CISPR/G/WG1(Ryser) 96-1
(Ref 02) September 1996

Using ferrite clamps on the cables leaving the turntable

A model is presented which shows why the different cabling conditions outside the turntable can influence the measurement result below 200MHz.

Therefore, the "global common mode " impedance of the cables leaving the turntable has to be defined somehow at the center of the turntable.

The practical problems and advantages of 3 different ideas to provide a defined impedance at the center of the turntable are listed.

Idea 3 is the proposal to use ferrite clamps at the center of the turntable. From the practical point of view this version is preferable.

Experimental results of 5 different EUTs in 5 different cabling situations are presented here.
The measurements were first performed according to the actual rules of CISPR 22 (including CISPR/G/96/FDIS) without ferrite clamps, and second without changing the test setup on the turntable but with ferrite clamps at the center of the turntable. In the first case, the spread of the results was up to 25 dB. In the second case, the spread of the results was reduced to less than 5 dB.

This effect is most pronounced for small EUTs with few cables attached. The proposal to use the ferrite clamps is most important for the measurement of small EUTs. The bigger the EUT and the more cables are connected, the less pronounced is the effect and the use of the clamps is less important in this case.

It is proposed to define and verify the ferrite clamps with an insertion loss measurement.

Appendix:

1. History of the proposal

This proposal stems originally from a comment of the Swiss NC to CISPR G(Secr)36.
It was proposed to add the following note in the figures of the test setup for radiated measurements:

Note: Each cable leaving the turntable shall be equipped with a ferrite tube (or clamp) close to the center of the turn table.

It was originally expected to be considered for inclusion into the following draft of the same document. The document following CISPR/G(Secr)36 was CISPR/G(Secr)67. An amendement, including some further additions from comments of other countries to the proposal was assembled in CISPR/G(Secr)73. For formal reasons, it was decided in San Francisco to treat CISPR/G(Secr)73 independent of CISPR/G(Secr)67 and to refer CISPR/G(Secr)73 back to WG1. The main document, CISPR/G(Secr)67, was reissued as CISPR/G/96/FDIS, which has been accepted according to the voting result reported in CIS/G/105/RVD.

The compilation of comments to CISPR/G(Secr)73 is assembled in CIS/G/95/CC.

2 Theoretical background

At frequencies below 250MHz, the cables attached to the EUT contribute to the radiation and, in fact, may dominate it in many cases. The radiation of an antenna depends on the current distribution along the antenna. The current distribution of a wire antenna depends on the impedance at either end.

In the case of a cable attached to the EUT, the radiating antenna is formed by the exposed part of the cable between the EUT and the center of the turntable ("antenna section" of the radiating cable).

The impedance seen by the "antenna section" of the radiating cable at the EUT side is defined by the ("global common mode") impedance of the cable at the EUT. The impedance seen at the center of the turntable is defined by the test setup and can vary depending on the situation in the test lab, as described below.

The impedance at the EUT side is basically defined by the EUT. It is part of the measurement and it can not be influenced by the test lab. The impedance at the center of the turntable, however, is defined by the test setup and the situation in the test lab and it can vary significantly from lab to lab and from measurement to measurement.

The current draft revision of Publ. 22 does not give any definition for the impedance of the cables leaving the turntable. (The definition of flush mounted mains junction boxes in Note 3 of Fig 10 does not define the relevant "global common mode" impedance of the cable.)

Figure 1 shows a number of possible situations concerning the cable layout as they occur in different test labs for the cable between EUT and AE. Similar drawings are possible for other types of cables (e.g. power supply) or for different types of open area test sites, but the basic problem can be explained by help of the situations shown in this figure.

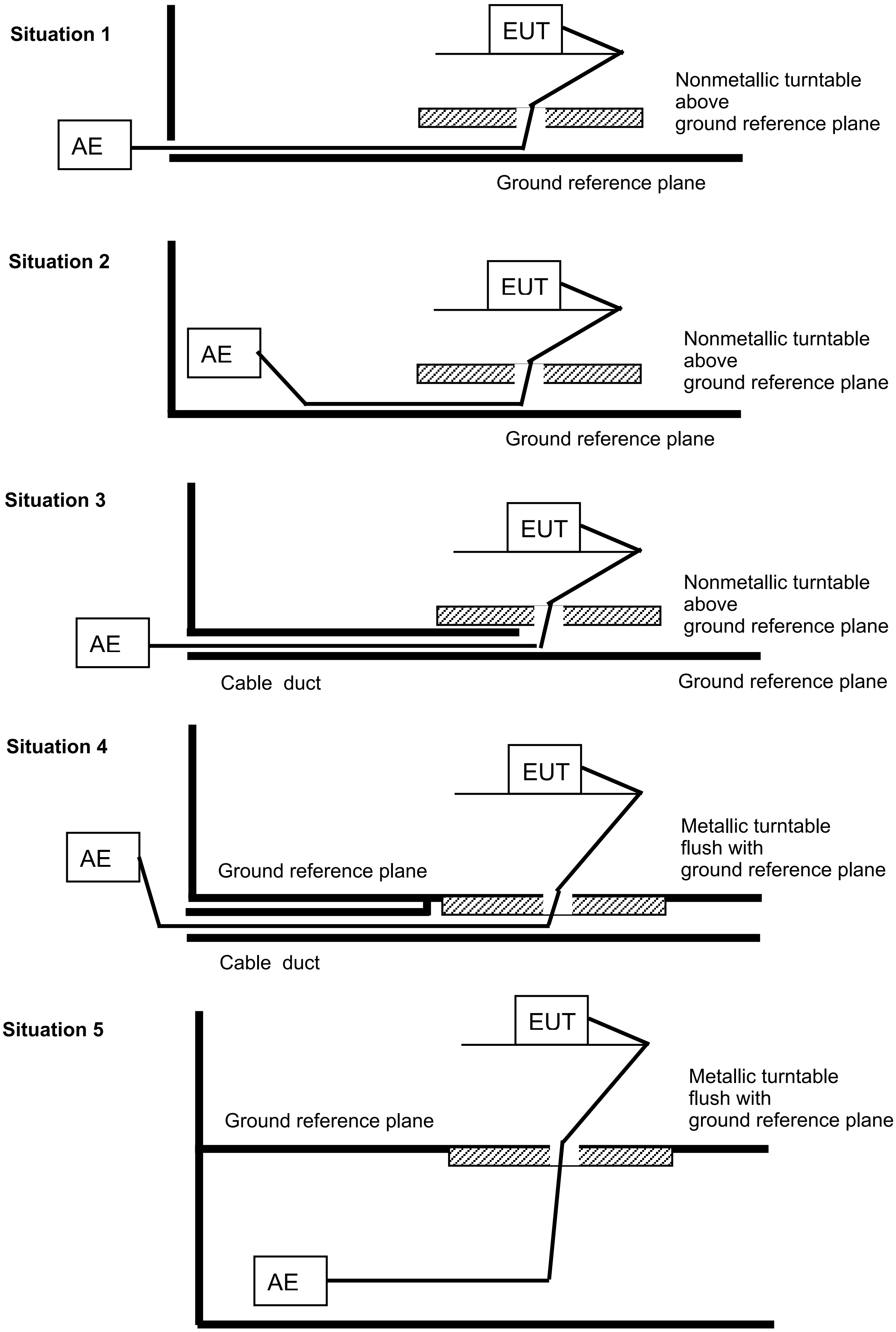


Fig. 1: Different situations concerning the cable layout in different test labs

Figure 2 shows a generalized high frequency model related to the radiation of a cable and it will be used for further dicussion.

