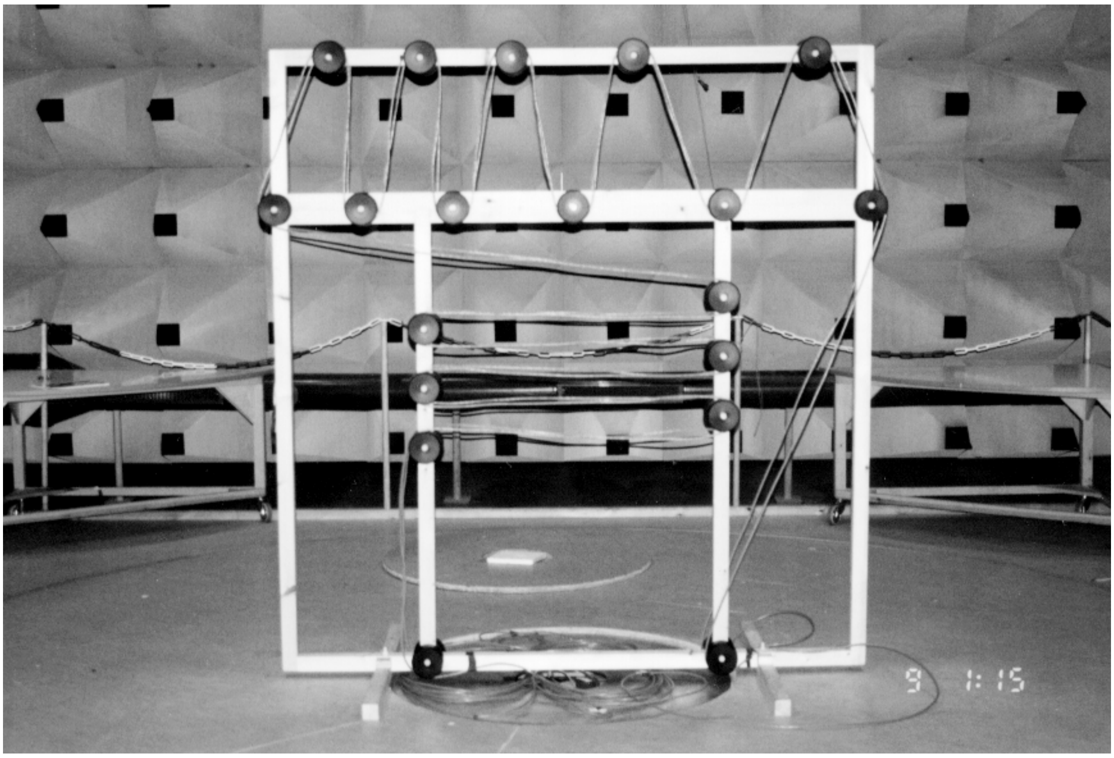

Fig. 2 Proposed cabling set-up.

A close up to show the deployment of excess cable (from the middle of the link) on the floor is shown in Fig. 3.

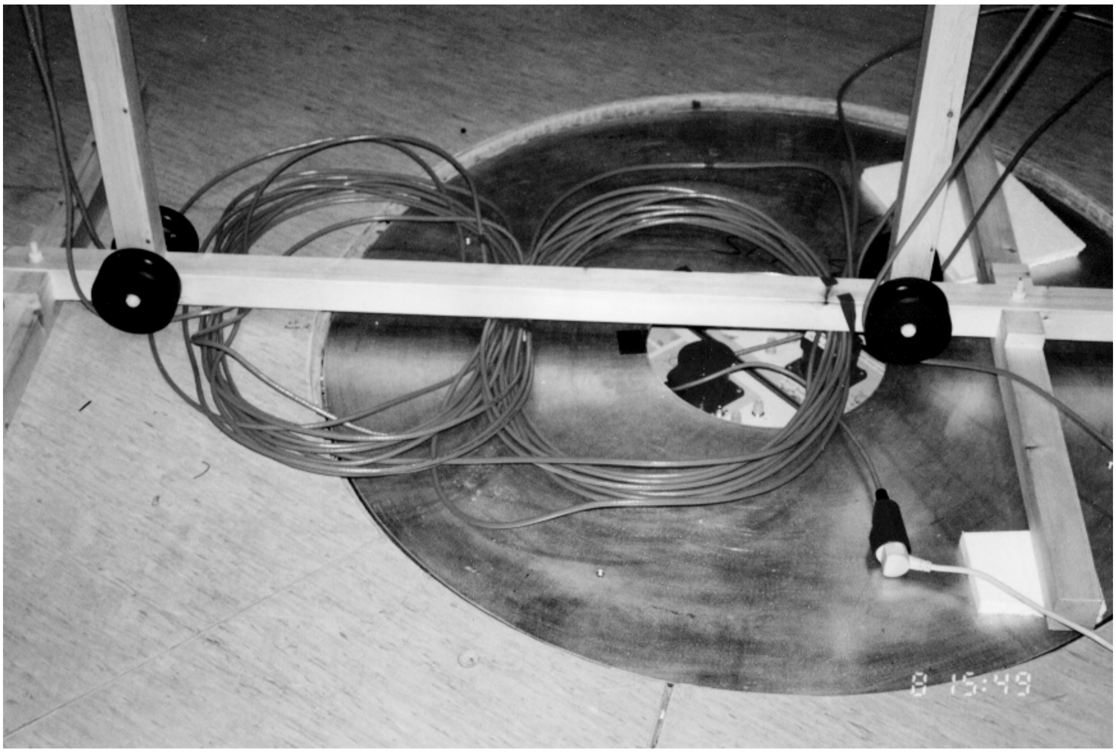

Fig. 3 Deployment of excess cable.

4. Radiation properties of the generic cabling set-up compared to an ideal dipole.

For the set-up to be usable for EMC tests, it is advantageous if it acts as a broadband radiating element, and if it has no major directional characteristics. Also it is beneficial if the polarisation of the radiated fields from the set-up is variable. If this is the case, the set-up will not suppress or enhance certain frequency ranges, and the direction to the test set-up and polarisation of the receiving antenna will not be critical.

In order to investigate if the proposed set-up is complying with these requirements, the radiation properties was measured when the set-up was exited by a common mode signal. The test was performed by use of a network analyser. The output signal of the analyser was connected to the one end of the cable in the set-up. The cable was a FTP data cable. The signal was connected to the screen, while the return patch was the ground plane (floor) of the chamber. The other end of the cable was connected to ground by a resistance of 300 Ω. The input test port of the analyser was connected to the receiving antenna of the chamber.

At first the site attenuation of this set-up was measured for the receiving antenna position 1 m vertical and 4 m horizontal. These positions gives the minimum attenuation. The measurements were performed for the turntable angle of 0°, 45° and 90°. At an angle of 0° the plane of the cabling set-up is perpendicular to the direction to the antenna. The result showed that the minimum attenuation is obtained for the direction 0°. At the lower frequencies minimum attenuation is with 1 m vertical polarisation, while at the higher frequencies minimum attenuation is with 4 m horizontal polarisation antenna. The attenuation for the other positions is not far from the minimum attenuation. This show that the set-up has no dominant direction or polarisation of the radiated signal.

