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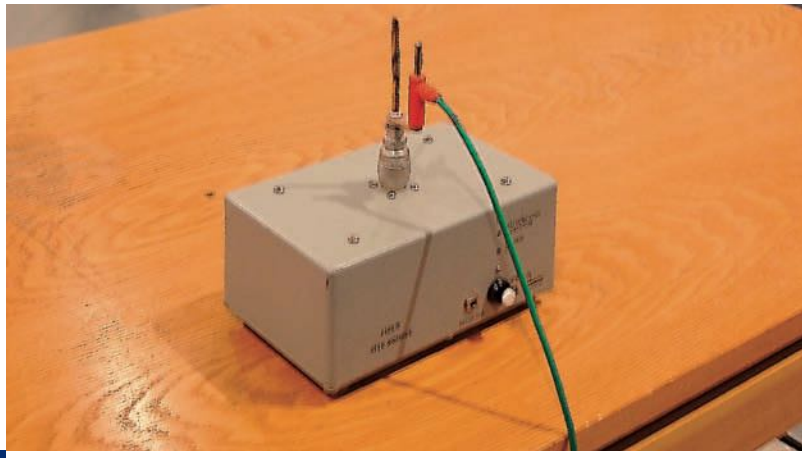
Motivation for the use of CMAD in radiated emission measurements

(CMAD: Common mode absorption devices)



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Motivation for the use of CMAD at radiated emission measurements

(CMAD: Common mode absorption devices)

Heinrich Ryser (he.ryser@bluewin.ch)

1. Introduction

The function of the CMAD is to avoid the influence of the difference in the connection point of the cables leaving the test volume (impedance of the connection to the ground plane and length ot the cable inside and outside the testvolume) to the radiated emission measurement.

This influence can be explained by the fact that the EUT is forming together with the cable leaving the test site a top loaded monopole antenna with undefined impedance at the foot point (point where the cable reaches the ground plane). The radiation of the monopole is influenced by this impedance.

It is important to note that this impedance is defined by the test site and not by the EUT.
In the actual standards this detail is not defined. The resulting differences of the measurement results are part of the standards compliance uncertainty. This uncertainty contribution is not under control and should be reduced by improving the standards.

The experiments of this report were made to explain and to illustrate these influences. The selected examples are relatively extreme cases showing clearly the influences in discussion. The amount of these influences is smaller for EUT's with higher dimensions or for EUT's with increased number of cables leaving the testvolume.

2. Description of the experiments

2.1. Description of the 5 EUT types

2.1.1 EUT 1

This EUT is a comb generator with dimensions 10 cm x 10 cm x 18 cm. The output of the comb generator (disturbance source) is vertically oriented and directly connected to the wire simulating the cable leaving the test site. The wire is falling straight to the ground plane through the wooden support and a hole in the table. The radiation should basically be vertically oriented and the pattern of the radiation should show a rotation symmetry with the azimuth of the turn-table.

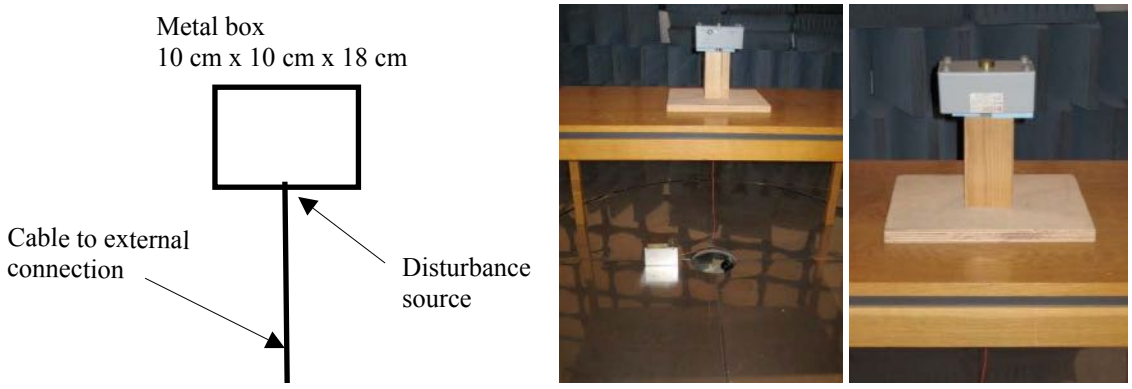


Fig 1: EUT 1 (Small metal box, radiating cable leaving the box vertically)

2.1.2. EUT 2

For EUT 2, the same comb generator was installed inside a metallic box with outside dimensions of 30 cm x 30 cm x 50 cm. The wire simulating the external cable was again vertically connected to the centre of the box. The wire is falling straight to the ground plane through a hole in the table. The radiation should basically be vertically oriented and the pattern of the radiation should show a rotation symmetry with the azimuth of the turntable.

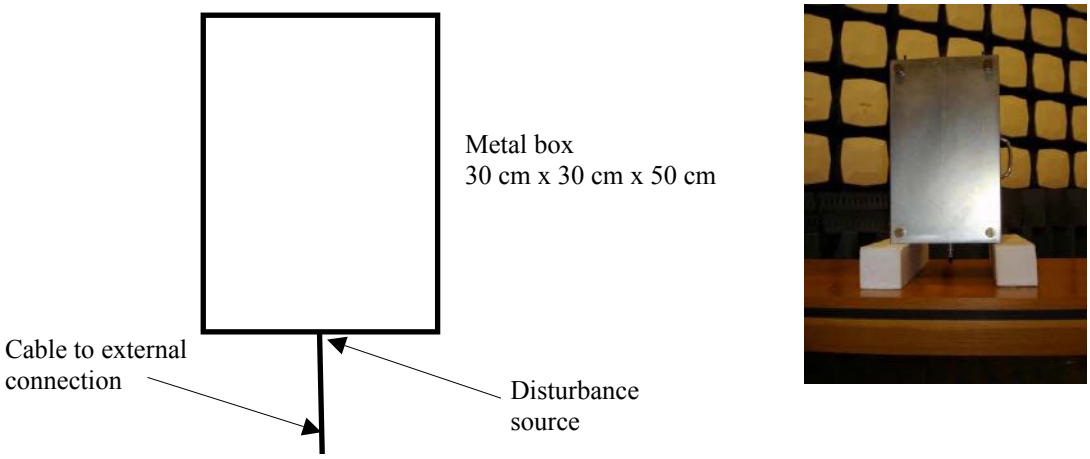


Fig 2: EUT 2 (Medium size metal box, radiating cable leaving the box vertically)

2.1.3. EUT 3

For EUT 3, the box was oriented horizontally and the output of the comb generator was connected to a small horizontally oriented monopole antenna. The wire simulating the external cable was directly connected to the body of the metal box at the other end. With this EUT Example the radiation should be horizontally oriented.

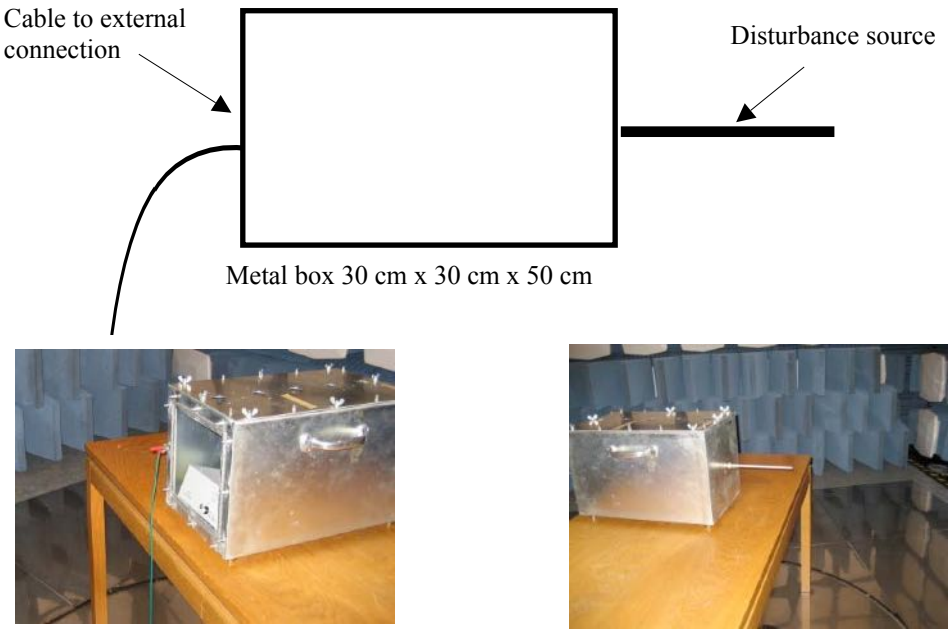


Fig 3: EUT 3 (Medium size metal box, horizontally oriented monopole)

2.1.4. EUT 4

For EUT 4, the wire simulating the external cable was directly connected to the output of the comb generator. The connection of the external cable was in the centre of the side wall of the box.

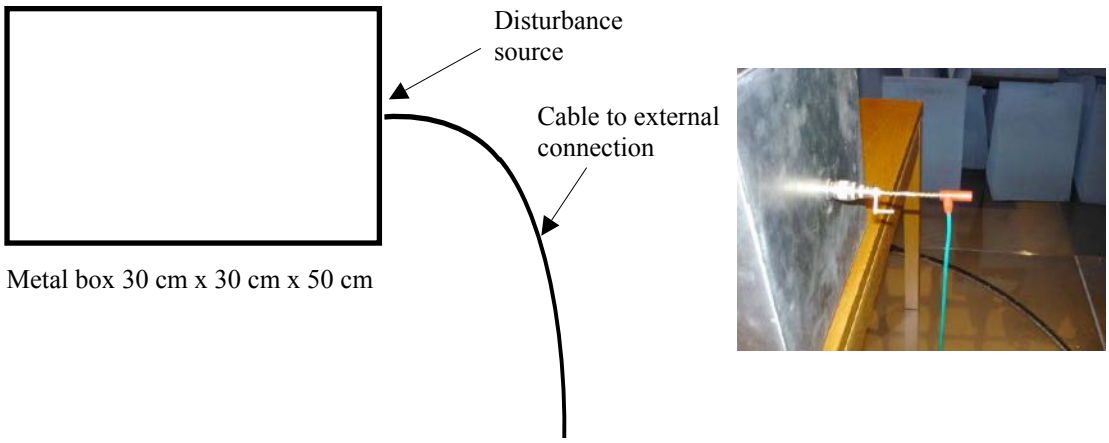


Fig 4: EUT 4 (Medium size metal box, radiating cable leaving the box at the side)

2.1.5. EUT 5

For EUT 5, the output of the comb generator was connected to a small vertically oriented monopole antenna. The wire simulating the external cable was directly connected to the body of the metal box close to the monopole antenna.

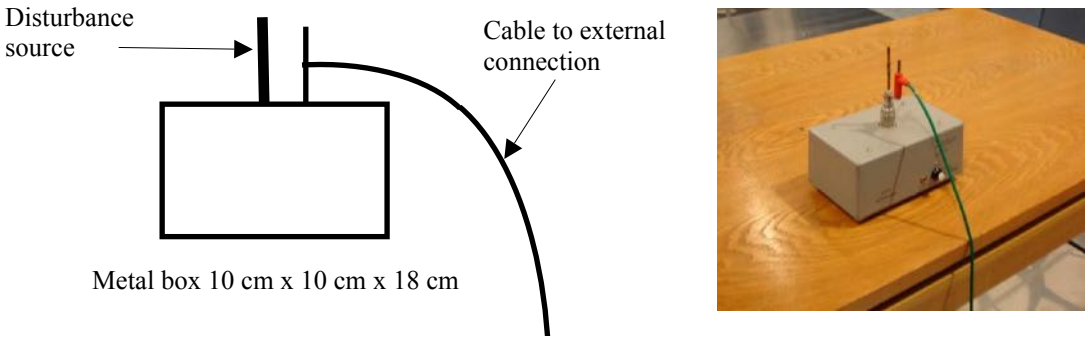
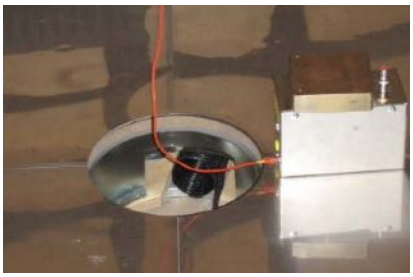


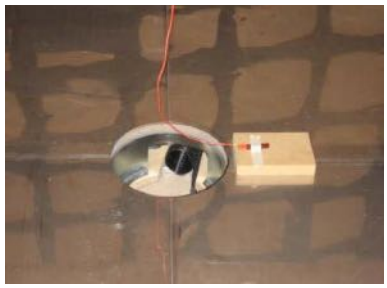
Fig 5: EUT 5 (Small metal box, small vertically oriented monopole)

2.2. Configuration of the 6 different cable connections at the ground plane

90 cm cable connected do the ground plane at the end (Using the ground connection of a CDN)



90 cm cable open at the end



230 cm cable connected do the ground plane at the end

230 cm cable open at the end

90 cm cable connected to a 150 Ohm CDN

Cable using a CMAD according to CISPR/A/754/CDV at the ground plane

Fig 6: The 6 different cable connections at the ground plane

3. Measurement results of the 5 EUT's in the 6 configurations

Each of the 5 EUT was measured according to CISPR 22 at 3m distance on a testsite fulfilling the NSA requirements of CISPR 16 . The 6 different configurations as shown in Fig 6 were used in order to simulate different possible connections of the cable to the ground plane. The CMAD used in the last configuration (blue points) is fulfilling the specification proposed in CISPR/A/754/CDV.