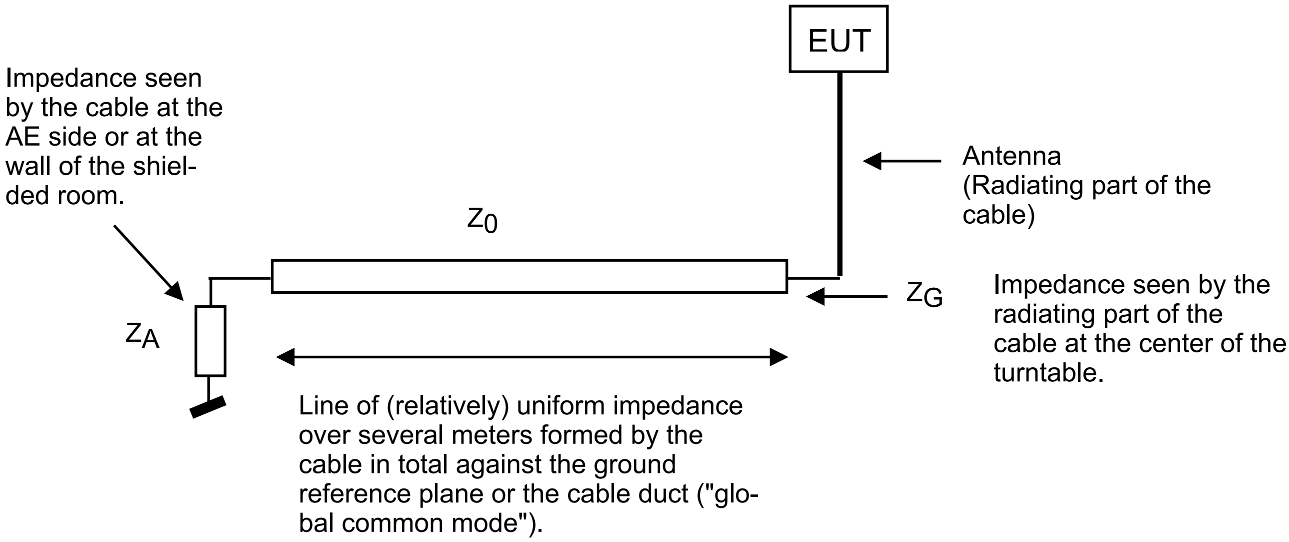


Fig. 2: Generalized high frequency model related to the radiation of a cable

$\mathbf{Z_{AE}}$ is the impedance of the cable seen in "global common mode" at the far end of the connection. This can be the impedance at the AE or, in many cases, the impedance at the wall of the faraday cage or the absorber room, where the cable is connected to a filter, or where the shield of the cable is connected to the shield of the room.

$\mathbf{Z_0}$ is the impedance of the line consisting of the cable in total as one conductor ("global common mode"), and the reference ground plane (or the cable duct) as the other conductor.

$\mathbf{Z_G}$ is the impedance seen by the radiating part of the cable at the center of the turntable. This impedance depends not only on the impedance Z_{AE} at the far end of the line with impedance Z_0 , but also on the relation between frequency and the length of this line.

If Z_{AE} is an open or a short circuit, it will depend on the combination of cable length and frequency, whether the radiating cable sees Z_G at the center of the turntable as an open circuit, a short circuit or any other impedance. This will influence the current distribution on the radiating part of the cable and, therefore, the radiation.

It is important to note that theese variations do not depend on the cable layout on the turntable itself. With exactly the same test setup on the turntable, the result of the radiation measurement can still be variable, depending on the impedance Z_G at the center of the turntable.

3. Practical background for possible improvements

Basically, for all cables leaving the turntable, it is necessary to produce a well defined ("total common mode") impedance at the center of the turntable.

Idea 1:

Use some kind of impedance stabilisation networks (ISNs) for all cables.

Problems with Idea 1:

- there are no ISNs having defined impedance in the frequency range 30 to 1000MHz. The construction of such networks would be very difficult.
- ISNs with defined impedance in the frequency range 30 to 300MHz are feasible, but every type of cable would need an individual network with construction adapted to the cable type.
- The ISNs have to be perfectly grounded, which is possible with flush mounted metallic turntables, but is problematic with most types of nonmetallic turntables.
- All cables would have to be cut and manipulated, which is not needed with Idea 3 below.

Idea 2:

High frequency grounding of all cables at the center of the turntable.

Problems with Idea 2:

- High frequency grounding is possible for all types of shielded cables (remove the insulation and attach the outside surface of the shield to the reference ground), but it is complicated or impossible for all types of nonshielded cables.
- Nonshielded conductors could be grounded by using feed-through capacitors at the reference ground, but most data lines would fail to operate with this capacitive loading.
- All cables would have to be cut and/or manipulated, which is not needed with Idea 3 below.

Idea 3:

High frequency insulation of all cables at the center of the turntable.

This is the basis of the proposed amendement in CISPR/G(Secr)73.

Advantages with Idea 3:

- Using ferrite clamps is possible for all types of cables.
- Using ferrite clamps is possible in the case of nonmetallic turntables above the ground plane as well as in the case of metallic turntables flush with the ground plane.
- The price of the clamps is negligible compared to the investement in the test site and the other test equipment.

4. Measurement results

In order to find out the importance of this effect, several different EUTs were measured according to CISPR 22, using 5 different cable connecting situations which are all within the frame allowed by CISPR 22 and CISPR/G/96FDIS.

Real EUTs have some disadvantages in performing such tests: They do not emit regularly at all the frequencies where a comparison would be interesting. Some of their emissions are not stable and a comparison of the influence of the parameters in question is not possible. For this reason, this test was performed with artificial EUTs using a metal box with a comb generator as noise source. The radiation source was a short wire of about 7 cm length at the surface of the metal box. A single cable was attached to the EUT in different ways simulating different types of EUTs.

Two sizes of EUTs were simulated:
EUT 1 and 2 (metal box 18 x 11 x 9 cm) represent very small devices, such as a modem, a laptop, or a telephone set. EUT3, 4 and 5 (metal box 50 x 30 x 30 cm) represent a medium size device, such as a small electronic rack, a small PABX, or a medium size printer. The detailed descriptions of the EUTs, together with the individual test results, can be found in the Appendix.

Each EUT was measured twice (A and B) with 5 different cable connection situations:

A if no ferrites are used,

B if a ferrite clamp is used at the center of the turntable
(without changing any other parameter of the measurement)

The 5 cable connection situations used are the following:

1 Cable connected to the reference ground plane at the center of the turntable

2 Cable laying on the reference ground plane and grounded after about 10 m

3 Cable laying on the reference ground plane and grounded after about 4 m

4 Cable laying on the reference ground plane and floating after about 10 m

5 Cable laying on the reference ground plane and floating after about 4 m

Taking the measurement results of EUT1 as example (Fig 3), we see significant deviations between the different cable connection situations if no ferrite clamps are used. For example, at 30MHz, changing the ground connection at 10m distance from the turntable from a short circuit to an open circuit changes the measurement result of the radiation measurement from 52dB(µV/m) to 25dB(µV/m). At 100MHz, the deviations between the different cable configurations outside the turntable are still up to 15dB.

Note:

This deviations are only due to effects outside the turntable. The EUT and the layout on the turntable are unchanged between the different connection situations. All the cable connection situations used in this test (including the use of ferrite clamps !) are within the possibilities allowed by CISPR 22 and CISPR/G/96FDIS, because there are no prescriptions at all concerning the cables leaving the turntable.