Secondly the site attenuation of a test dipole, which replaced the cabling set-up, was measured. The test dipole was adjusted for resonance at the frequencies, 40, 95, 200, 500 and 1000 MHz. Horizontal polarisation was used and the height of the receiving antenna was adjusted for minimum attenuation for each measurement. By comparing the maximum envelope of the attenuation plots (horizontal and vertical polarisation) for the set-up, with the results for the dipoles, the relative antenna gain for the set-up referenced to a dipole was obtained. The procedure for obtaining the relative gain of the set-up is shown in Fig. 4 - 5. Figure 4 shows the site attenuation of the set-up (1 m vertical). Fig. 5 show the site attenuation for the dipole adjusted for resonance at 200 MHz.

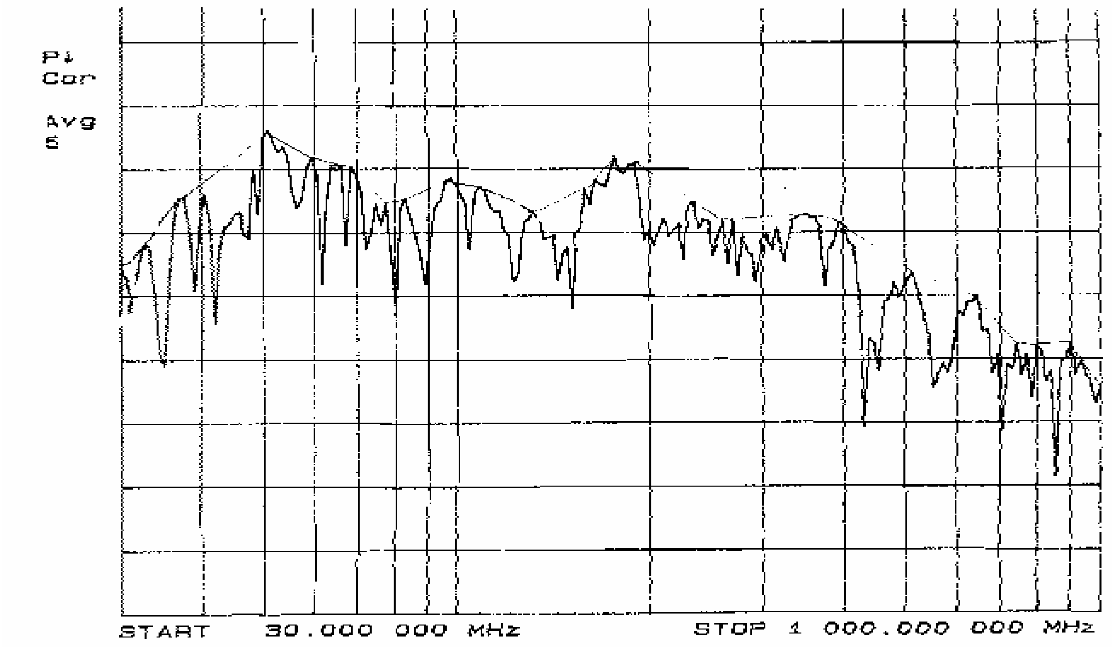

Fig. 4. Site attenuation of cabling set-up. Common mode excitation.

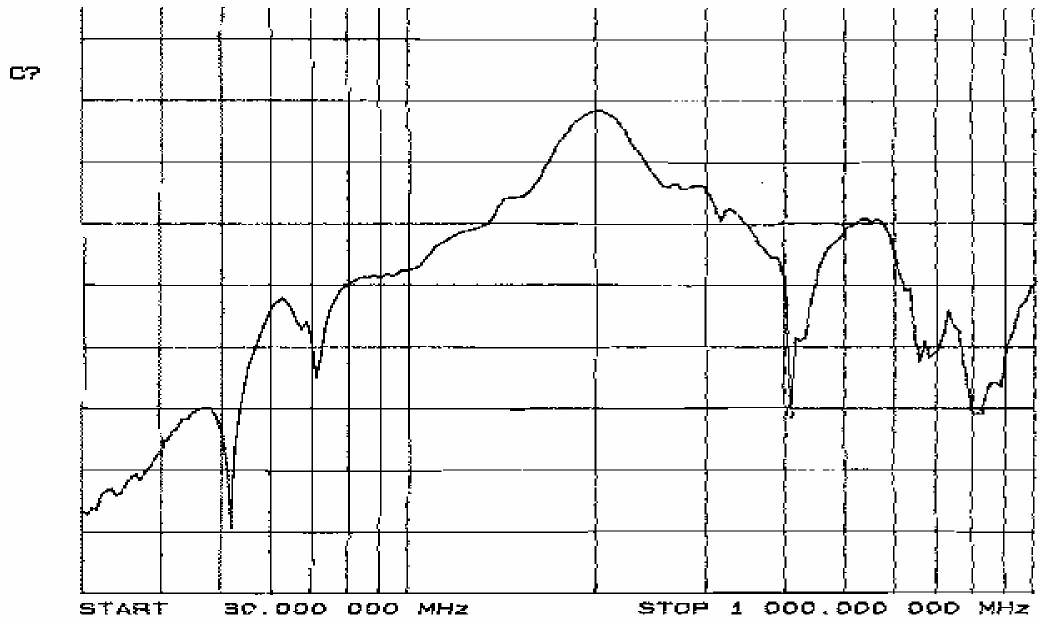

Fig. 5. Site attenuation of dipole adjusted for resonance at 200 MHz.

In table 1 the calculated relative gain of the set-up is shown.

Frequency	40 MHz	95 MHz	200 MHz	500 MHz	1000 MHz
Relative gain	+3 dB	-5 dB	-8 dB	-4 dB	-5 dB

It is concluded that the relative gain of the cabling set-up is quite constant over the frequency range and that the set-up has no dominant polarisation or directional characteristic. This is advantageous for use of the set-up to characterise EMC performance of connected electronic equipment as well as for characterising coupling attenuation performance of cabling. It is not anticipated that it is possible to construct another configuration, which is better than the proposed set-up in respect to gain variations and polarisation insensitivity.

5. General radiated emission considerations

In order to observe the European EMC directive, electronic equipment and installations must not emit harmful electromagnetic noise or be subject to disturbances from electromagnetic noise. Conformance may be demonstrated by issuing a technical construction file or refer to compliance with harmonised standards. The harmonised standard for radiated emission of information technology equipment is EN 55022. The equipment has to fulfil requirements according to class A or class B. Radiated emissions are measured in the frequency range of 30 MHz to 1000 MHz. The class A limits are 40 dBμV/m from 30 MHz to 230 MHz and 47 dBμV/m from 230 MHz to 1000 MHz in a distance of 10 m, while class B limits are 10 dB lower. Class A equipment is intended for application in industrial areas while class B equipment is intended to be used in domestic areas.