3.1. Summary of the measurement results

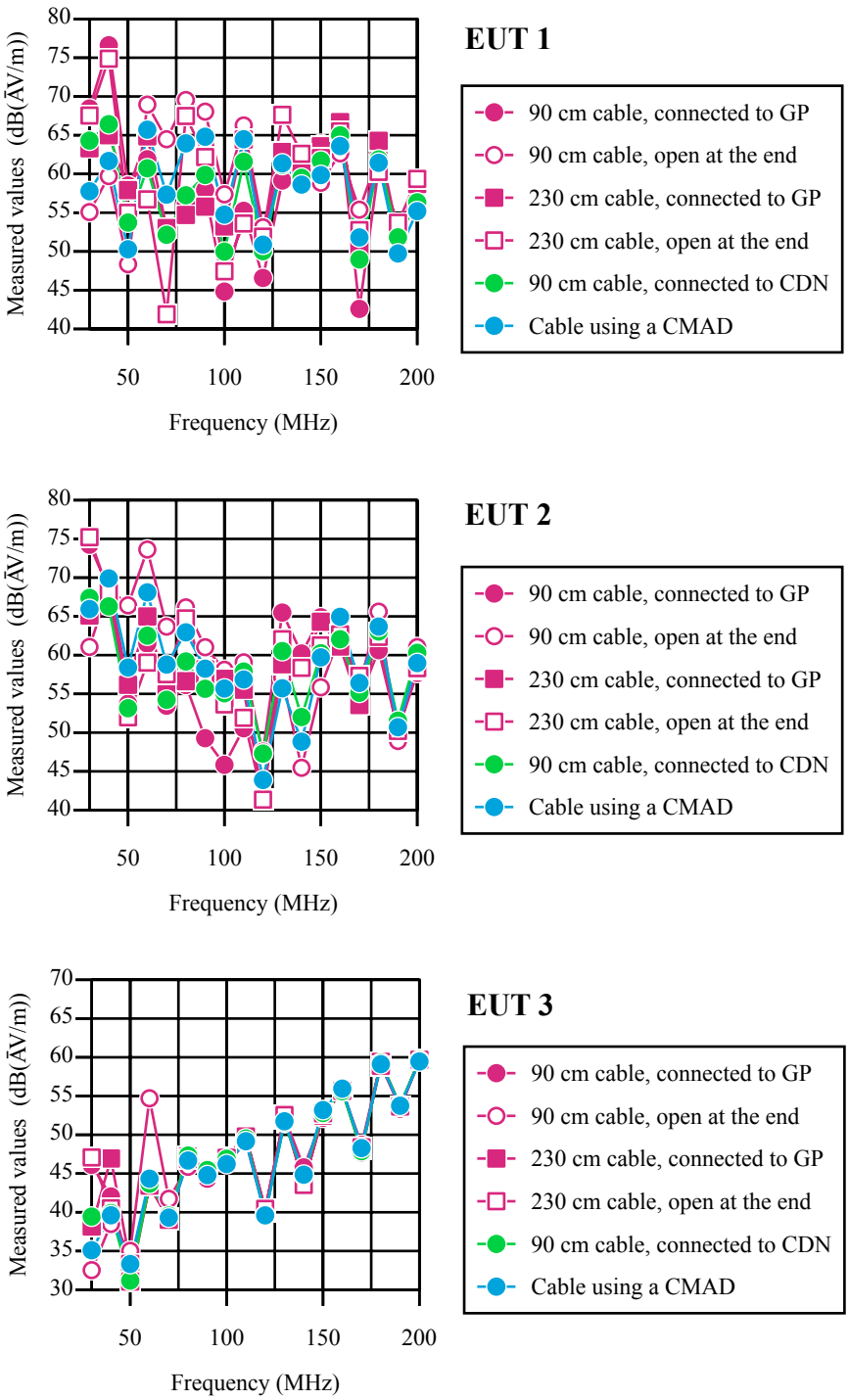


Fig 7 a: Measured values of of EUT 1 to 3 for the 6 configurations

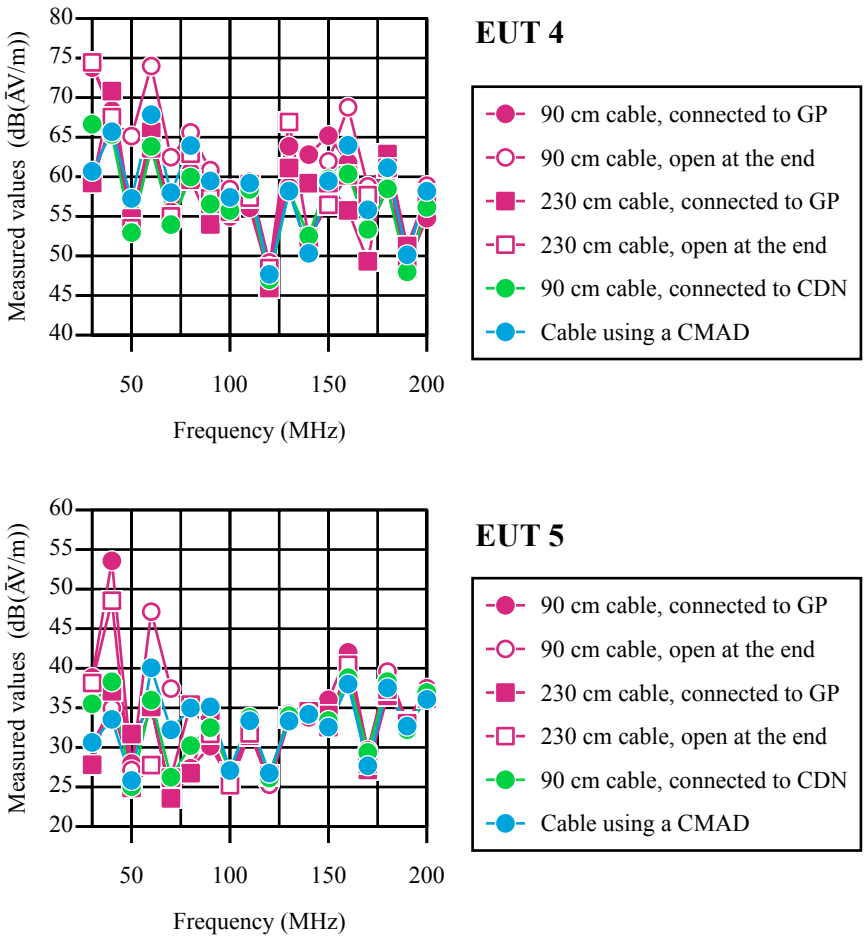


Fig 7 b: Measured values of of EUT 3 to 5 for the 6 configurations

The difference between the measured values of different configurations can be up to 15 dB in many cases and up to 25 dB in some special situtions if no CMAD is applied.

3.2. Normalisation for the comparison of the results

The amount of the deviations is not well visible in the presentation of Fig 7, because the measured value is not the same for each frequency. To make the differences visible, we need some kind of normalisation. It is the question which should be the reference for such a normalisation.

Proposal 1 for the reference:
Use the average of all measurements as reference.
However it has to be noted that the average is only a correct reference if all individual samples are of the same type and statistically independent. This is not the case here and the result could have been biased by the selection of the examples.

Proposal 2 for the reference:
Use the measurement with CMAD as reference.
One of the questions to be answerde by these experiments was the question whether and in which direction the limits should be adjusted if the CMAD's are systematically applied.

The figures in 3.3 show the deviations from the reference with two possible reference values:

1. The left side of the figures in 3.3 shows the deviations from the average (proposal 1)
2. The right side of the figures in 3.3 shows the deviations from the measurement with CMAD (proposal 2)