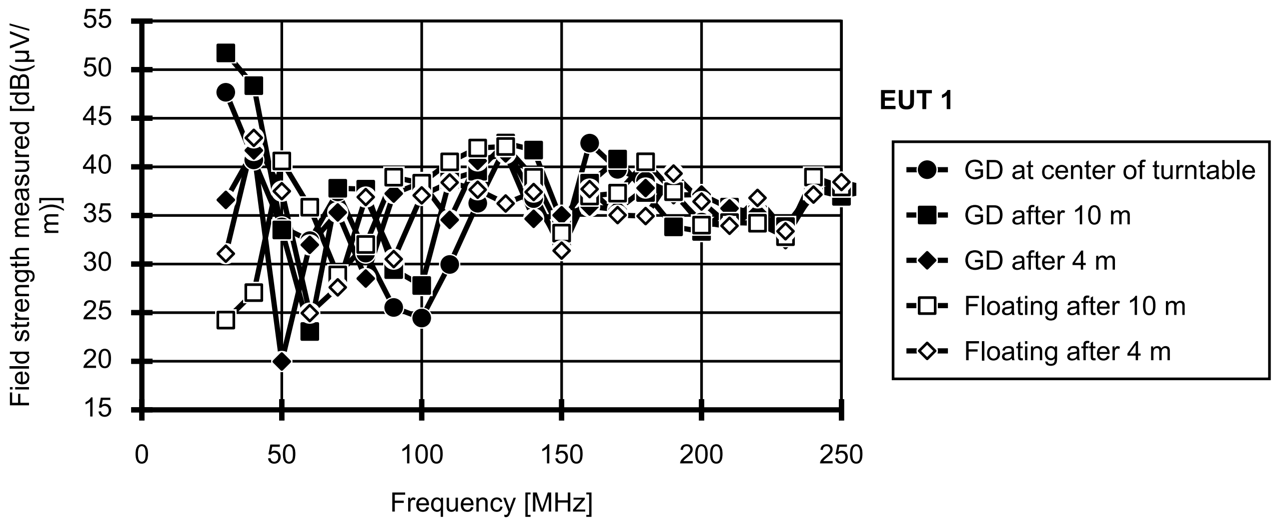


Fig. 3: Measurement results of radiated emission with EUT 1 if no ferrite clamps are used

The effect of the ferrite clamps can be seen in Fig 4 where the same measurements are shown if the ferrite clamps are used at the center of the turntable. The deviations are reduced to less than 5 dB.

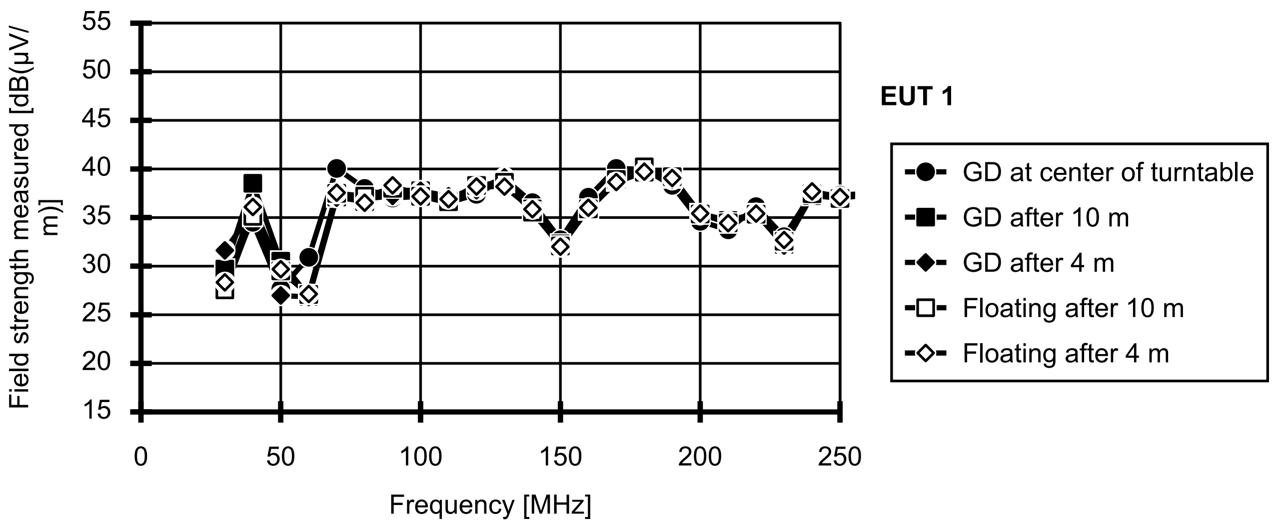


Fig. 4: Measurement results of radiated emission with EUT 1 if ferrite clamps are used

If we compare for each individual EUT the difference between the maximum and minimum measured result with the 5 connection situations, we get the maximum deviations shown in Fig. 5 if no ferrites are used, and the maximum deviations shown in Fig. 6 if ferrite clamps are used.

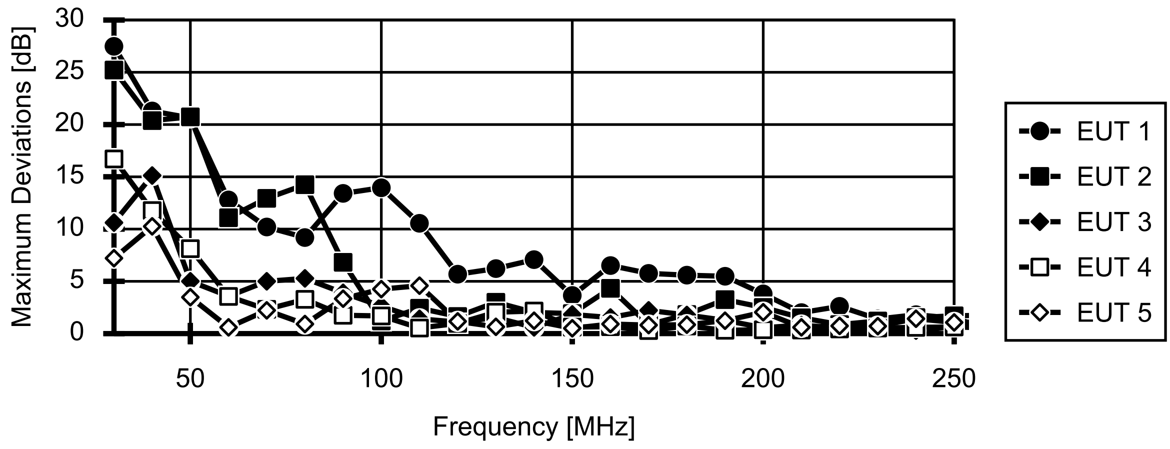


Fig. 5: Difference between maximum and minimum result for each EUT if no ferrite clamps are used

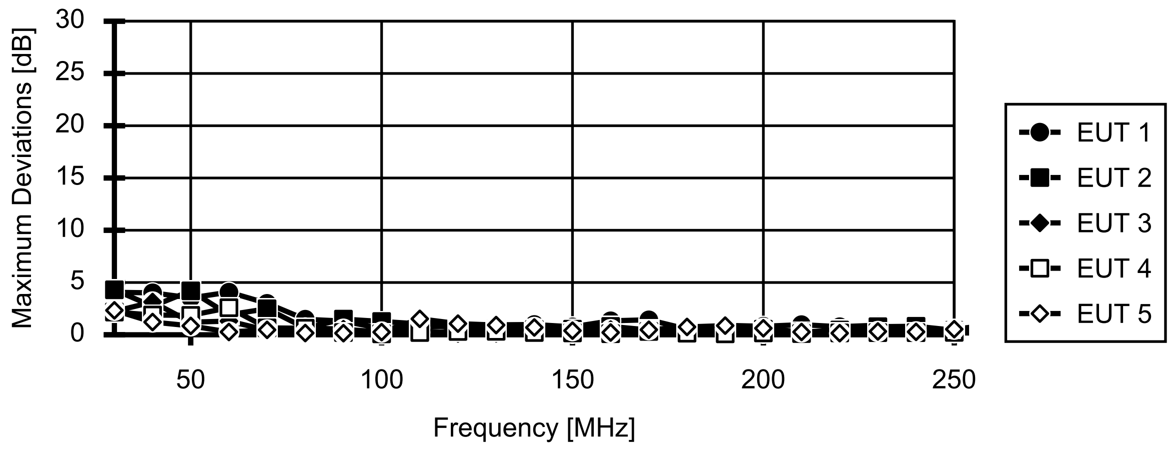


Fig. 6: Difference between maximum and minimum result for each EUT if ferrite clamps are used

Size of the metal box used for EUT1 and EUT2: 18 x 11 x 9 cm

Size of the metal box used for EUT3, EUT4 and EUT5: 50 x 30 x 30 cm

The smaller the EUT, the more pronounced is the effect described here. The proposal to use the ferrite clamps is most important for the measurement of small EUTs.

The results obtained here from the measurements with artifitial EUTs fit well with the experience gained during the last years with real EUTs. The numbers shown here can be taken as representative for EUTs with small dimensions and with few cables. The bigger the EUT and the more cables are connected, the less pronounced is the effect, making the use of the clamps less important in this case.