6. Radiation properties of test PC running 100 Mb/s Ethernet tested according to EN 55022.

The radiated emission of a PC running 100 Mb/s Ethernet was tested according to EN 55022: “Limits and methods of measurement of radio disturbance characteristics of information technology equipment”. In this standard the configuration of the equipment under test is specified in section 9.1. It is stated that a worst case configuration shall be used, and that it shall be noted if screened cables are used for the test. No exact directions for the layout of cabling is given. For the test performed here the LAN cable is extended horizontally from the PC in a length of 1 m, then guided to the floor (see fig. 6).

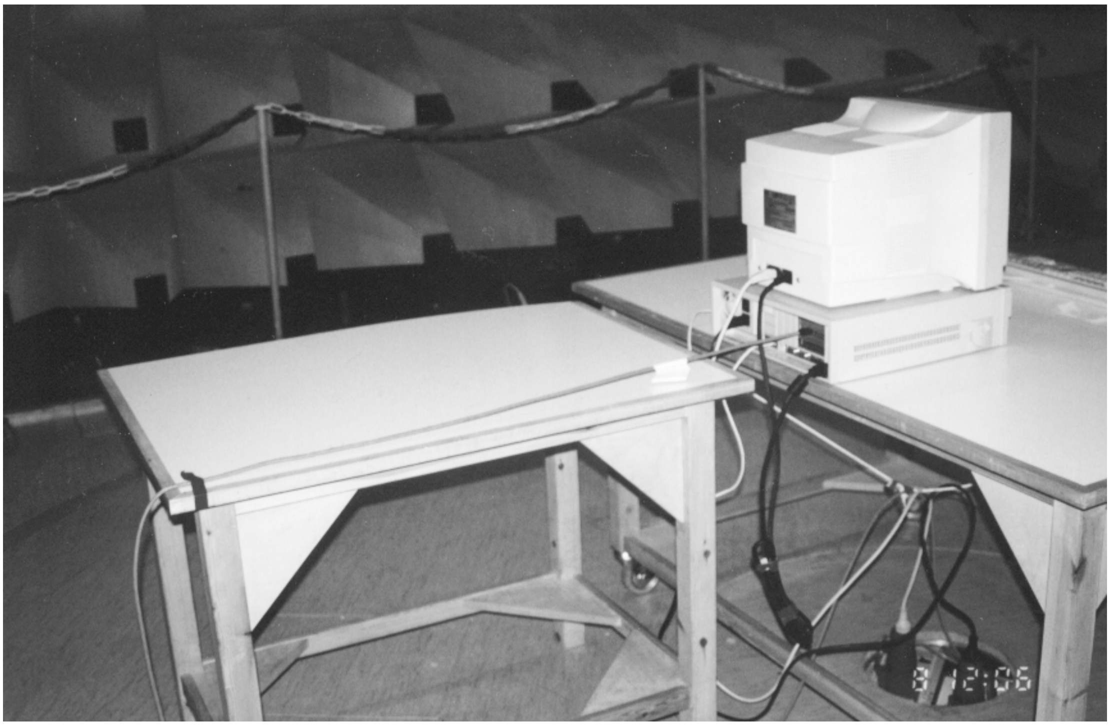

Fig 6 Radiated emission set-up according to CISPR 22.

The result for the radiation test is shown in Fig. 7 - 8.

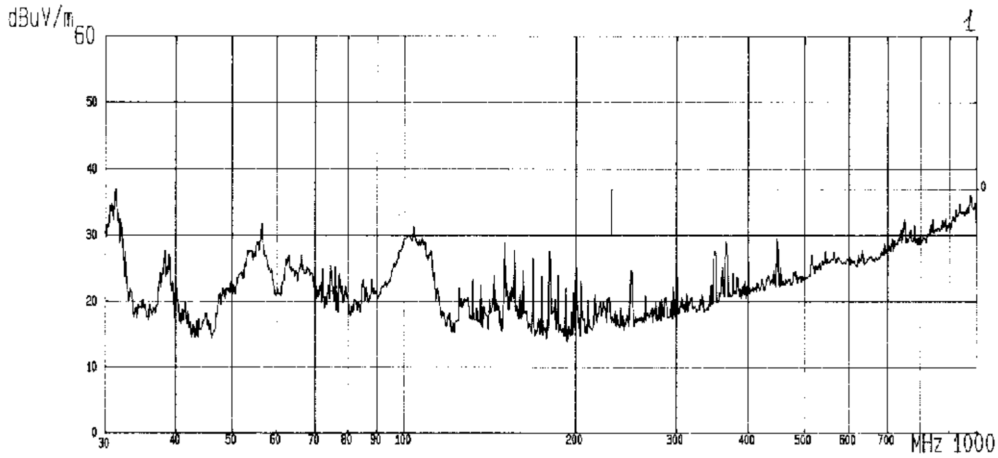

Fig. 7. Radiated emission for PC with UTP cable.

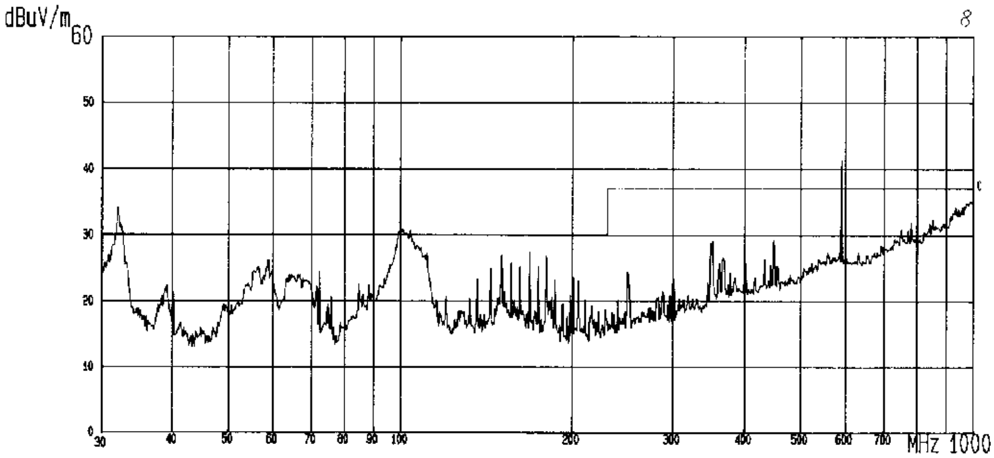

Fig. 8. Radiated emission for PC with S-FTP cable.

Fig. 7 shows the radiation for the set-up, connected with UTP cable. The radiation is measured with vertical polarisation at an antenna height of 1 m. This is the antenna configuration which received maximum radiation. The radiation was also measured for horizontal polarisation. The radiated emission for this polarisation is much lower than for vertical polarisation. To save pages these plots are omitted in the report. It is seen from Fig. 7 that limit B is just exceeded at some frequencies.