3.3. Comparison of the results

3.3.1. Comparison of results with EUT1

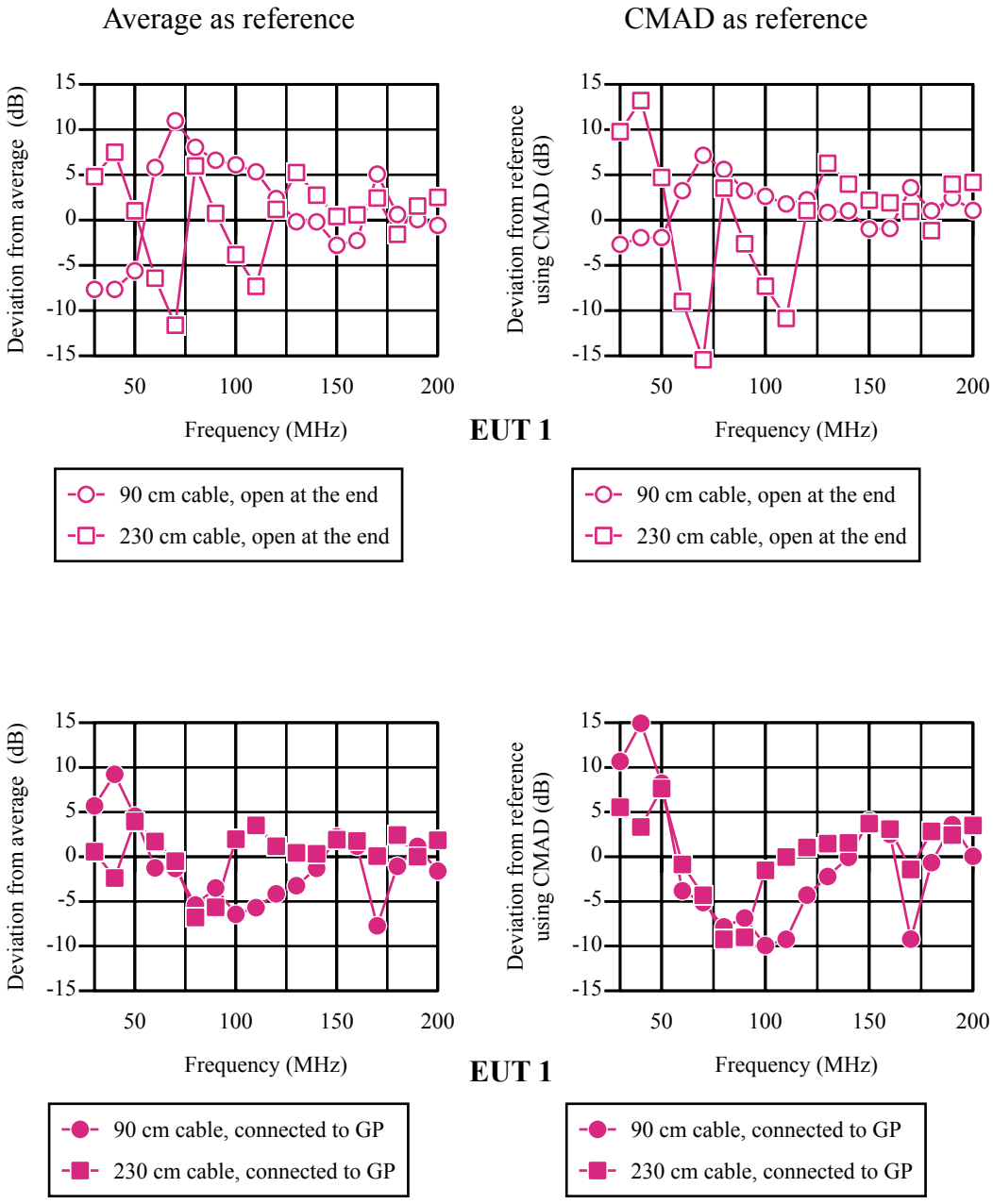


Fig 8 a Comparison of different cable lengths with EUT 1

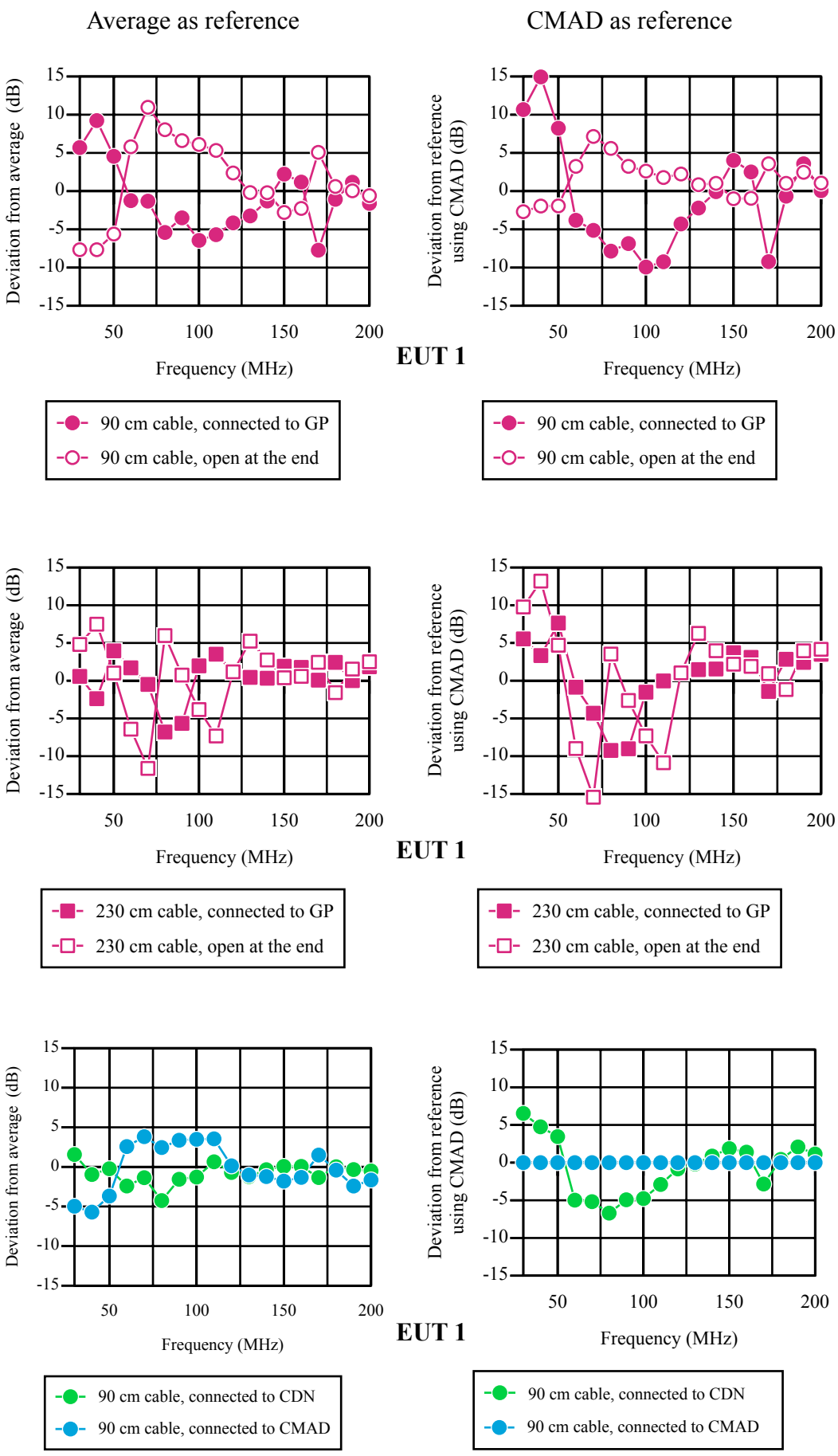


Fig 8 b Comparison of different grounding conditions with EUT 1

3.3.2. Comparison of results with EUT 2

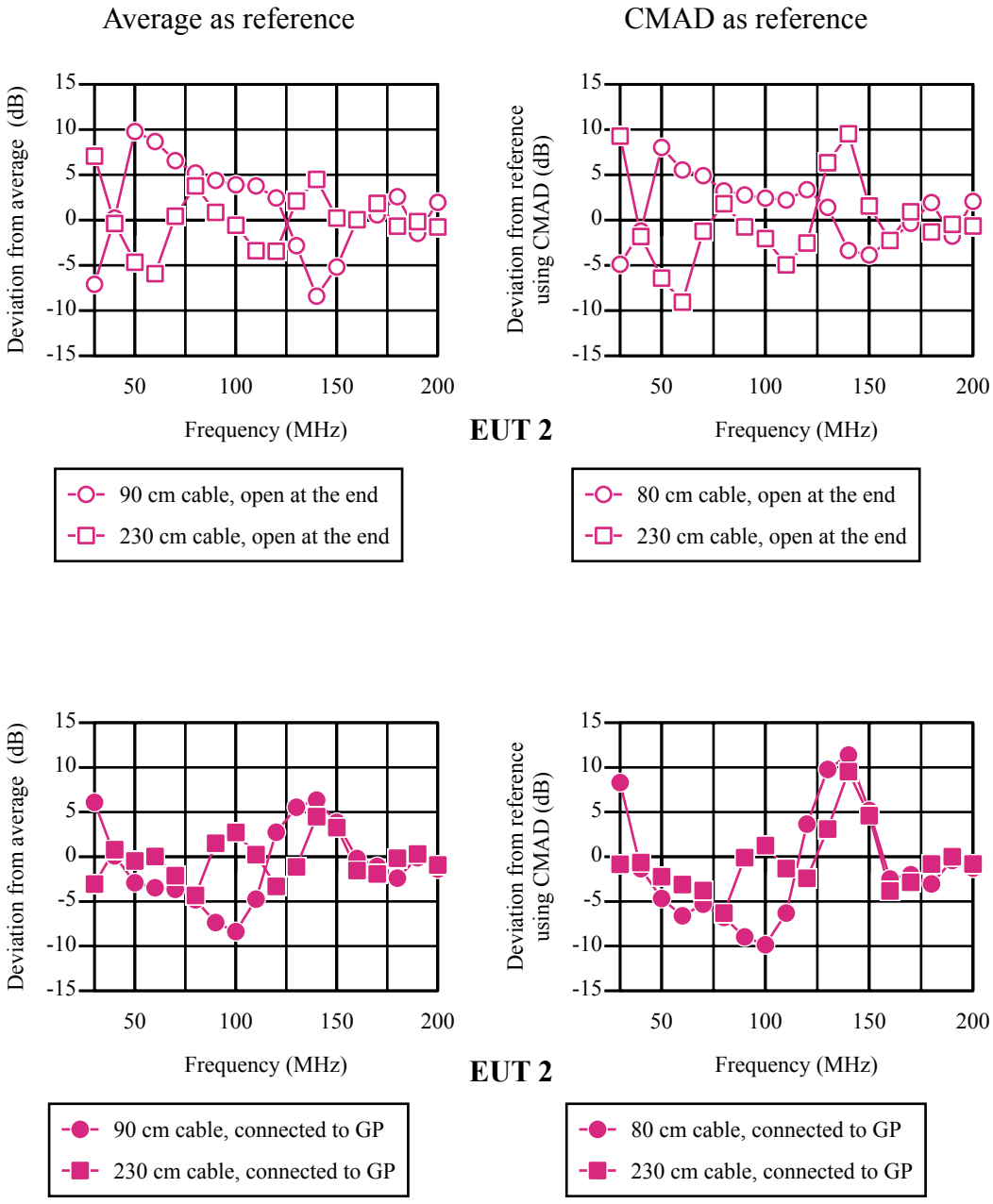


Fig 9 a Comparison of different cable lengths with EUT 2

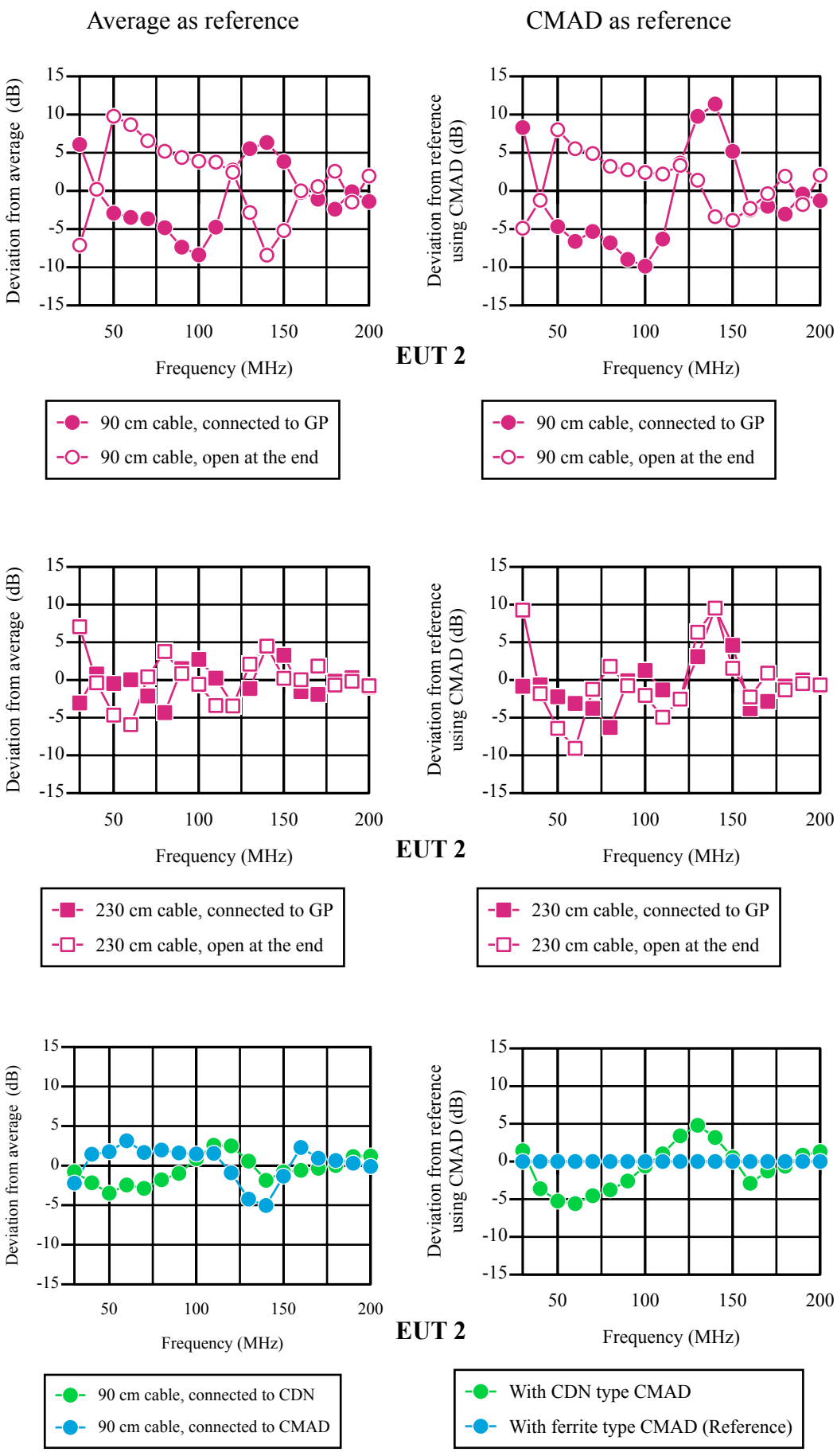


Fig 9 b Comparison of different grounding conditions with EUT 2

3.3.3. Comparison of results with EUT 3

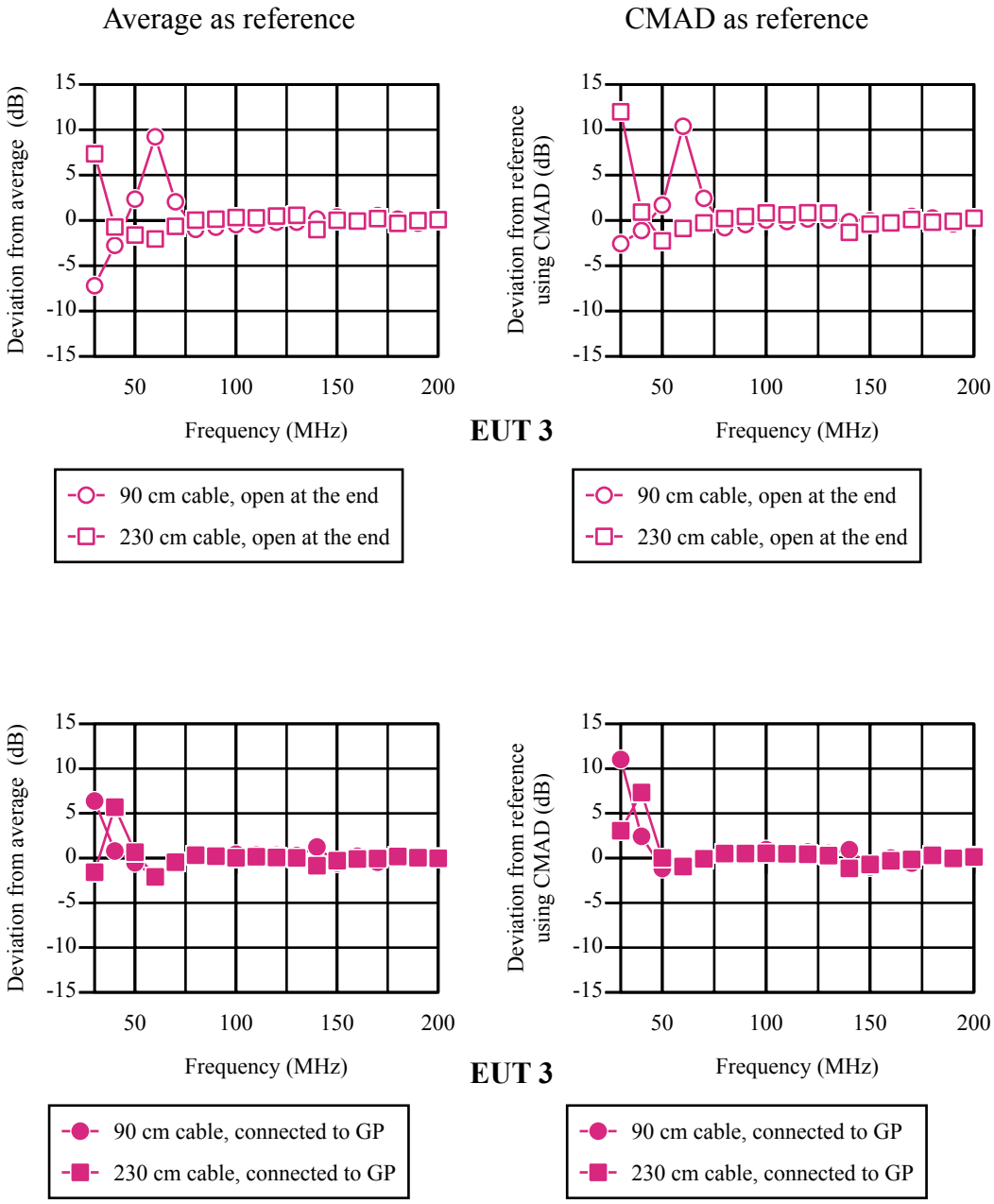


Fig 10 a Comparison of different cable lengths with EUT 3

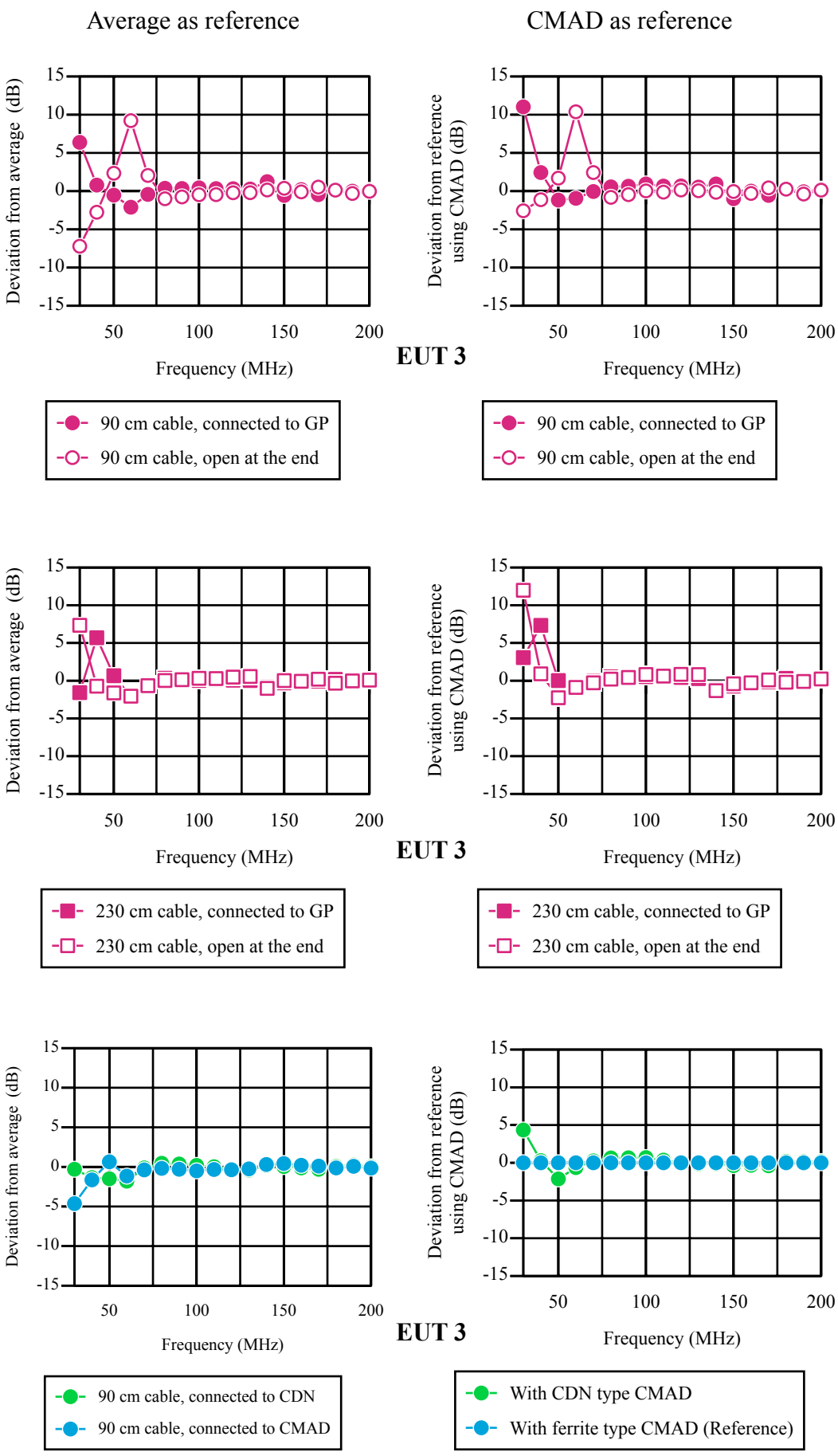


Fig 10 b Comparison of different grounding conditions with EUT 3

3.3.4. Comparison of results with EUT 4

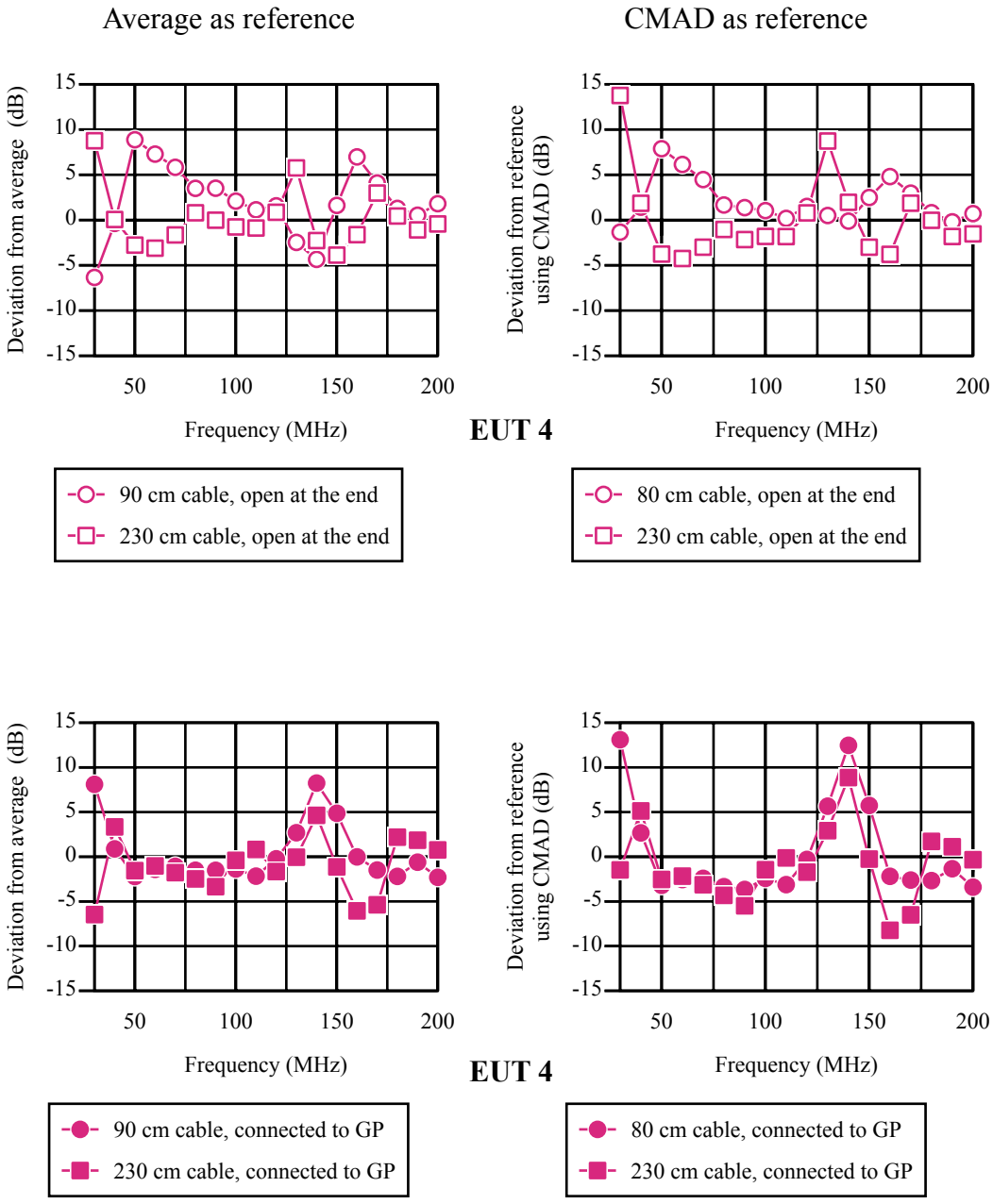


Fig 11 a Comparison of different cable lengths with EUT 4

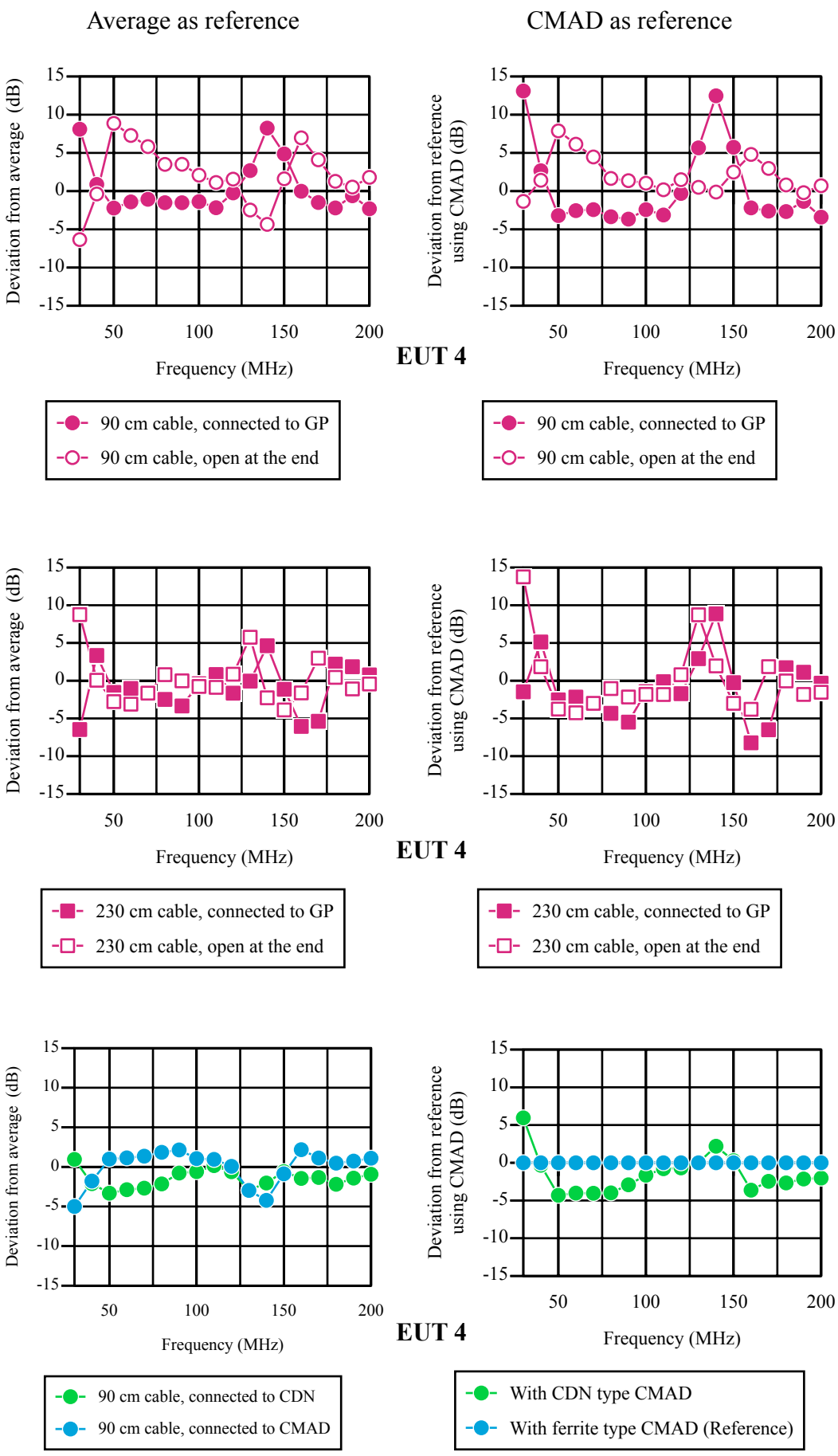


Fig 11 b Comparison of different grounding conditions with EUT 4

3.3.5. Comparison of results with EUT 5

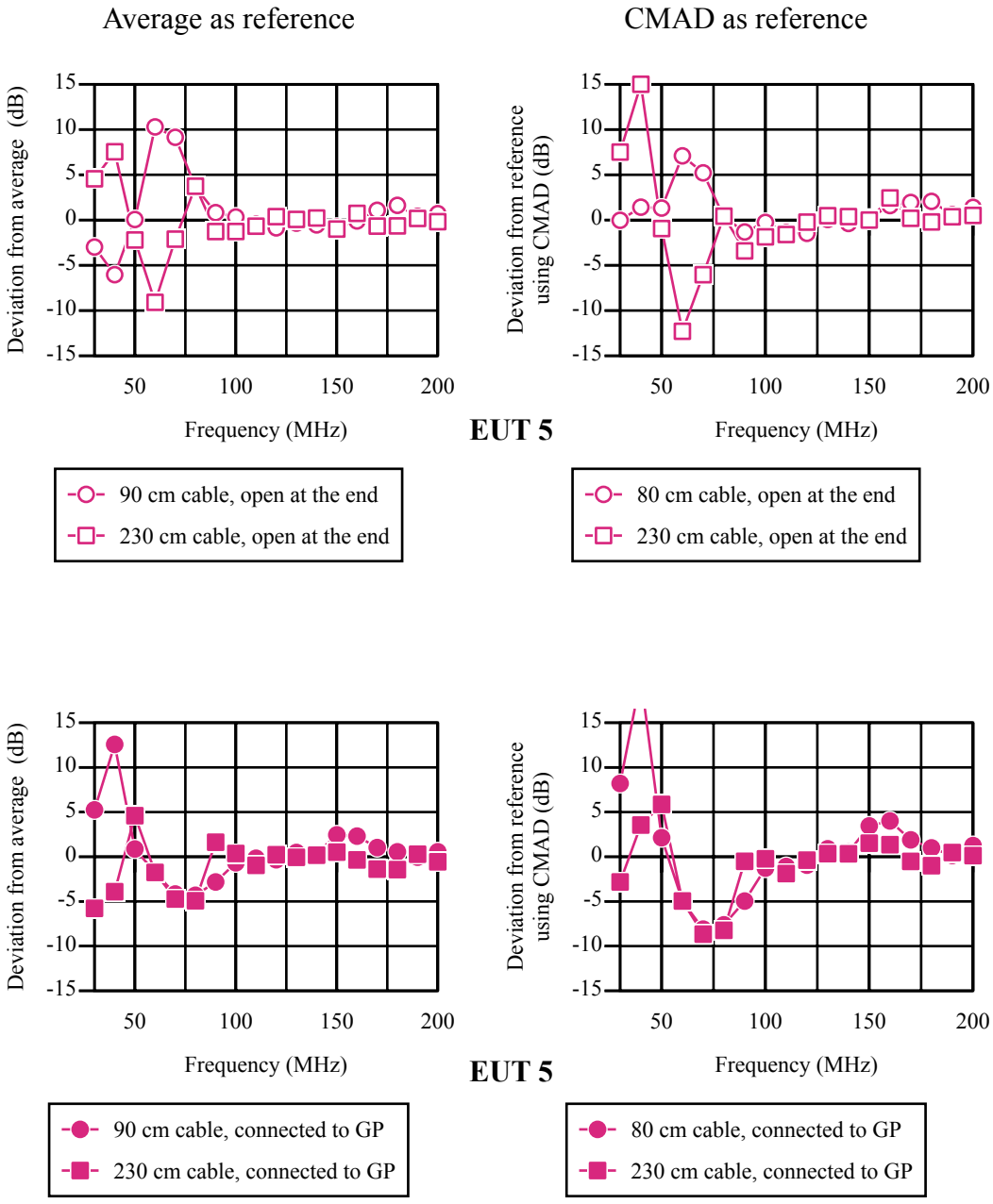


Fig 12 a Comparison of different cable lengths with EUT 5

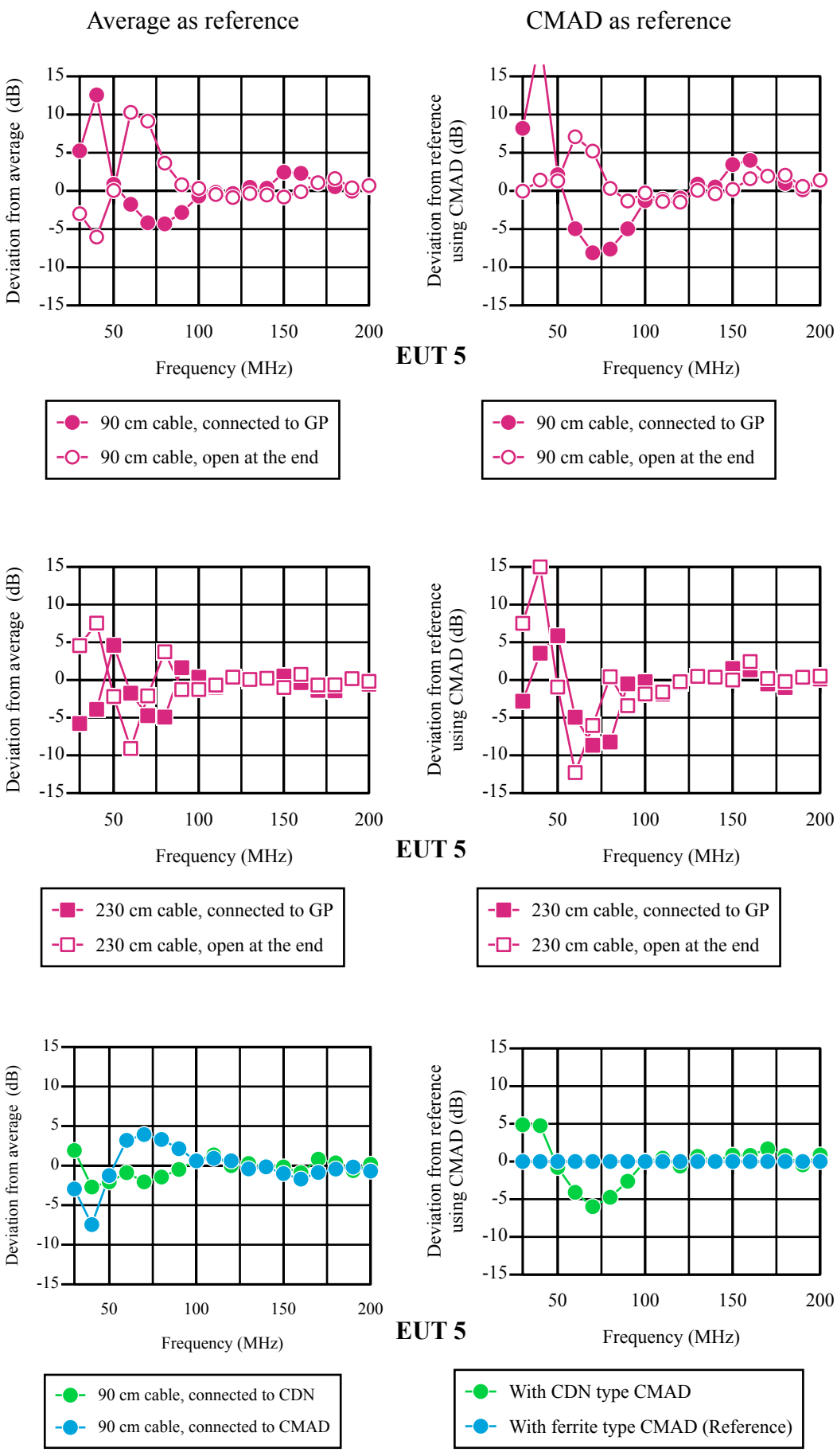


Fig 12 b Comparison of different grounding conditions with EUT 5

3.4 Recapitulation of older results with other EUT's

In CISPR/A/WG1(Ryser)07-01 we reported different measured examples to show the functional benefits of CMAD. In CISPR/A/WG1(Ryser)07-01, we used two independent averages for the results with CMAD (blue points) and for the results without CMAD (red points). An example of this presentation is shown here as Fig. 13

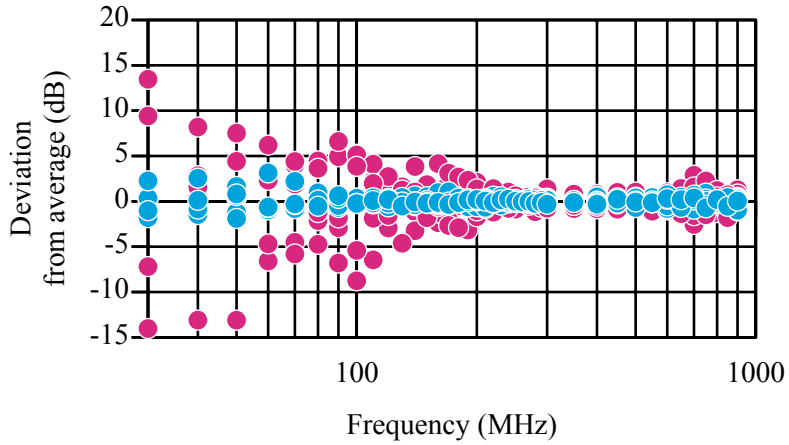


Fig. 13 EUT Example 1 as shown in CISPR/A/WG1(Ryser)07-01

The question was rised at the London meeting in April 2007, how far the average of blue points deviates from the average of the red points. Therefore we repeated the evaluation of the results for some of the examples using the overall average as reference. The result is shown in Fig 14 to 16 below.

EUT Example 1 of CISPR/A/WG1(Ryser)07-01 is similar to EUT 5 of this report.
EUT Example 3 of CISPR/A/WG1(Ryser)07-01 is similar to EUT 4 of this report.
EUT Example 7 of CISPR/A/WG1(Ryser)07-01 is a simulated PC with 2 cables

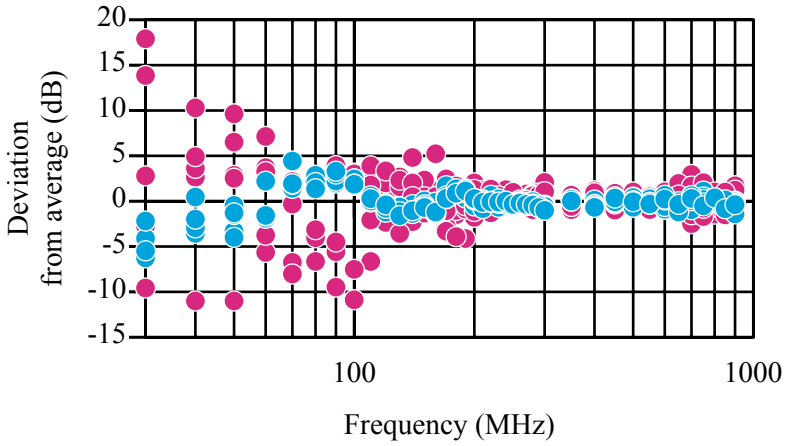


Fig 14 EUT Example 1 in CISPR/A/WG1(Ryser)07-01 (similar to EUT 5 of this report)

As already discussed in 3.2 the average is influenced by the selection of the individual sampling values. In these examples we had measured 5 different setups without CMAD (red points) and 5 different setups with CAMAD (blue points). If for example we would have measured more samples of the type with CMAD (blue points), the average would be closer to the zero line. Nevertheless we can see from these figures that the deviation of the results without CMAD are as much positive as negative. A discussion on adjusted limits for measurements with CMAD is not necessary.