5. Definition and verification of the ferrite tubes

In the long term, it would be useful to have a method to verify the ferrite clamps used for this task.

It is the task of CISPR SC A to decide on such a method and to include it in Publ. 16. The proposal shown below is written in order to show that such a verification is relatively easy to carry out and it can be done with tools and equipment normally available in an EMC lab.

The verification should check the insertion loss of the system including the clamp, the cable under test, and the reference ground plane. The insertion loss is the difference between measurements 1 and 2 shown in Figure 7.

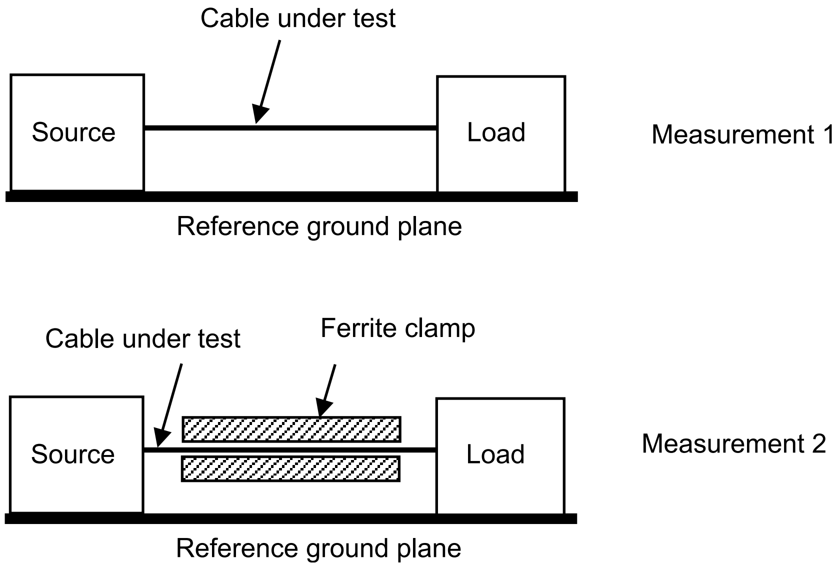


Fig. 7: Principle of the insertion loss measurement

The source and load impedance can either be 50Ω or 150Ω. The verificacion with 50Ω does not give the same numbers as the verification with 150Ω. Which of the two is to be used should be decided by CISPR SC A. Using 50Ω sounds simpler at first sight, but using 150Ω is simpler in practice, because the 50Ω to150Ω adaptors used in IEC1000-4-6 for the verification of CDNs can easily be used to adapt the sample cable under test via 100Ω to the 50Ω measuring system.

Some further hints to this verification can be given to CISPR SC A if the work is accepted there.

Figure 8 shows the insertion loss of the clamps used in this test

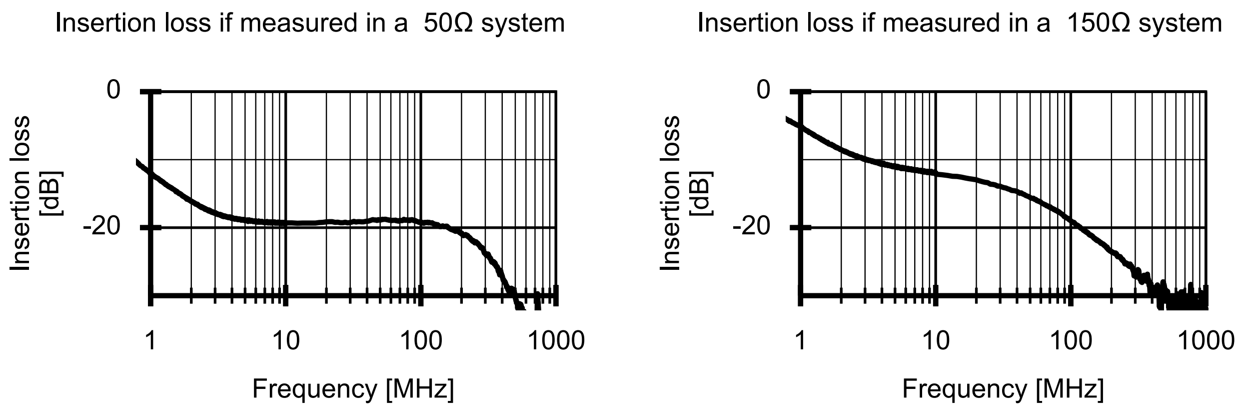
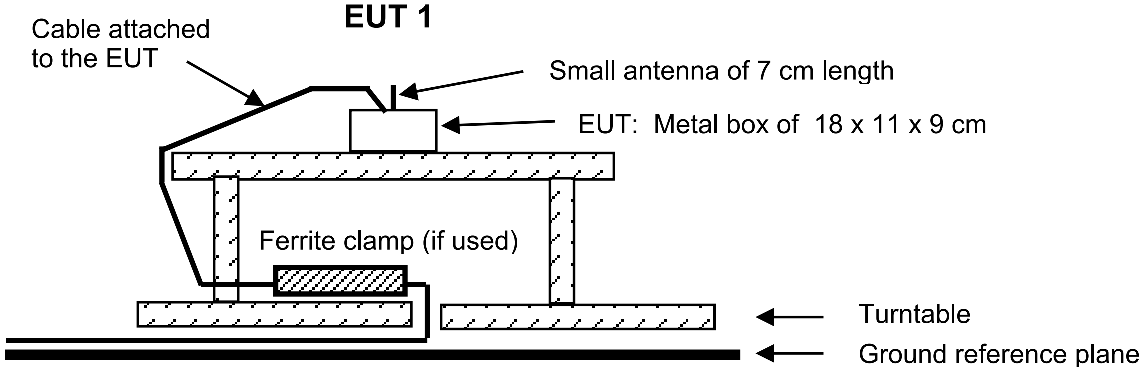
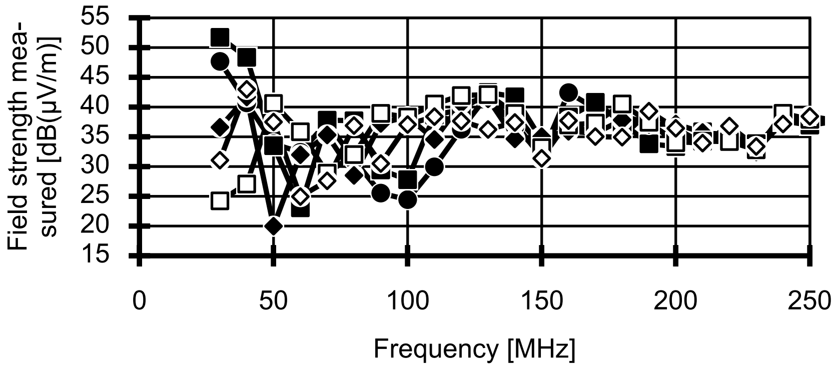


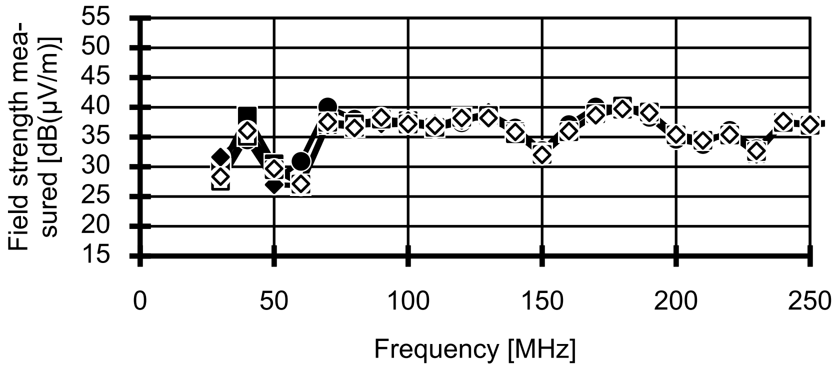
Fig 8: Insertion loss of the clamps used in this test.