Fig. 8 shows the radiation for the same set-up, but now a S-FTP cable is used. It can be seen that the radiation for the two configurations are the same. There is no influence from the kind of cable used. The direct radiation from the PC equipment masks the radiation from the LAN cable.

7. Radiation properties of test PC connected to proposed cabling set-up.

The PC was connected to the proposed cabling set-up and radiation properties measured. The set-up is shown in Fig. 9.

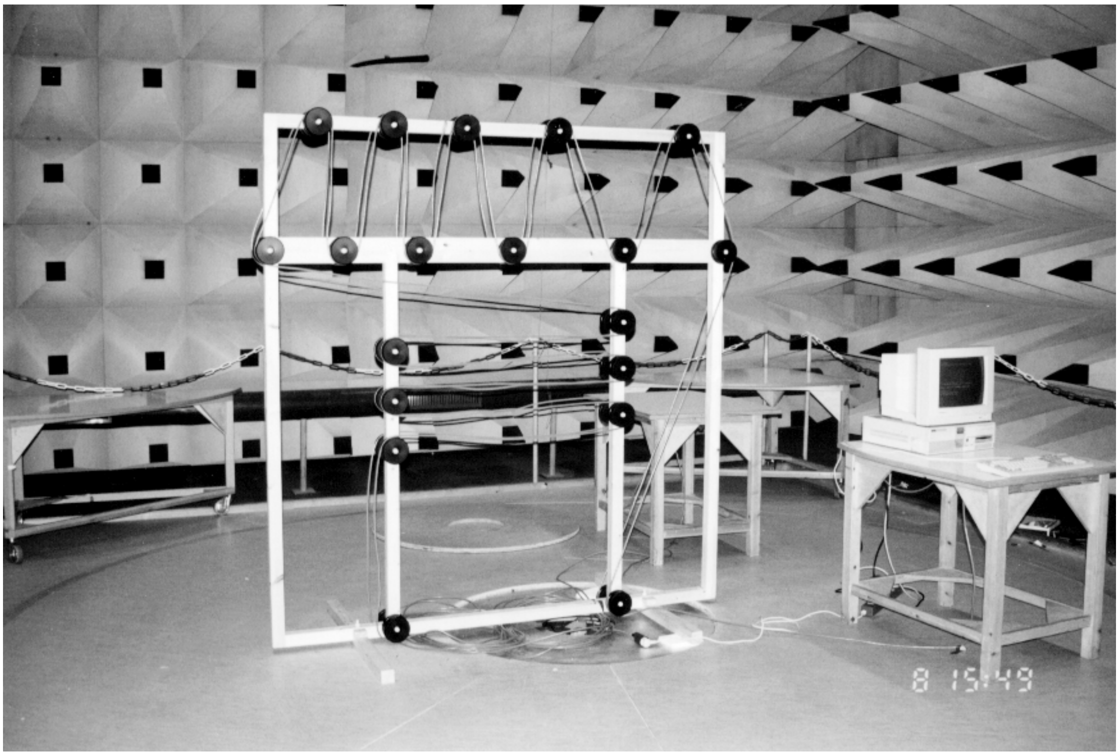

Fig. 9 Cabling set-up attached to a PC

The measured radiation from the PC connected to an UTP link is shown on Fig. 10. The measured points marked with a * is maximised quasi peak radiation.

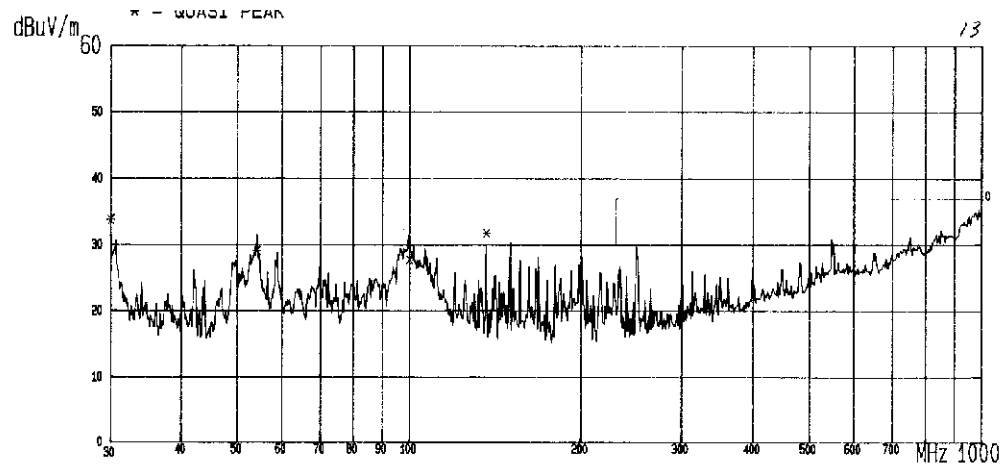

Fig. 10. Radiated emission. PC connected to UTP link.

The measured radiation from the PC connected to a S-FTP link is shown on Fig. 11.

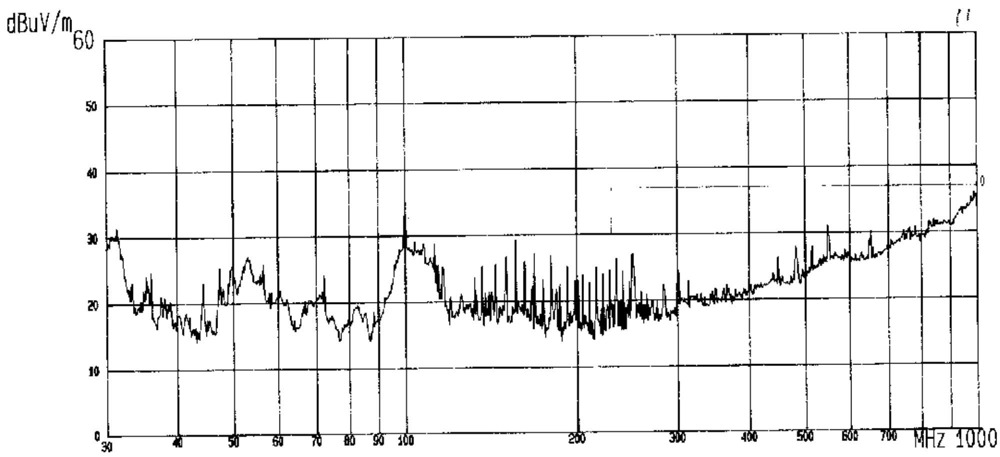

Fig. 11. Radiated emission. PC connected to S-FTP link.

It is seen that radiation is only influenced a little by the kind of cabling used. The direct radiation from the PC is dominant in respect to the radiation from the cabling system.