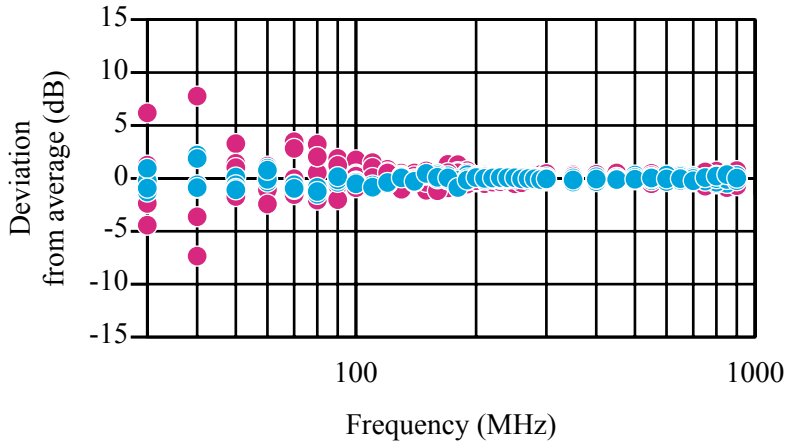


Fig 15 EUT Example 3 in CISPR/A/WG1(Ryser)07-01 (similar to EUT 4 of this report)

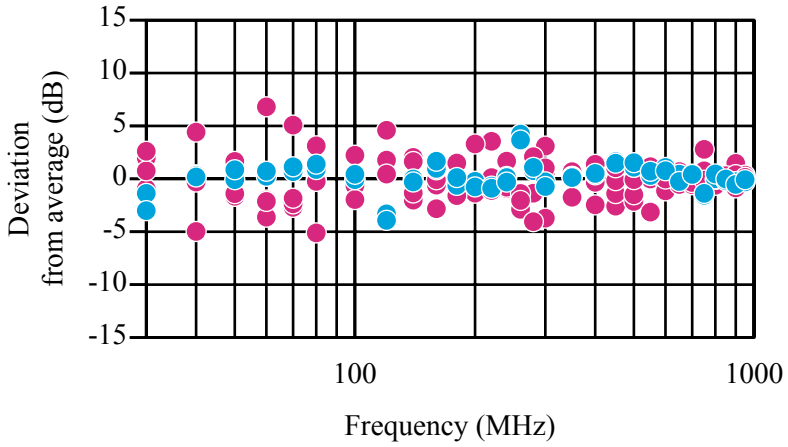


Fig 16 EUT Example 7 in CISPR/A/WG1(Ryser)07-01

It can be seen, that the average of the measurements with CMAD (blue points) is in general close to the overall average. It can also clearly be seen how the spread of the results (compliance uncertainty contribution) is significantly reduced by applying the CMAD.

The deviations are in general restricted to the frequency range below 200 MHz.
(See Fig 14 and Fig 15). The deviations above 200 MHz in Fig 16 are possibly due to other instabilities of the experiment which have nothing to do with the effects studied here.

4. Discussion of the results

4.1. Variation of cable length and impedance to the groundplane

It can be seen by many of the examples that changing the length has a similar effect as changing the impedance (Fig 8a, 8b, 9a, 9b, 12a, 12b). This can be explained by the fact that the cable laying on the ground plane acts as a transmission line. An open circuit at the end of a transmission line can be translated to a short circuit at the other end of the transmission line and vice versa, depending on frequency and lengh of the transmission line section.

4.2. Horizontal and vertical polarisation

The influences are in general only appearing for the frequency range where the vertical polarisation is responsible for the maximum. This is plausible because the cable affected by the grounding conditions is vertically oriented.

4.3. CDN or ferrite clamp CMAD ?

At the London meeting in April 2007 the question was rised whether CDN's should be used instead of the ferrite clamp type CMAD. Theoretically the stabilsation of the impedance with CDN is as good as with CMAD. However, if CDN's (with 150Ā common mode impedance) are used instead of the ferrite clamp type CMAD's with the specification according to CISPR/A/754/CDV, the measurement result of radiated emission can be up to 5 dB different (See Fig 8b, 9b, 10b, 11b and 12b). Ferrite clamp type CMAD with 150Ā common mode impedance combined with sufficient attenuation (S_{21}) do not exist.

The CDN has howewer the following important practical drawbacks:

1. Every cable has to be cut to appropriate length and connected to the CDN.
2. For each cable type we need an appropriately constructed CDN.

In contrast to this, the ferrite clamp CMAD can be used an any cable without the need to cut the cables for the test, and without the need to have an inventory of a high number of CDN types.

3. CDN's need a ground plane as reference.

This ground plane reference is available for measurements on an open area test site or in the semianechoic room. If we change to fully anechoic rooms, this ground reference does not exist. For these applications, the ferrite clamp CMAD is the only appropriate solution.