EUT 1

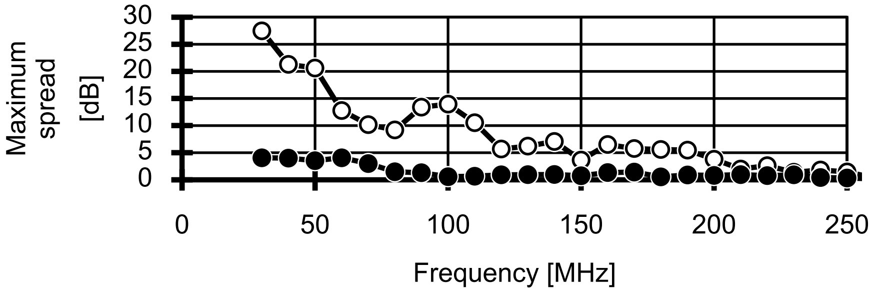




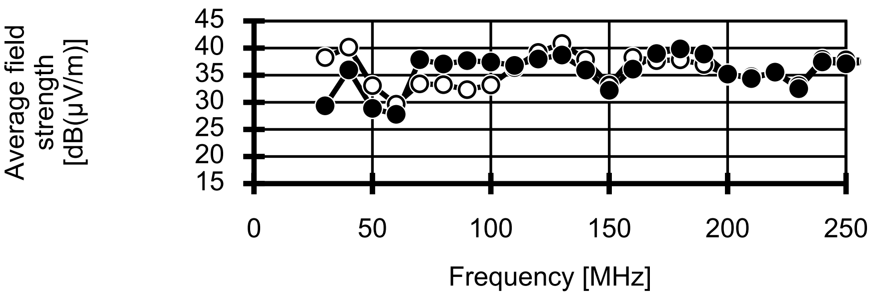
EUT1 Measurement results without ferrite clamps



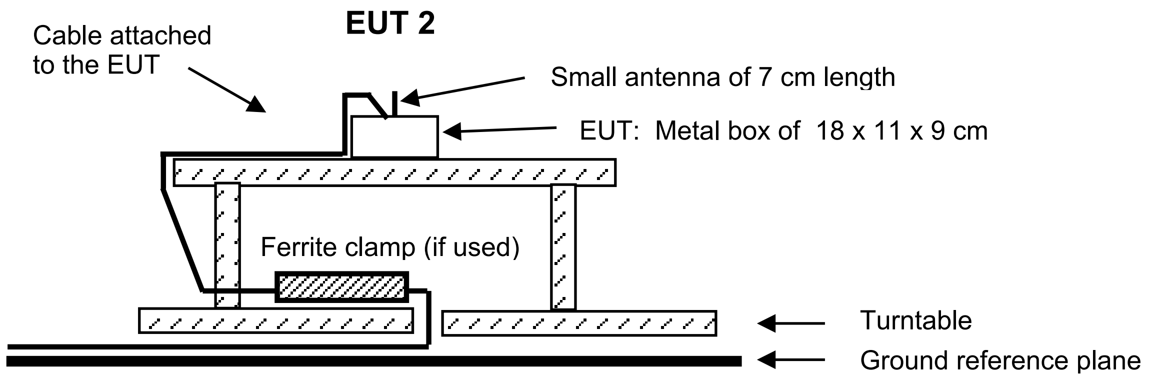
EUT1 Measurement results with ferrite clamps

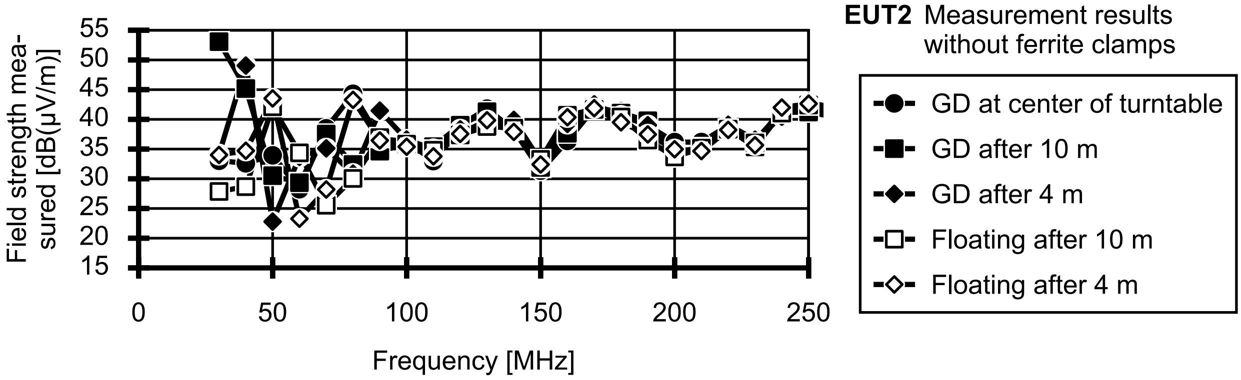


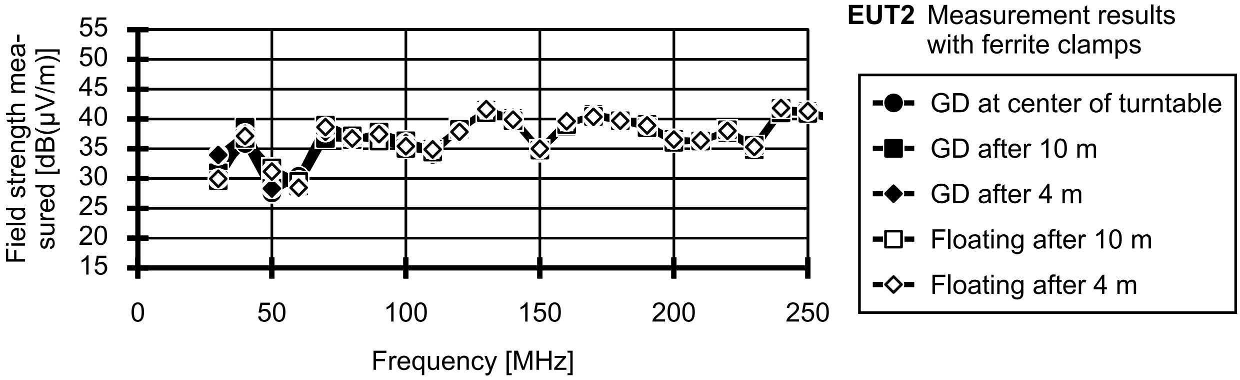
EUT1 Maximum spread of the results

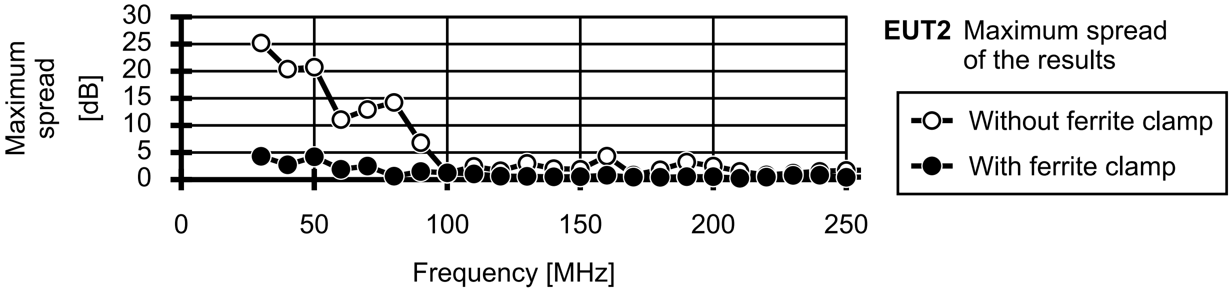


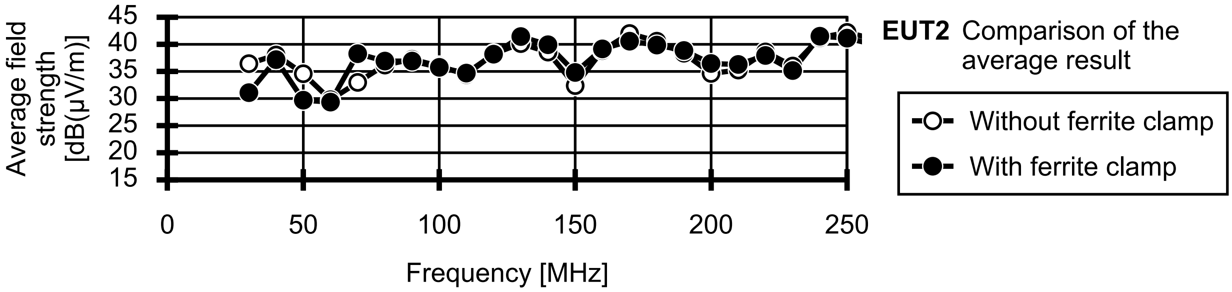
EUT1 Comparison of the average result


EUT 2
Cable attached to the EUT
Small antenna of 7 cm length
EUT: Metal box of 18 x 11 x 9 cm
Ferrite clamp (if used)
Turntable
Ground reference plane