8. Radiation properties of proposed cabling set-up conducting 100 Mb/s signals.

Measurements were performed using a set-up with the cabling fixture placed in the EMC test chamber and the active equipment placed outside. The communications signals were connected to the cabling under test by two well screened cables drawn in conduits under the floor of the chamber. The screens of these cables were connected to the screen of the chamber where the cable was fed in. As the set-up is wished to model a situation where the output circuit of the electronics is connected directly to the cabling, the attenuation of the feeding cable has to be accounted for. The levels of the measured radiation shall be increased by the attenuation values.

The attenuation of the feeding cable is tabled in table 2.

Frequency	50 MHz	100 MHz	500 MHz	1000 MHz
Attenuation	3 d**B**	4 dB	11 dB	22 dB

Table 2. Attenuation of feeding cable.

The radiated emission from the 100 Base T signals were measured for the fixture mounted with unscreened and screened cabling.

The results for the unscreened cabling is shown in Fig. 12. The emissions are generally 6 dB below the class B limit. Also after correction for the attenuation of the feeding cable (table 2) the class B limit is observed.

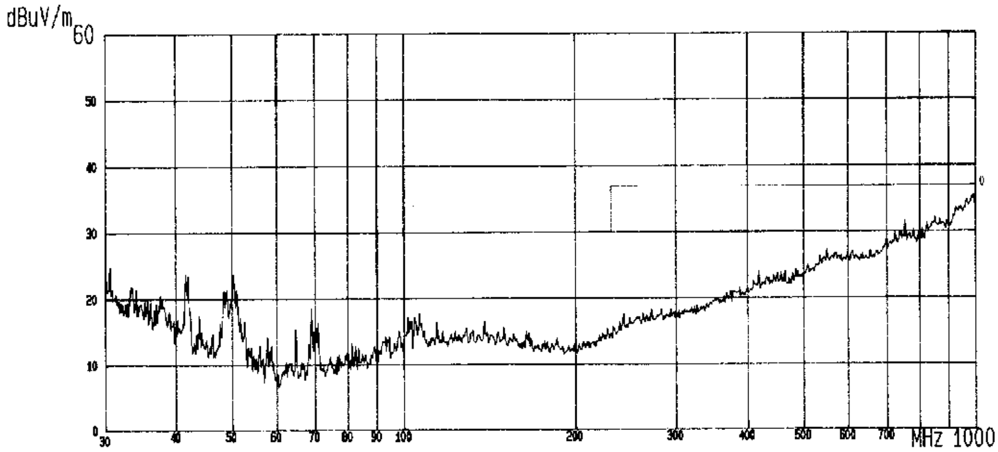

Fig. 12. Emissions from UTP cabling. Active equipment outside test chamber.

The results for screened (S-FTP) cabling is shown in Fig. 13. The emissions are hardly noticeable over the noise floor of the measurement system.

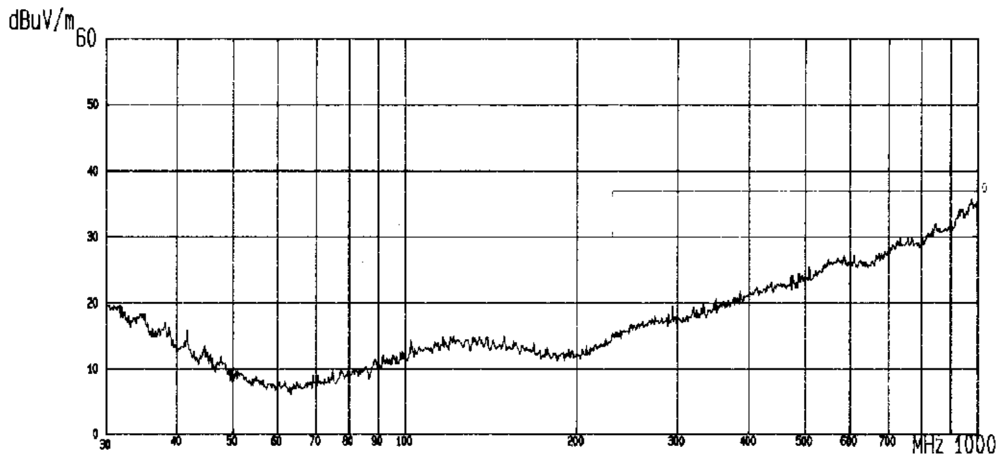

Fig. 13. Emissions from S-FTP cabling. Active equipment outside test chamber.

These results show that EMC requirements for radiated emission is observed for a link mounted in the proposed fixture, carrying signals for 100 Base T LAN. The results also show that screening reduces the radiation considerably.

9. Immunity considerations

The harmonised generic immunity standard EN 50082 is used for reference for measurements performed in this report. Equipment and installations have to fulfil requirements of part 1 or part 2 of EN 50082. Radiated immunity is measured in the frequency range of 27 MHz to 500 MHz (part 1)[1] and 80 MHz to 1000 MHz (part 2). The limits for radiated immunity are 3 V/m (part 1) and 10 V/m (part 2). Part 1 is for residential, commercial and light industry while part 2 is for industrial environment.

10. Received signal from cabling set-up exposed to a field of 3 V/m

For this report immunity was measured at the passive cabling link. The idea was to measure the differential noise voltages, which will be present at the interfaces to electronic equipment, when a disturbing radio frequency field is applied. Evaluation of signal levels in different architectures in respect to the measured noise can then tell if the noise levels are dangerous for the equipment. The final proof for EMC compliance is, however, still the responsibility of the equipment manufacturer, who shall test the electronics according to the EMC standards.

The test set-up for immunity tests is depicted in Fig. 14.

[1] In Annex A, EN 50082-1, a frequency range of 80 MHz to 1000 MHz is proposed. In the measurements performed in this report the full range of 26 MHz to 1000 MHz was investigated in order to get as much experience as possible.