4.4. Adjustement of the limits

At the London meeting in April 2007 the question was rised, whether the limits need to be adjusted as soon as the CMAD are systematically applied.

From the data of this report we can conclude that such a correction of limits is not justified. For all measured examples, the deviations of the measurement results without CMAD compared to the results with CMAD are as much positive as negative.

The frequency of the positive and negative deviations depends on the cable length and the impedance at the connection to the ground plane.

Please note that the deviations are the result of measurements according to the actual standards. Depending on the situation in the measurement laboratory, any of these results shown in the figures 8 to 12 could have been measured and reported as result.

5. Recommendations for the application of CMAD

The following proposals are the personal opinions of the author of this report. The CISPR commitees responsible will have to take the appropriate decisions.

5.1. Number of cables

According to different experiences we know that the influence in discussion is most severe if the EUT has only one cable leaving the test site. The more cables of the EUT are leaving the test site, the smaller is this influence. Also, the more cables are to be fitted to CMAD the more complex becomes the test set up.

My proposal is to limit the application of CMAD to table top equipment with 3 cables or less leaving the test site. If more than 3 cables are leaving the testsite during the test, the CMAD need not be applied.

5.2. Restriction to tabletop equipment

According to different experiences we know that the influence in discussion is most severe if the EUT is rather small. The greater the dimensions of the EUT, the smaller is this influence. The restriction to table top equipment automatically excludes EUT's with big dimensions.

5.3. Position of the CMAD

For measurements on an open area test site or in the semianechoic room, the CMAD should be flat on the ground plane in such a way that the cables falling down from the EUT setup are introduced into the CMAD without laying on the ground plane for more than 10 cm before it enters the CMAD.

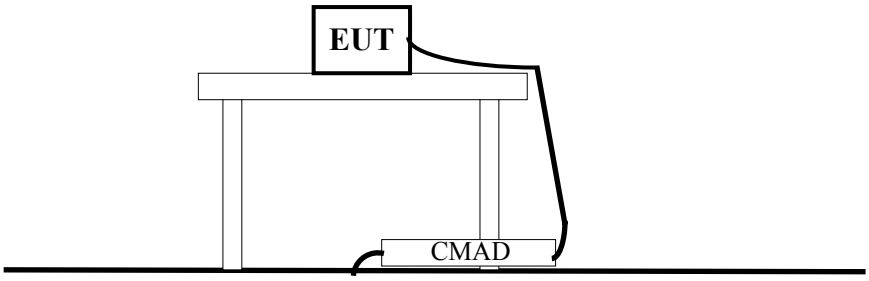


Fig 17 Position of the CMAD on an open area testsite

For measurements in the FAR, the CMAD should be arranged perpendicular to the floor (or to the wall) in such a way that the cables are entering the CMAD and be guided in the CMAD before they come close to the metallic outside surface of the FAR.

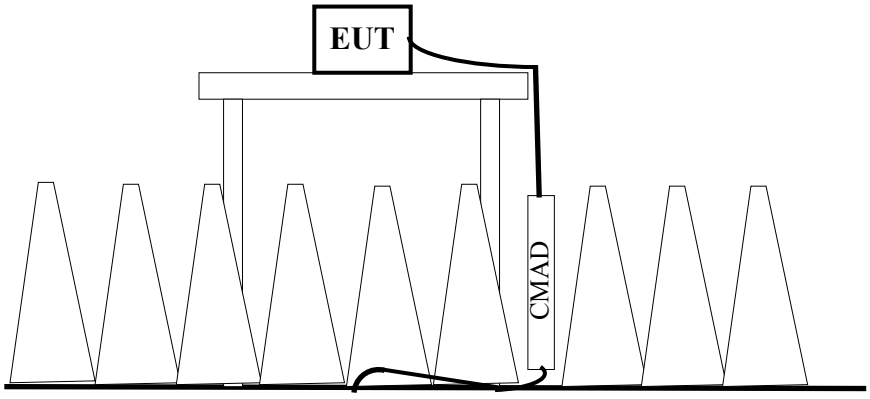


Fig 18 Position of the CMAD in a FAR (Fully anechoic room)

6. Additional information recorded for EUT1 to EUT4 on polarisation and field pattern

For EUT1 to EUT4 we had recorded additional information which is presented on page 24 to 35.