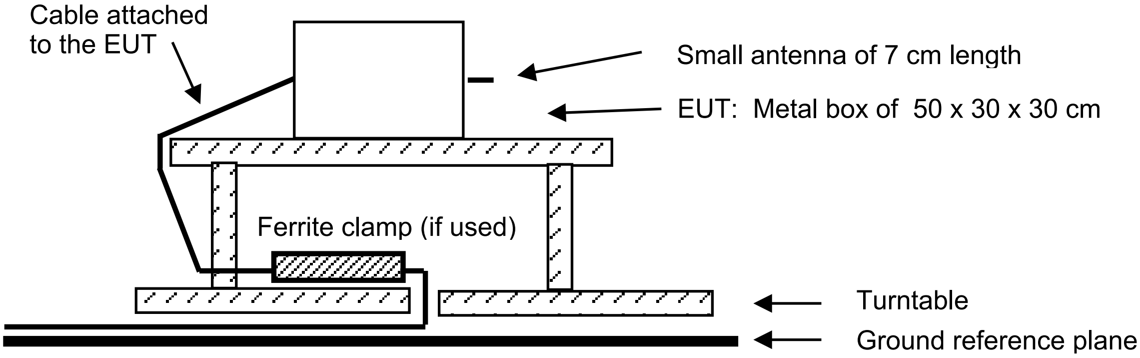

Field strength measured [dB(µV/m)]
Frequency [MHz]
EUT2 Measurement results without ferrite clamps
GD at center of turntable
GD after 10 m
GD after 4 m
Floating after 10 m
Floating after 4 m

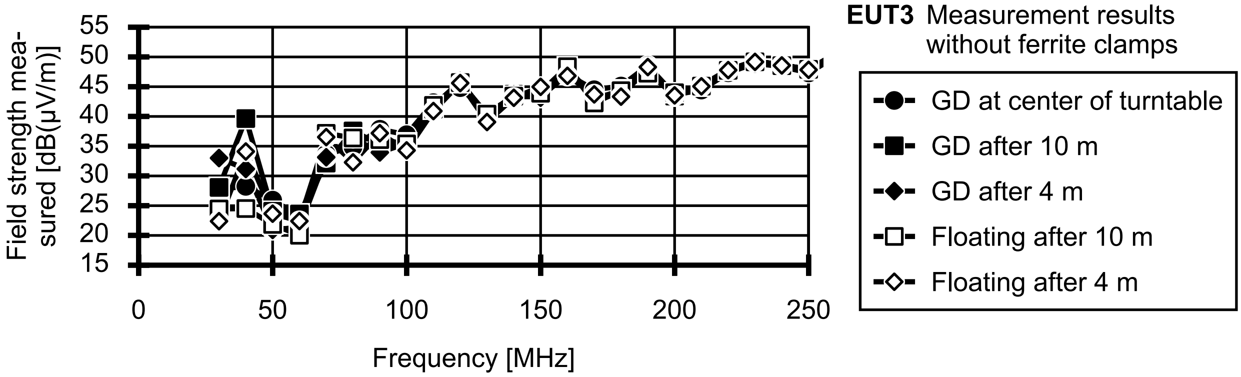

Field strength measured [dB(µV/m)]
Frequency [MHz]
EUT2 Measurement results with ferrite clamps
GD at center of turntable
GD after 10 m
GD after 4 m
Floating after 10 m
Floating after 4 m


Maximum spread [dB]
Frequency [MHz]
EUT2 Maximum spread of the results
Without ferrite clamp
With ferrite clamp

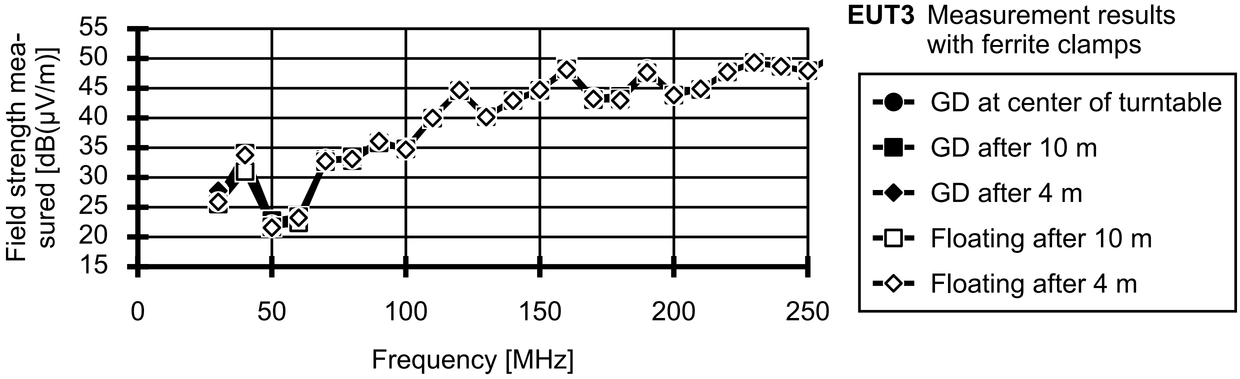

Average field strength [dB(µV/m)]
Frequency [MHz]
EUT2 Comparison of the average result
Without ferrite clamp
With ferrite clamp

EUT 3

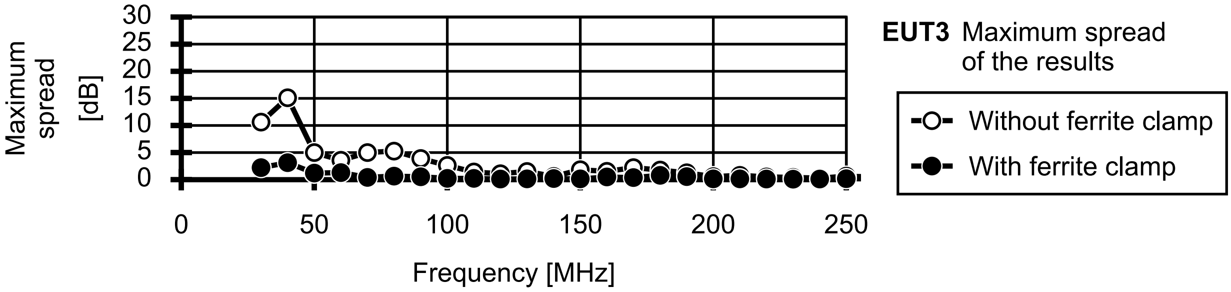




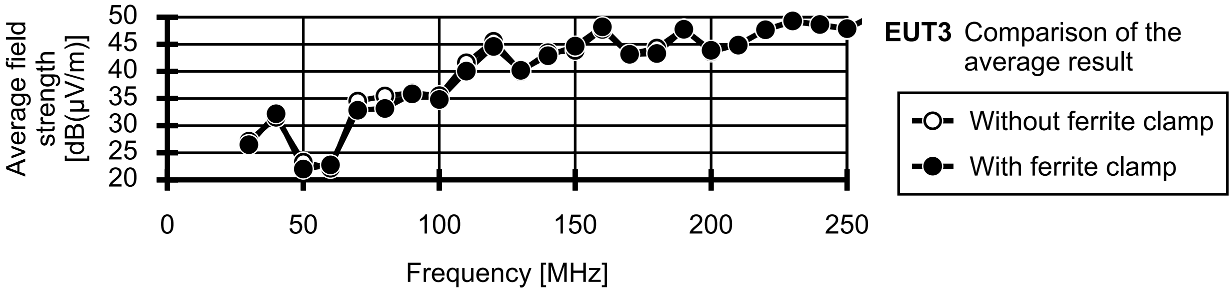
EUT3 Measurement results without ferrite clamps