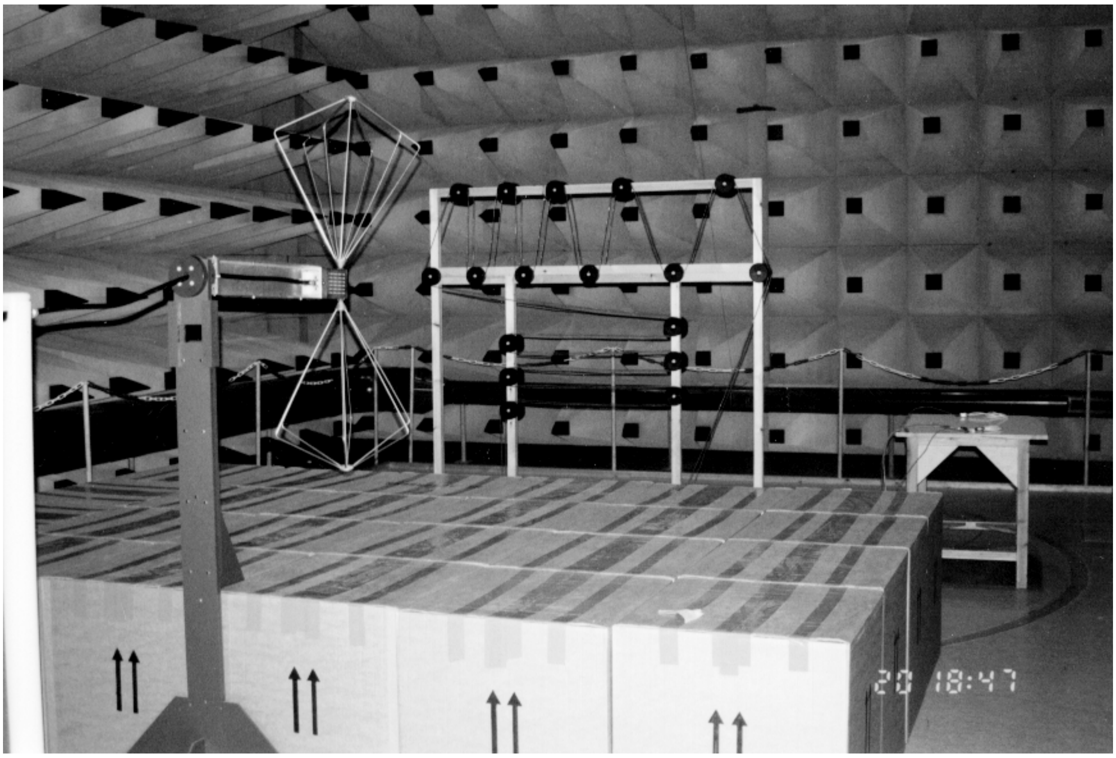

Fig. 14. Test set-up for immunity measurements.

Note: The cardboard boxes are contenting absorbers which serves to suppress reflections from the floor.

The results reported in the first version of this report was for the set-up exposed to a field of 3 V/m in the frequency range of 30 MHz to 1000 MHz. The signal frequency was shifted in steps every second. The signal was received by a spectrum analyser which scanned the frequency range with the max. hold function applied. At the new test session (Feb. 1997) the repeatability of the level measurement was tested. Variations of some dB's were found, and as inaccuracy of the signal level recording should not be influencing the accuracy of the measurement, it was decided to use a network analyser instead. Due to limited available test time, only the frequency area up to 200 MHz was measured.
The cabling set-up was exposed to a variable field and all the results corrected as if a field of 3 V/m was applied. The differential mode signal voltage caused by this field was measured by the network analyser. The signal was fed to the network analyser through a double screened coaxial cable, which was drawn along the floor directly to a feed through connector in the wall of the test chamber. A balun was used to convert the signal from balanced to unbalanced in order to match the coaxial system. The attenuation of the cable and balun was added to the measured level in order to get the signal level at an electronic equipment input terminal, if it was connected directly to the cabling. The far end of the cabling was terminated differentially with a 100 Ω resistor.

The ratio of common mode to differential mode signal at the cabling interface is of the same size of order as the balance of the cabling. This is around 40 dB. To measure a differential voltage, which is masked by a common mode voltage 100 times larger, requires very good common mode rejection of the balun. It was needed to improve the rejection ratio by applying an air wound balancing transformer in front of the balun. The correctness of the measurement was verified by taking a measurement where the 2 conductors in the tested pair was shorted.

The measured signal level, from the common mode signal, shall then be lower than the measured level when the conductors are not shorted.

When the screened system was tested, it was necessary to mount the balun directly at the wall of the test chamber. The flexible cable in the cabling set-up was then directly connected to the balun. If this was not done the balun and the coaxial cable would collect more signal than the cabling set-up. This is of course especially important for the tested S-FTP cabling, which has a very high screening efficiency.

The results for unscreened and screened cable (S-FTP) is shown in Fig. 15 - 16.

Note that all 4 pairs were measured.

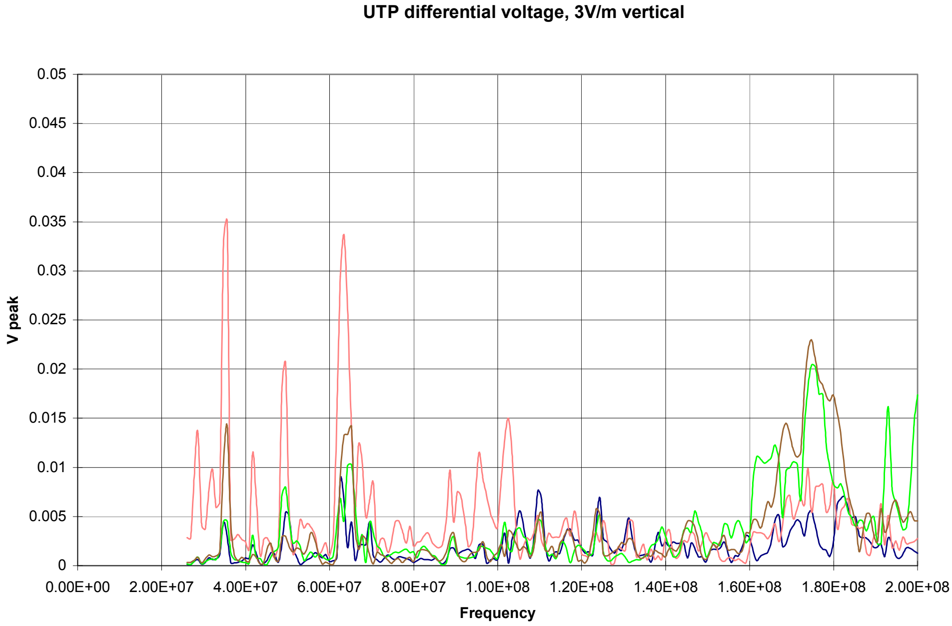

Fig. 15. Voltage at cabling interface, UTP cabling (vertical polarisation)