For each EUT type, the result of horizontal maximum and vertical maximum is shown for each of the six configurations.

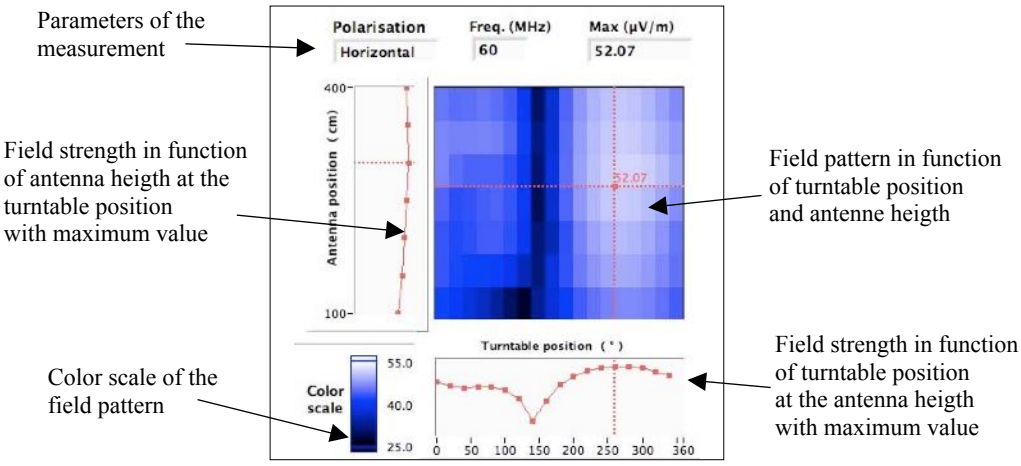
For EUT 1 and 2, the maximum is at all frequencies measured with vertical polarisation.

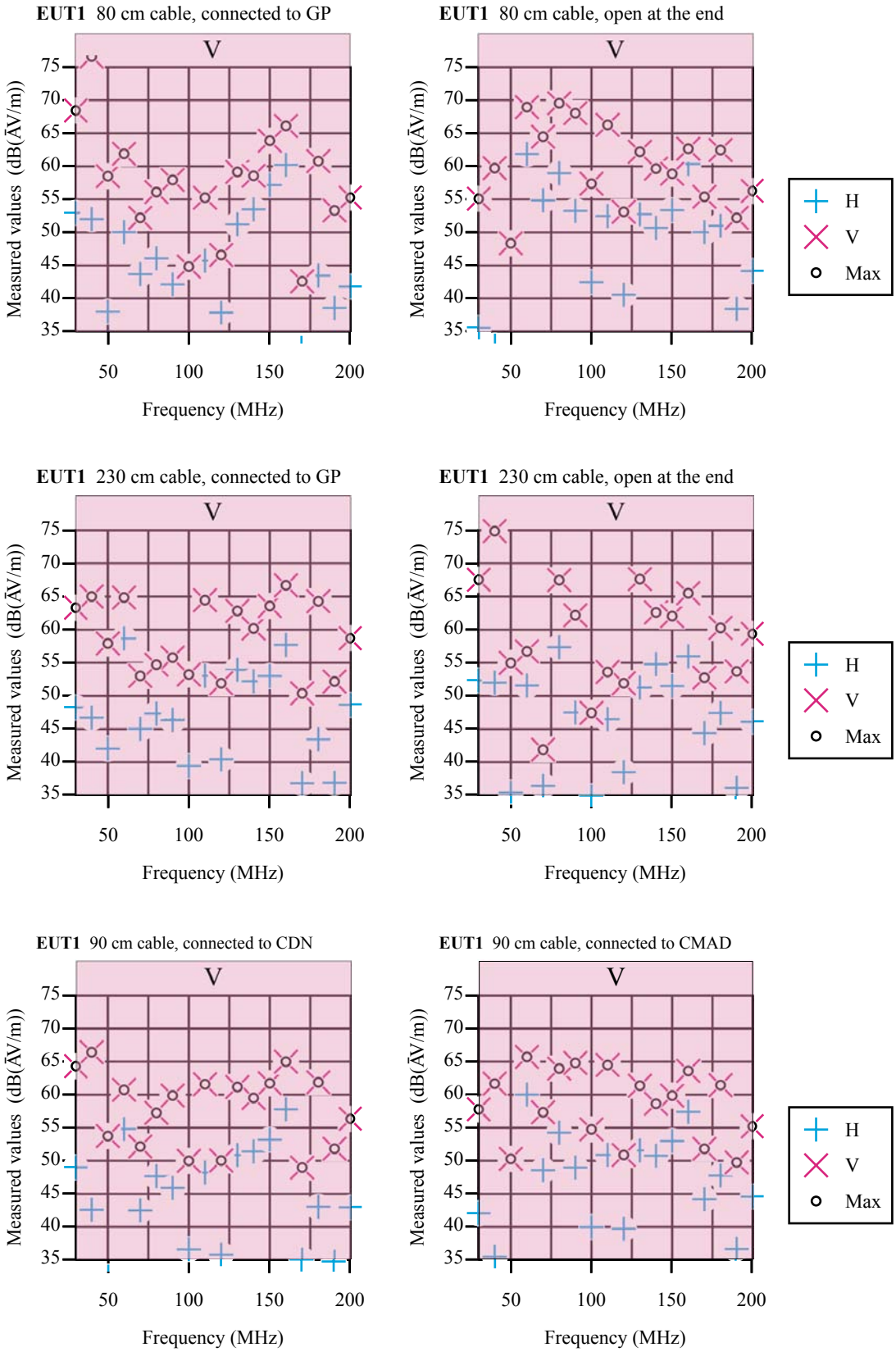
EUT 3 has a horizontal radiation source. The maximum is measured with horizontal polarisation at frequencies higher than 50 MHz. However below 50 MHz the vertical vertical component is dominant. This is the frequency range where the influence is appearing.

EUT 4 has a more complex radiation pattern. While at frequencies higher than about 120 MHz the maximum is measured with horizontal polarisation, the deviations are appearing also in this frequency range.

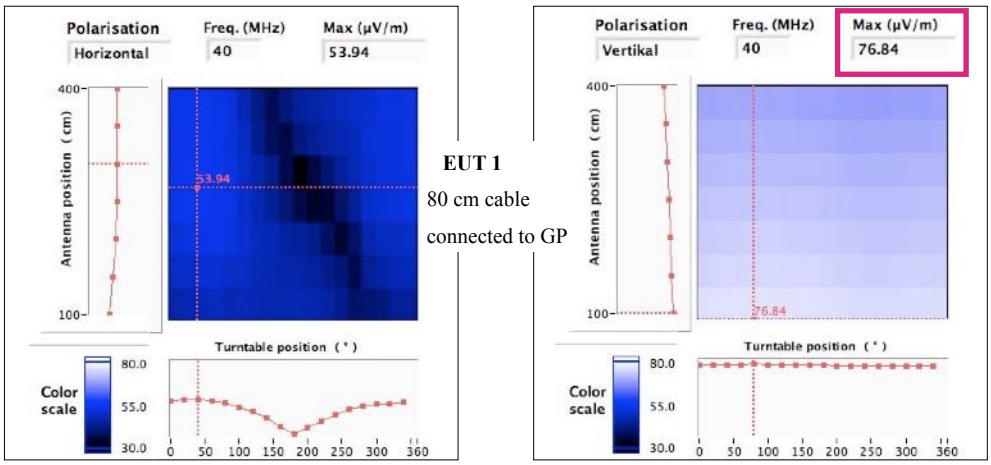
For EUT 5 we have no data about polarisation.

For some selected setups and frequencies, we also reproduced the field pattern in function of turntable position (in °) and antenna height (in cm). The pictures have the following format:

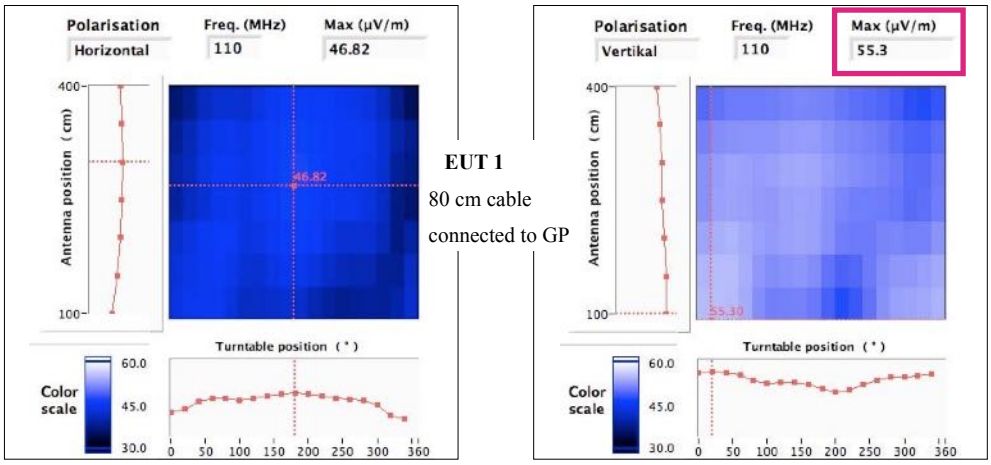




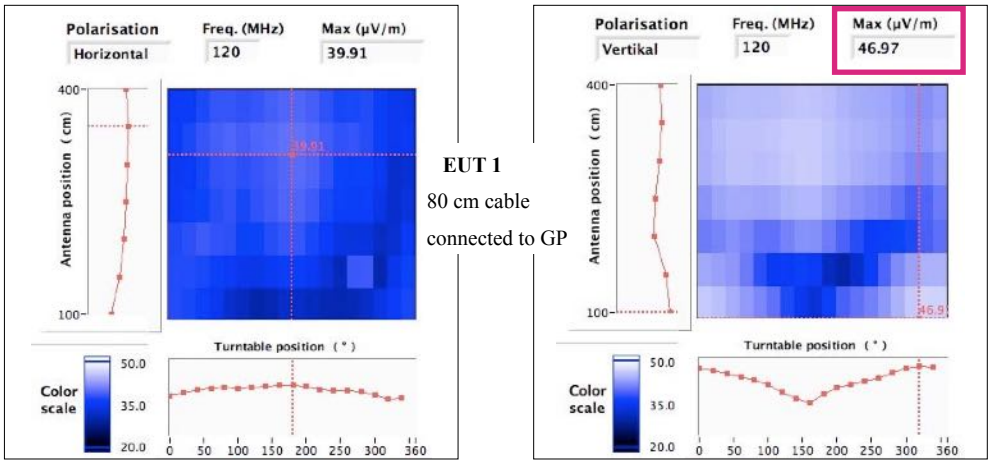
Measurement results with EUT1
Maximum results for horizontal and vertical polarisation (blue and red cross) and indication for which polarisation the maximum occurs (black points, all vertical for this example)