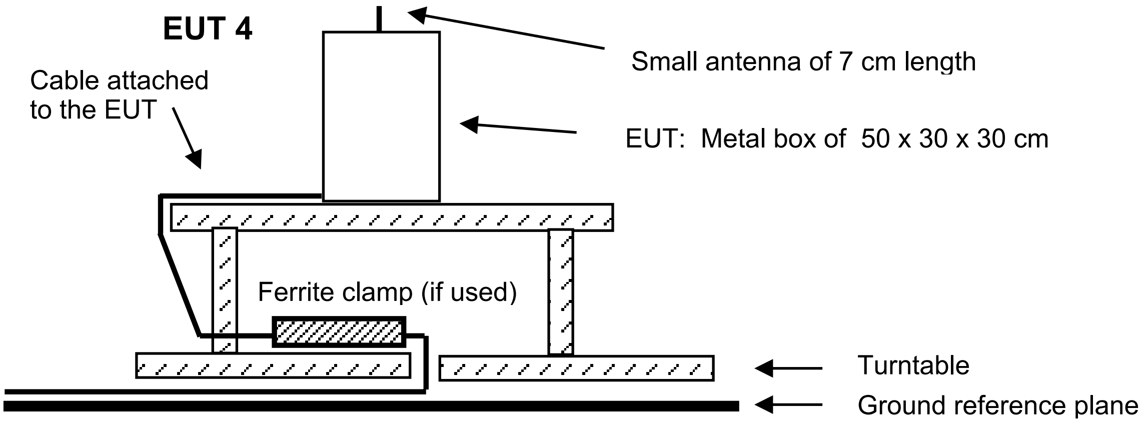
EUT3 Measurement results with ferrite clamps

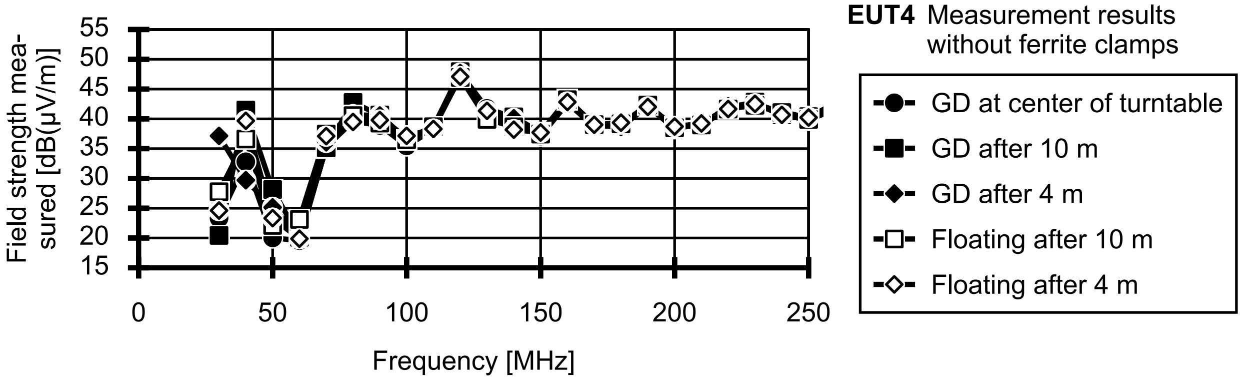


EUT3 Maximum spread of the results

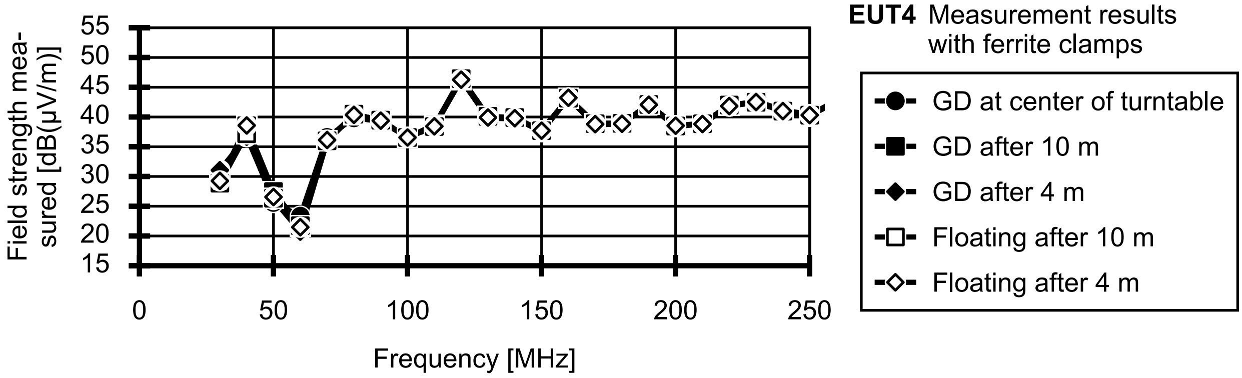


EUT3 Comparison of the average result

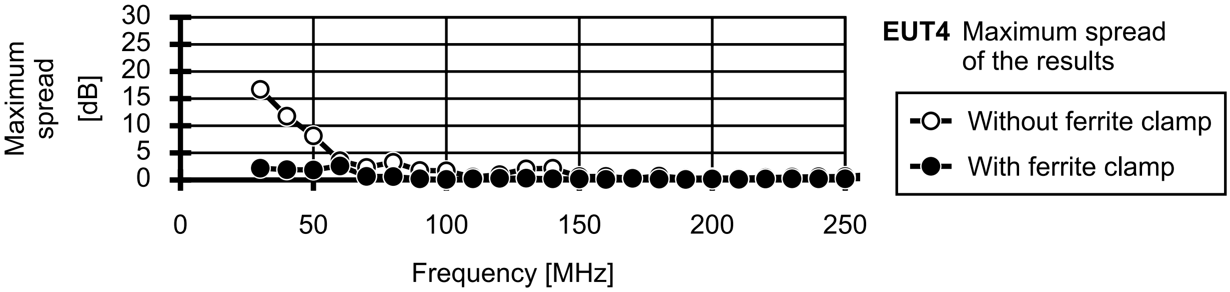




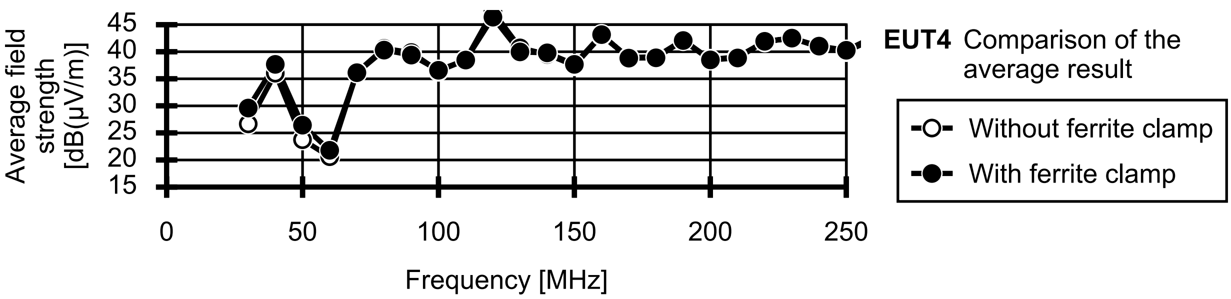
EUT4 Measurement results without ferrite clamps