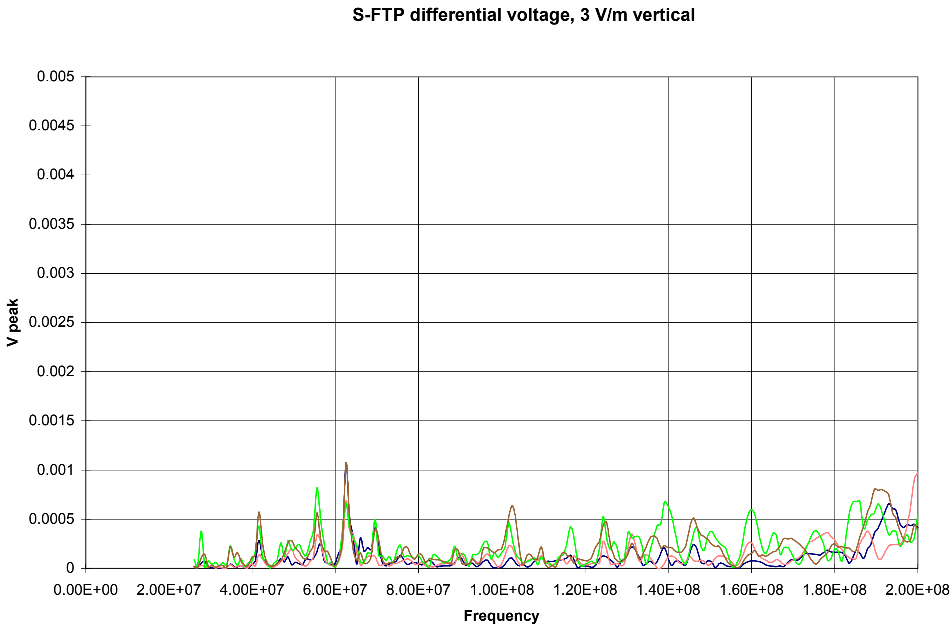

Fig. 16. Voltage at cabling interface, S-FTP cabling (vertical polarisation)

Note: Different scale on Y axis!

For the UTP cabling the maximum voltage was around 15 mVp with peaks up to 35 mVp.
For the S-FTP cabling the maximum voltage was around 0.5 mVp with peaks up to 1.1 mVp.
In the tested frequency range the screening attenuation of the screened link is then about 30 times or 30 dB.

11. Coupling attenuation properties based on the immunity measurements

The results of the measured voltage due to the radio frequency field can be used to determine the coupling attenuation of the cabling link.
Coupling attenuation is defined as the conducted power in a system with respect to the radiated power. Coupling attenuation is normally measured using the absorbing clamp method, which is standardised in IEC 1196 for determining screening attenuation of coaxial cables in the frequency range of 30 MHz to 1000 MHz. The definition for coupling attenuation can be used for balanced cabling as well as for coaxial cabling. For balanced cabling systems the coupling attenuation is the added attenuation of the radiated field due to balance and screening. The test method is now being developed as a standard for all cables by a CENELEC committee, TC 46X/WG 3.

As there is reciprocity in a passive system, one can also measure coupling attenuation by applying a field and measure the conducted power in the system.

None of the methods can perform the measurements strictly in accordance with the definition, as it is required to measure the total of the radiated power in all directions and for all polarisations. In the absorbing clamp method, the summation is performed by measuring near end and far end surface waves on the cable. Using an immunity test as proposed here the field comes from one direction, but measurements for two perpendicular polarisations can be included. A week point with this test is that the field intensity cannot be exactly the same over the complete area of the set-up, but it is interesting to note that the result both includes the property of cables and connectors in the link.

For a field strength of F = 3 V/m[2] as used in this test, the power density, Pd of the field is:

$$Pd = F^2/377 = 9/377 = 0.024 \text{ W/m}^2$$

This is 13.8 dBm pr. square metre.

As the area of the set-up is close to 2 m^2, the power flux through the set-up is 3 dB higher, that is 16.8 dBm.

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[2] As this test is performed at a linear system, a lower field strength may be used. This will relax the need for high power amplifiers for the test system.

In Fig. 17 and 18 the results are shown for the two cabling links investigated.

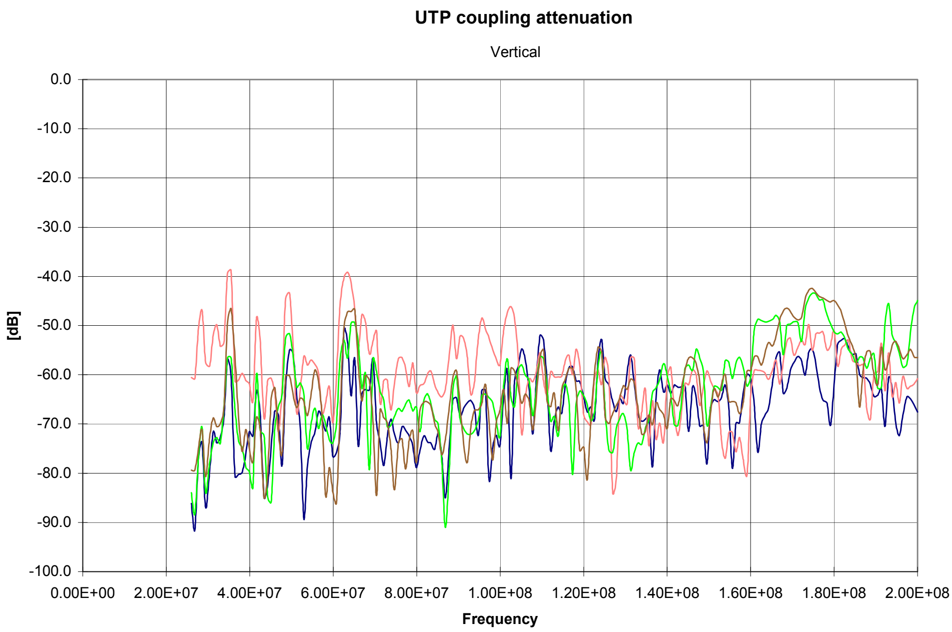

Fig. 17. Coupling attenuation for UTP link

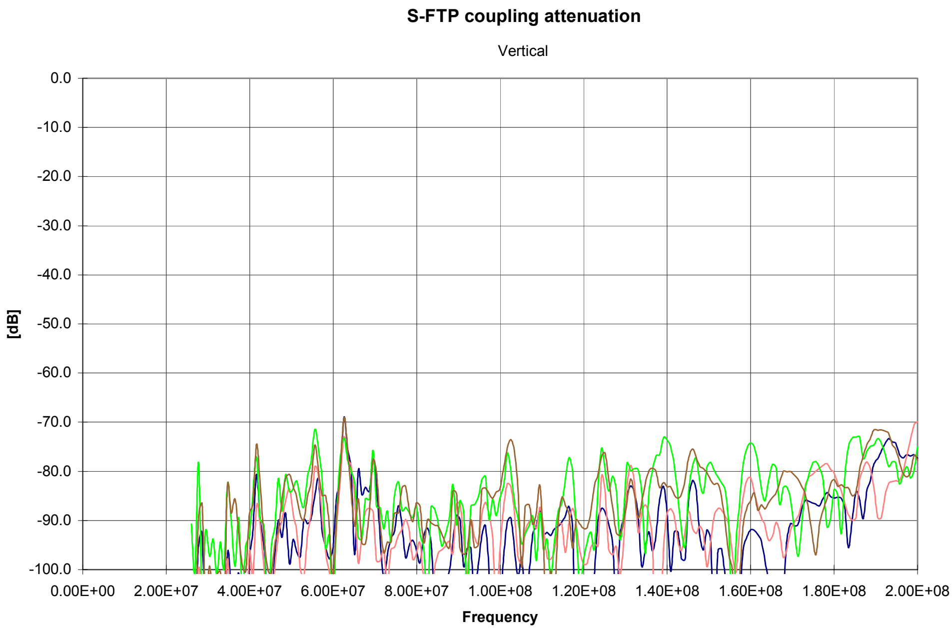

Fig 18. Coupling attenuation for S-FTP link

Coupling attenuation for the horizontal cables used in the 2 links has been measured by the absorbing clamp method.