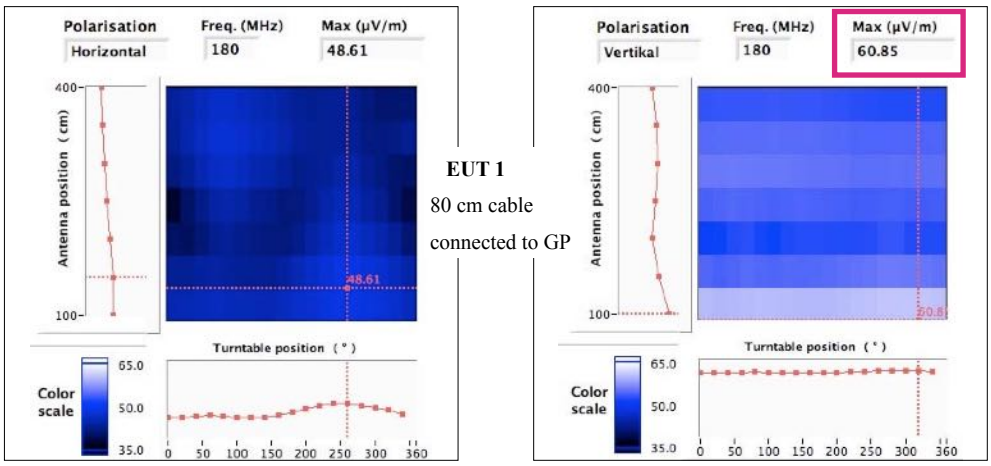
EUT 1
80 cm cable
connected to GP



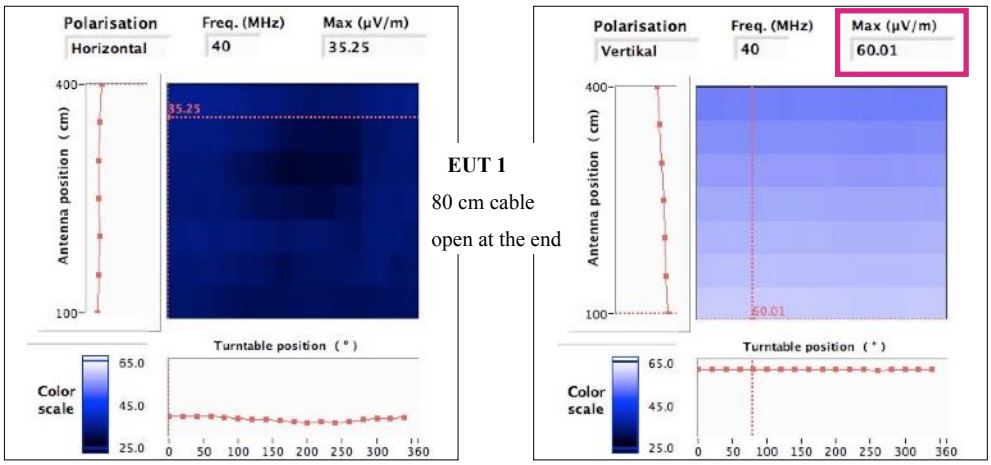
EUT 1
80 cm cable
connected to GP



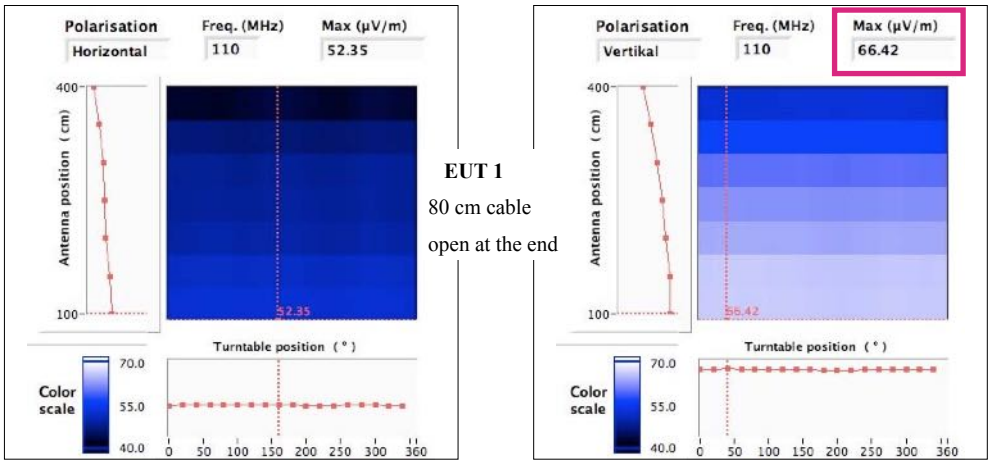
EUT 1
80 cm cable
connected to GP



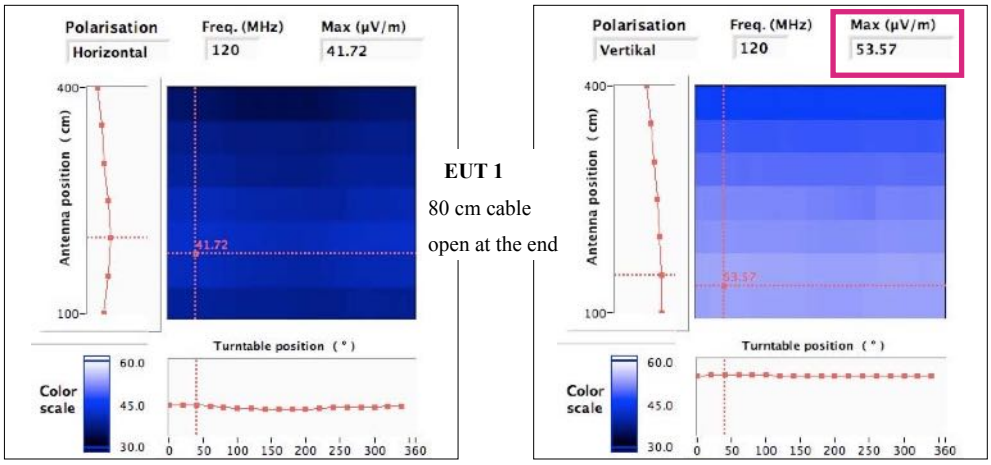
EUT 1
80 cm cable
connected to GP



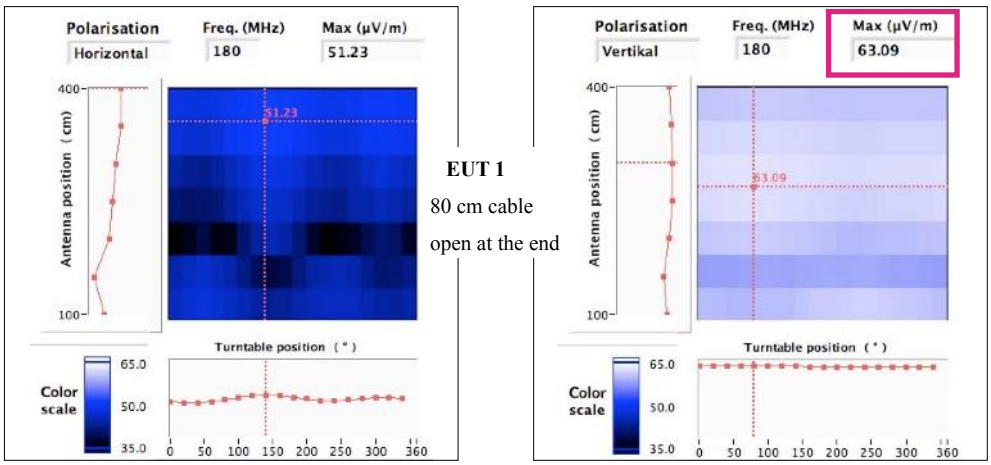
EUT 1
80 cm cable
open at the end



EUT 1
80 cm cable
open at the end

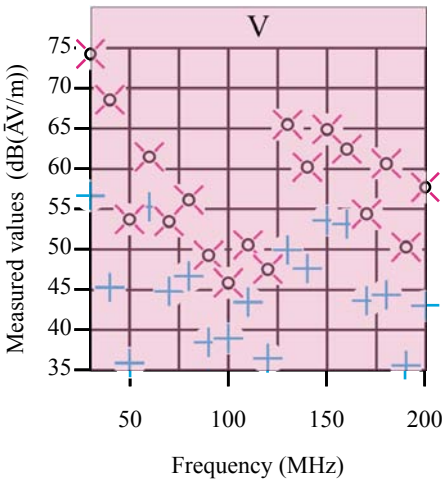


EUT 1
80 cm cable
open at the end

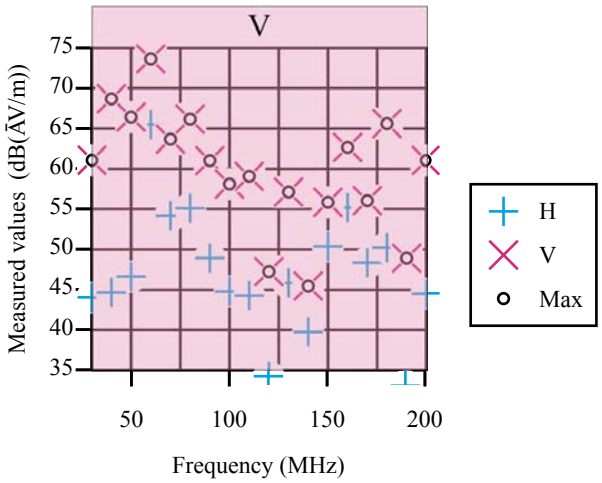


EUT 1
80 cm cable
open at the end

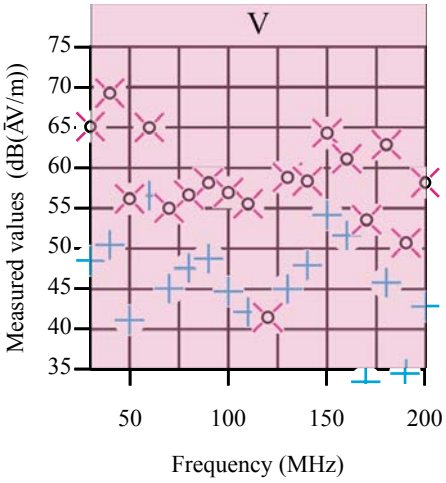
EUT2 80 cm cable, connected to GP



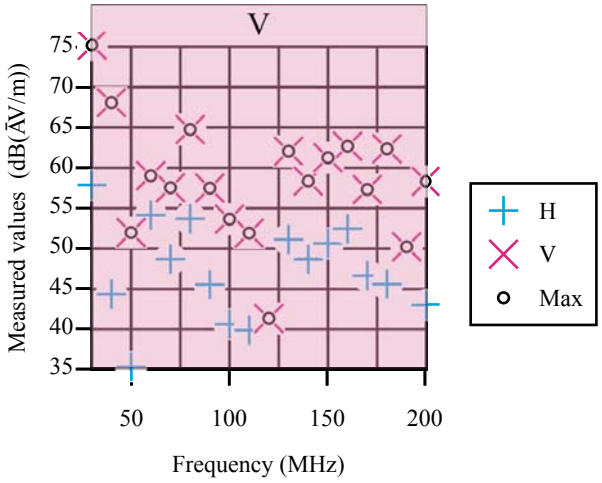
EUT2 80 cm cable, open at the end



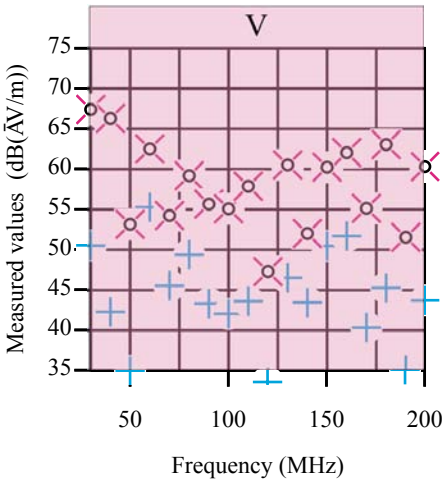
EUT2 230 cm cable, connected to GP



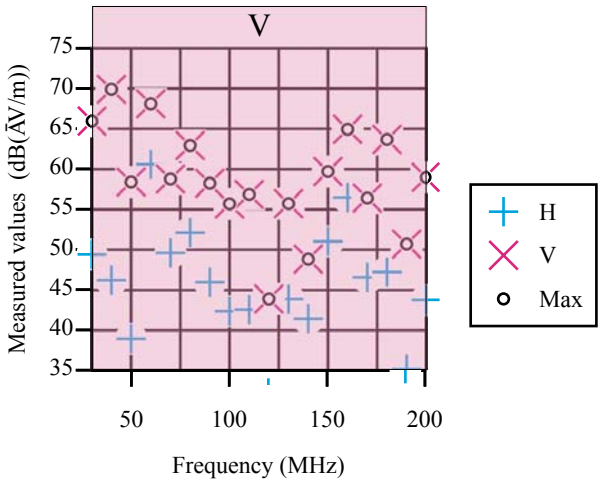
EUT2 230 cm cable, open at the end



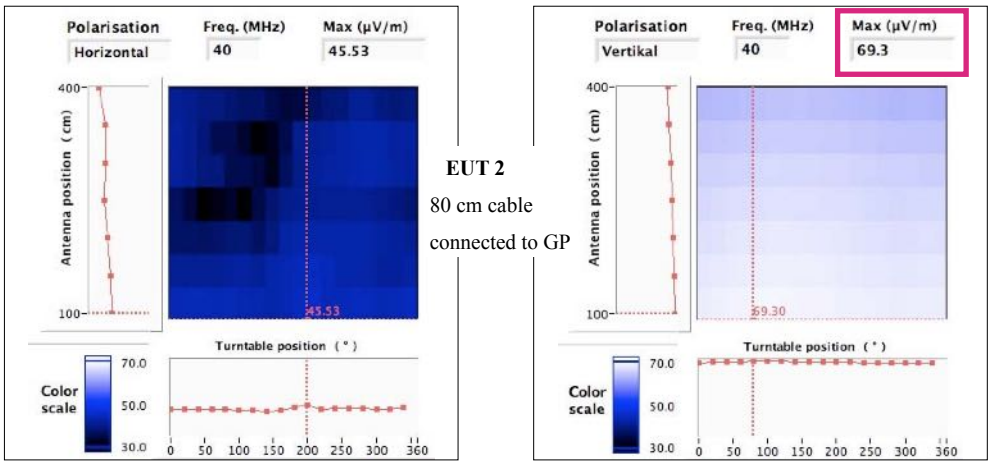
EUT2 90 cm cable, connected to CDN



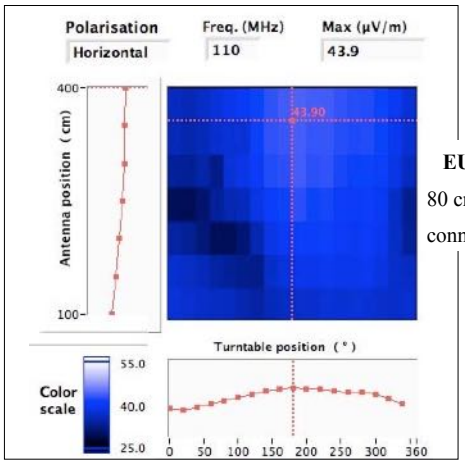
EUT2 90 cm cable, connected to CMAD



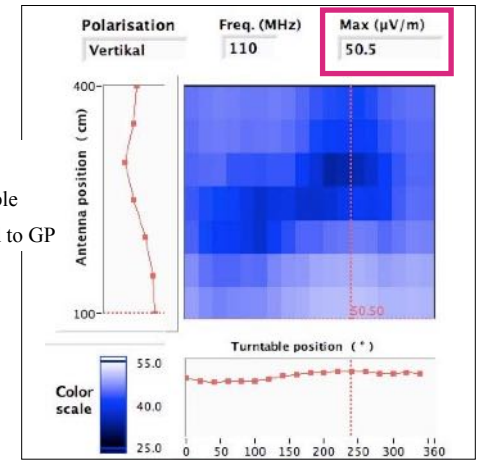
Measurement results with EUT2
Maximum results for horizontal and vertical polarisation (blue and red cross) and indication for which polarisation the maximum occurs (black points, all vertical for this example)