EUT4 Measurement results with ferrite clamps

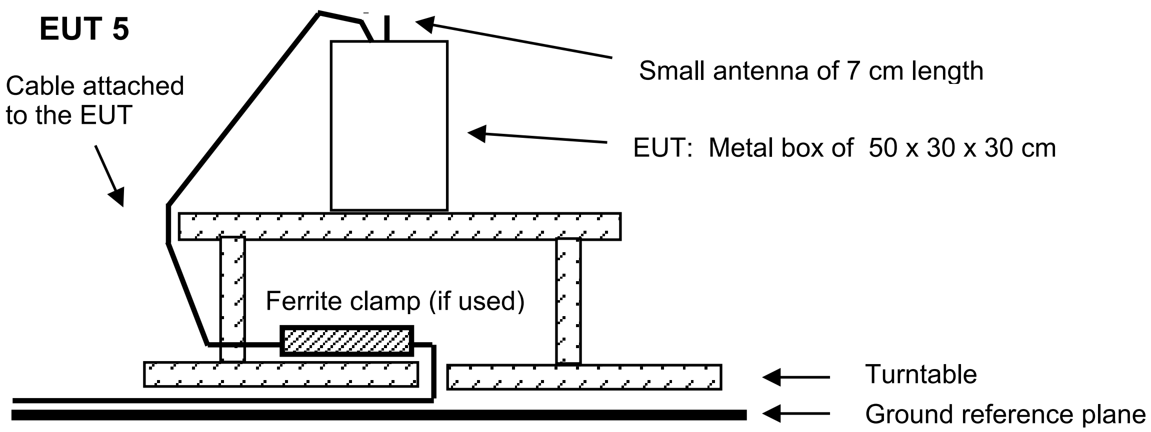


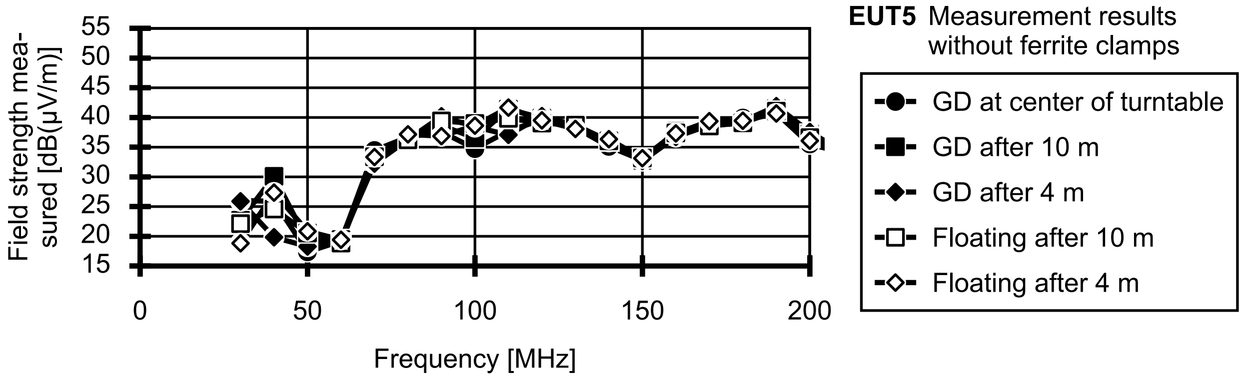
EUT4 Maximum spread of the results

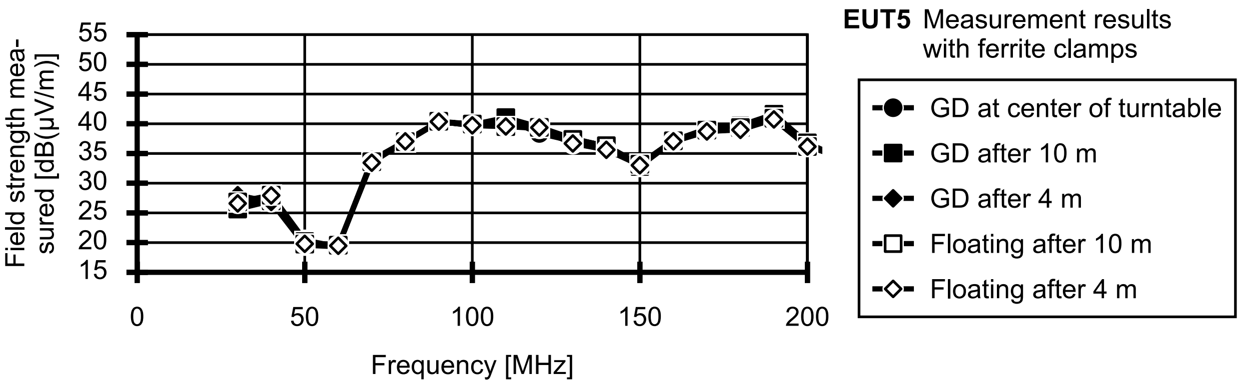


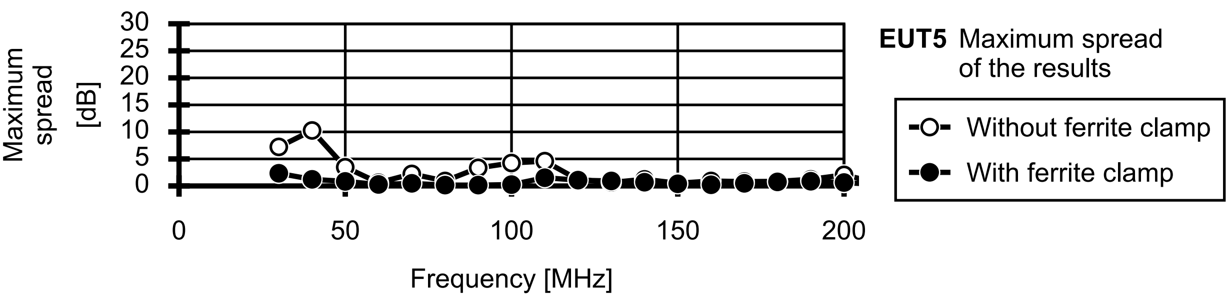
EUT4 Comparison of the average result

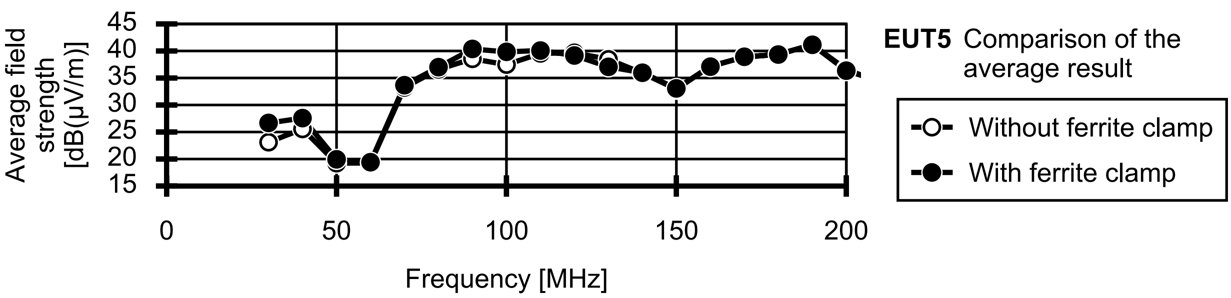
EUT 5


Cable attached
to the EUT
Small antenna of 7 cm length
EUT: Metal box of 50 x 30 x 30 cm
Ferrite clamp (if used)
Turntable
Ground reference plane


Field strength measured [dB(µV/m)]
55
50
45
40
35
30
25
20
15
0
50
100
150
200
Frequency [MHz]
EUT5 Measurement results without ferrite clamps
GD at center of turntable
GD after 10 m
GD after 4 m
Floating after 10 m
Floating after 4 m


Field strength measured [dB(µV/m)]
55
50
45
40
35
30
25
20
15
0
50
100
150
200
Frequency [MHz]
EUT5 Measurement results with ferrite clamps
GD at center of turntable
GD after 10 m
GD after 4 m
Floating after 10 m
Floating after 4 m


Maximum spread [dB]
30
25
20
15
10
5
0
0
50
100
150
200
Frequency [MHz]
EUT5 Maximum spread of the results
Without ferrite clamp
With ferrite clamp


Average field strength [dB(µV/m)]
45
40
35
30
25
20
15
0
50
100
150
200
Frequency [MHz]
EUT5 Comparison of the average result
Without ferrite clamp
With ferrite clamp