The results for the 2 cables is shown in Fig. 19 - 20. The trace was obtained up to 1000 MHz but for ease of comparison only the section up to 200 MHz is shown.

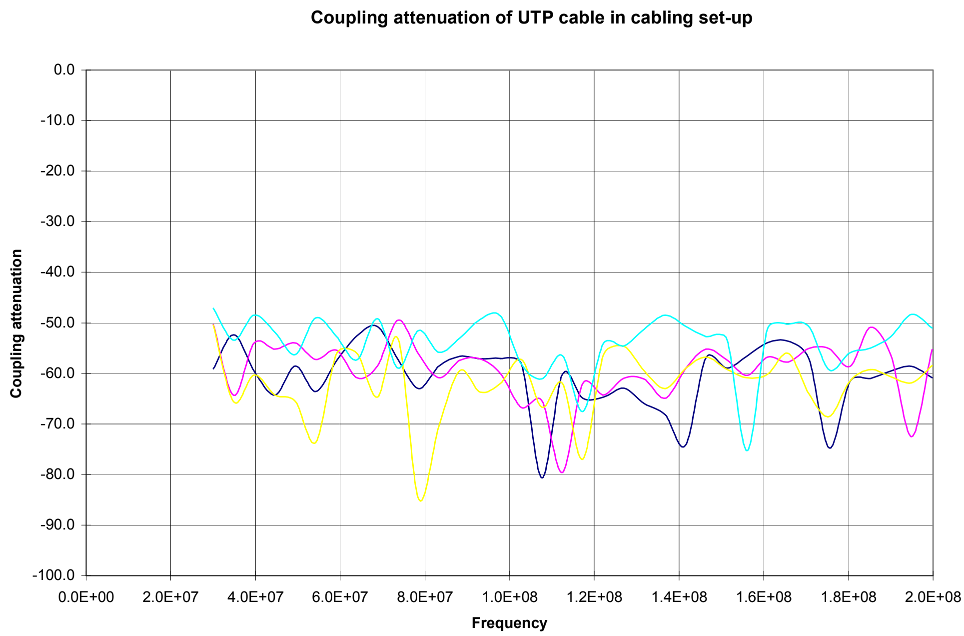

Fig. 19. Coupling attenuation for UTP cable.

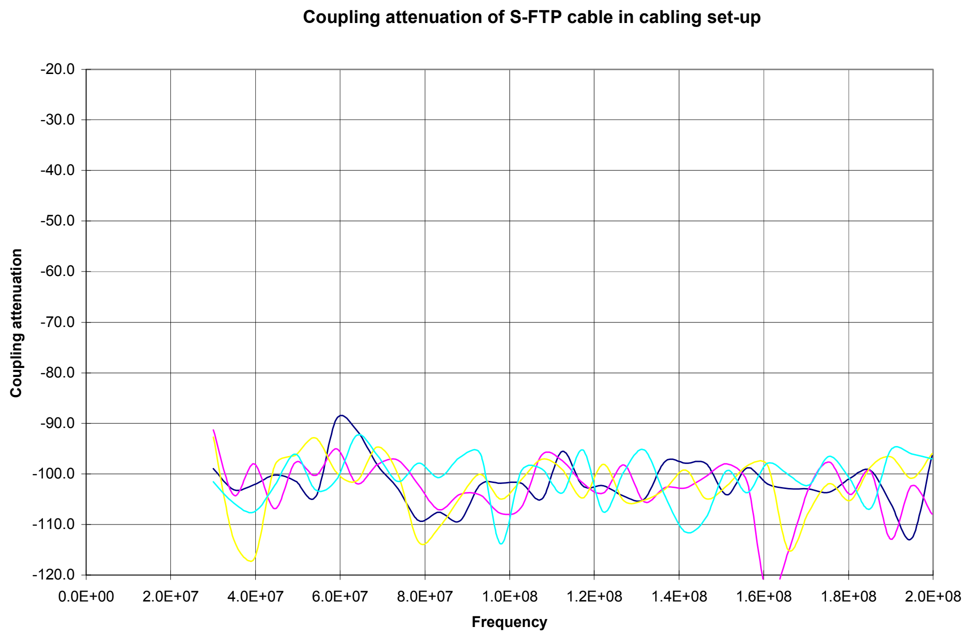

Fig. 20. Coupling attenuation for S-FTP cable.

It is seen form the figures that coupling attenuation for the UTP link is about 10 dB worse than for the horizontal cable. For the S-FTP link coupling attenuation is about 20 dB worse as for the horizontal cable. This is quite understandable as the link balance and screening is deteriorated by the connectors and flexible cables.

12. Comparison with results found in version 1 of this report.

In version 1 of this report the differential voltage, measured in the immunity set-up, was generally found to be 6 dB higher than reported here. The difference is believed to be due to insufficient common mode rejection ratio of the receiving set-up used. In this revision of the report it was found necessary to improve the common mode rejection ratio by use of a balancing transformer (see section 10).

13. Conclusion

The gain of the proposed set-up, as a radiating element, has been found to be quite constant over the frequency range of 26 MHz to 1000 MHz, with no dominant polarisation and directional characteristic. The configuration is therefore well suited for set-up of a cabling link for EMC tests of equipment and for characterisation of coupling attenuation.

The performed radiation measurements on a PC connected to the cabling link set-up show that the direct radiation from this particular PC enclosure, almost completely masks the radiation from the cabling set-up. The difference between the coupling attenuation performance of UTP and S-FTP cabling can therefore hardly be seen in these measurements.

The radiation measurements performed with the PC outside the test chamber shows that the radiation from the S-FTP cabling is less that of the UTP cabling. UTP cabling in this set-up, however, satisfies the class B limit carrying 100 MB/s Ethernet signals.

The immunity tests shows that the coupling attenuation of the UTP cabling is less that that of the S-FTP cabling. At the cabling interface up to 35 mV peak exists when the cabling is subject to a field of 3 V/m for UTP cabling and 1.1 mV for S-FTP cabling.

It is also shown that it is possible to measure coupling attenuation characteristics of the cabling set-up by applying a field to the set-up and measure the picked up power.

14. Referenced standards

1 EN 55022, Limits and methods of measurements of radio disturbance characteristics of information equipment.

2. EN 50082-1, Electromagnetic compatibility - Generic immunity standard Part 1: Residential, commercial and light industry.

3. EN 50082-2, Electromagnetic compatibility - Generic immunity standard Part 2: Industrial environment.

4. IEC 1196, Radio-frequency cables.