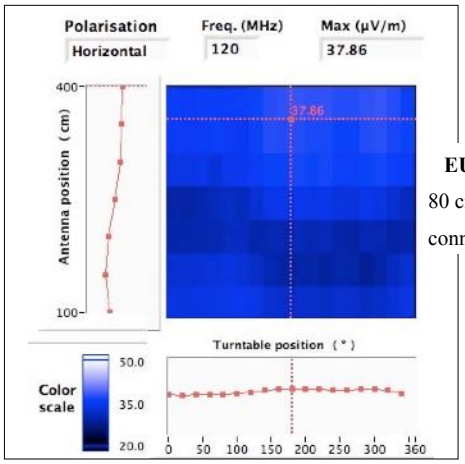


EUT 2
80 cm cable
connected to GP

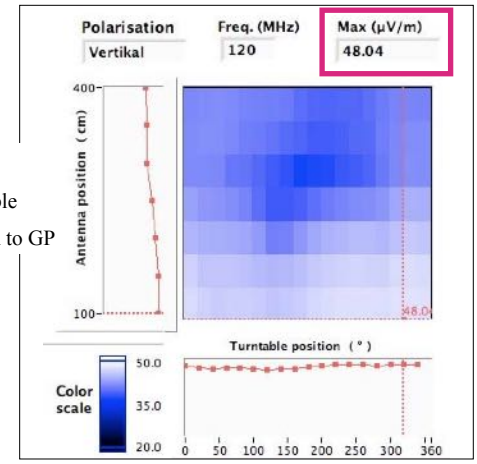


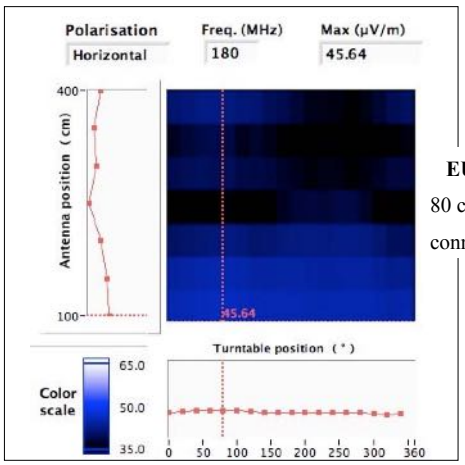
EUT 2
80 cm cable
connected to GP



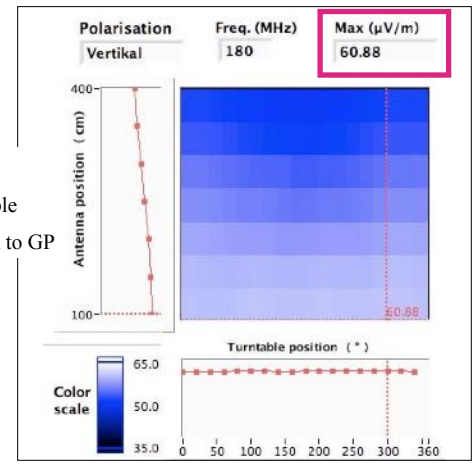


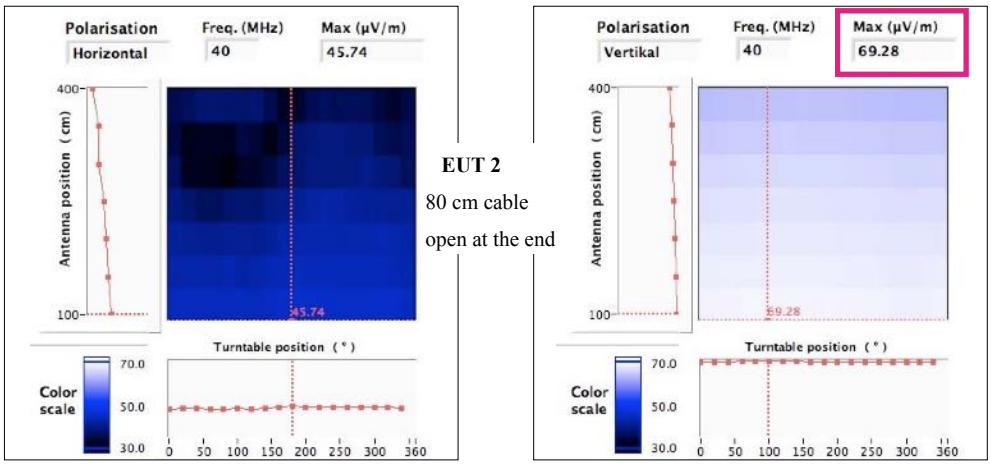
EUT 2
80 cm cable
connected to GP



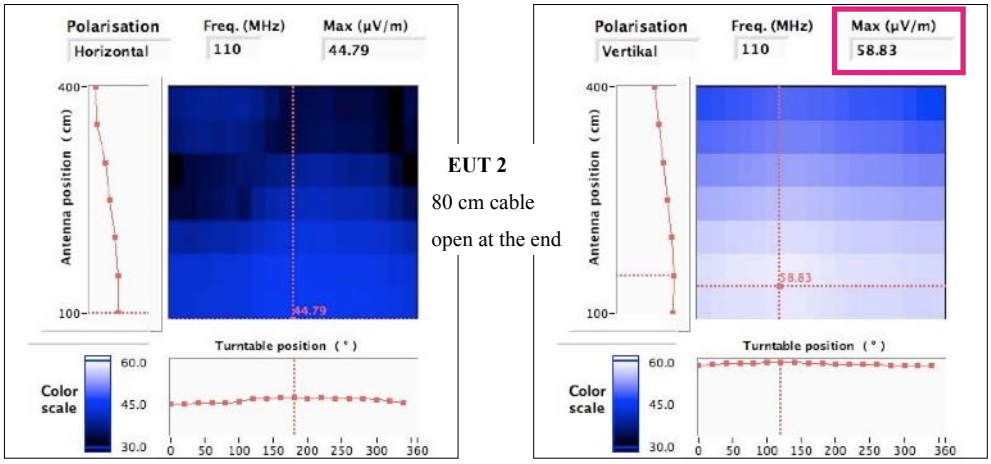


EUT 2
80 cm cable
connected to GP

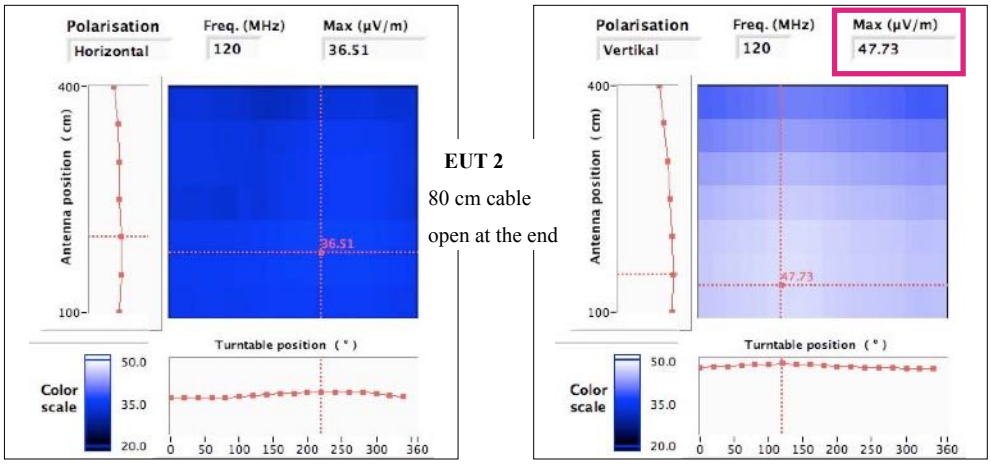




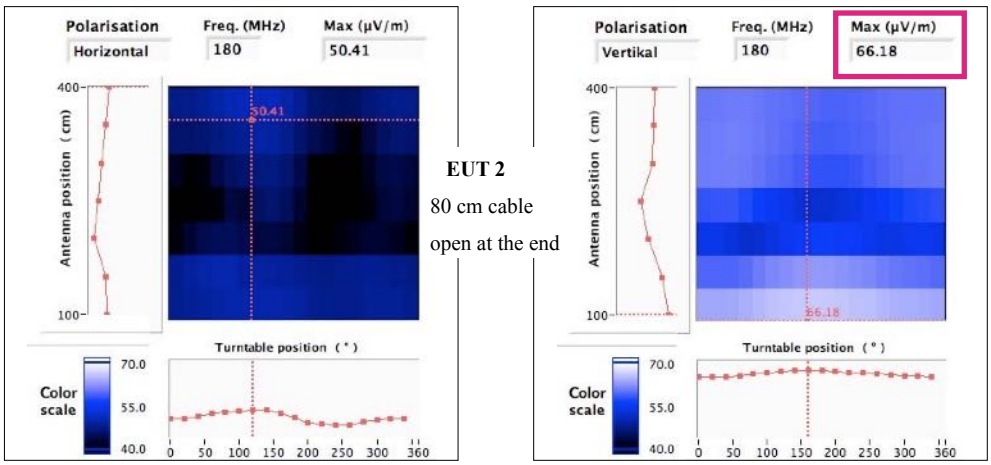
EUT 2
80 cm cable
open at the end



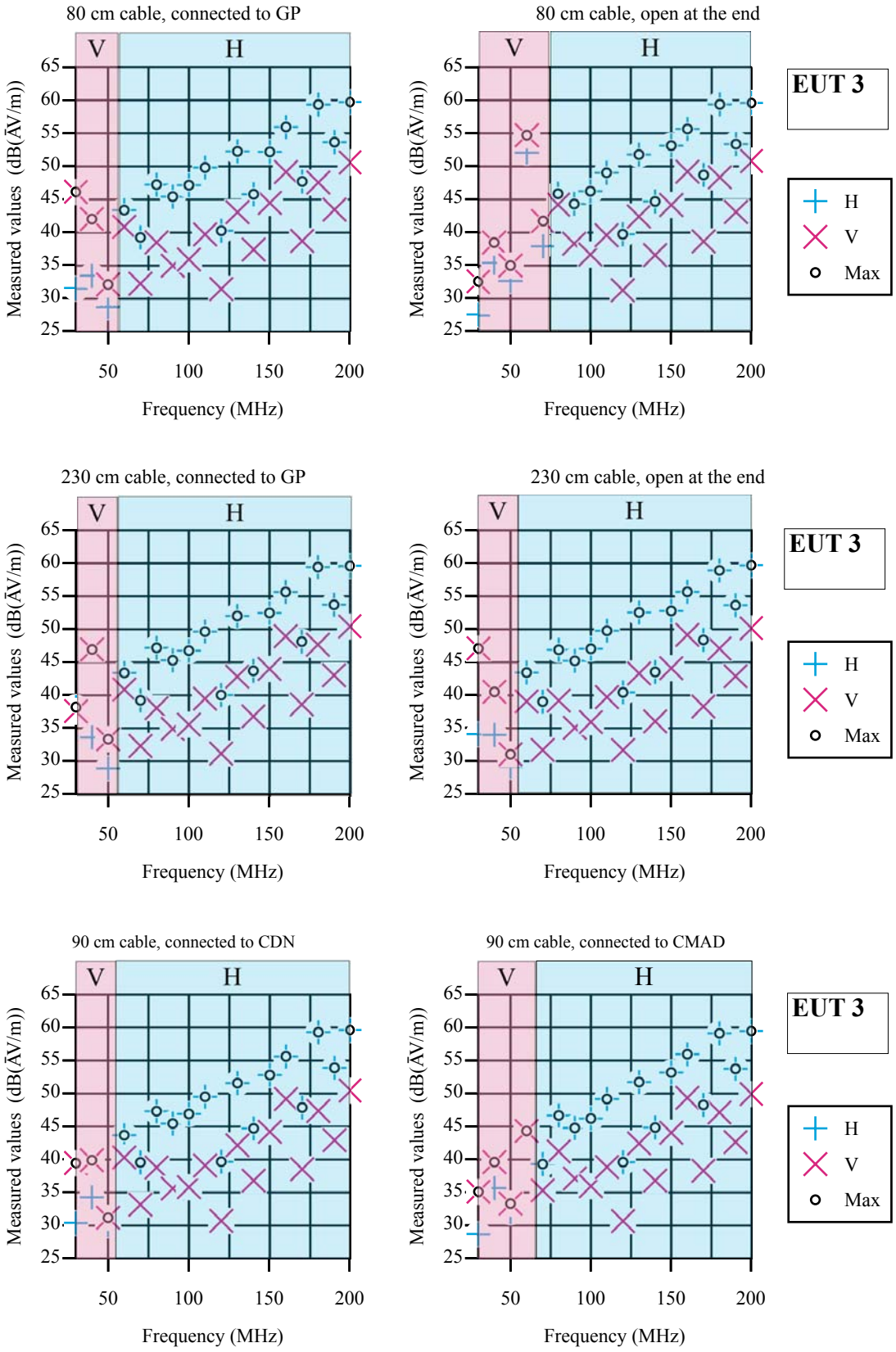
EUT 2
80 cm cable
open at the end



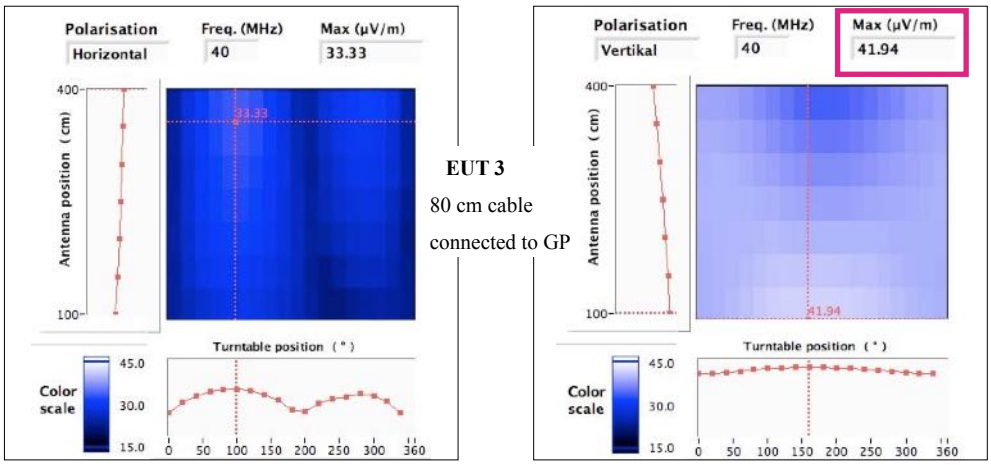
EUT 2
80 cm cable
open at the end



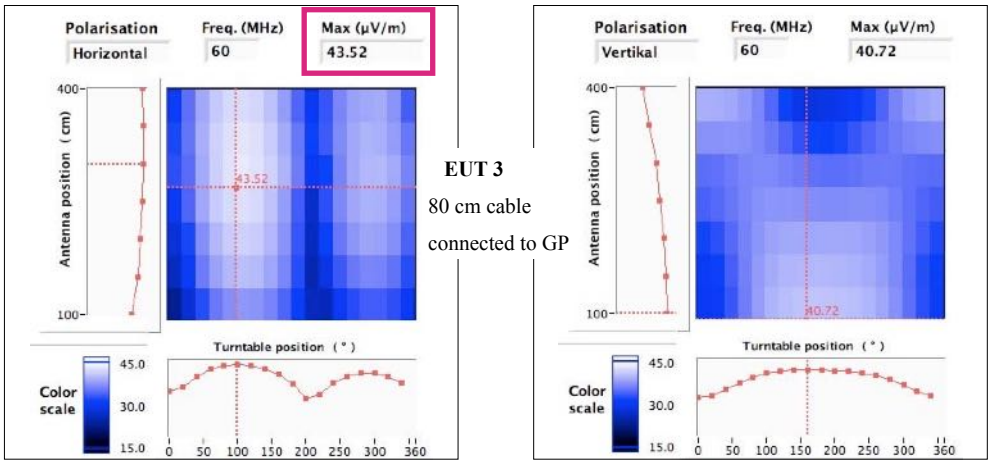
EUT 2
80 cm cable
open at the end



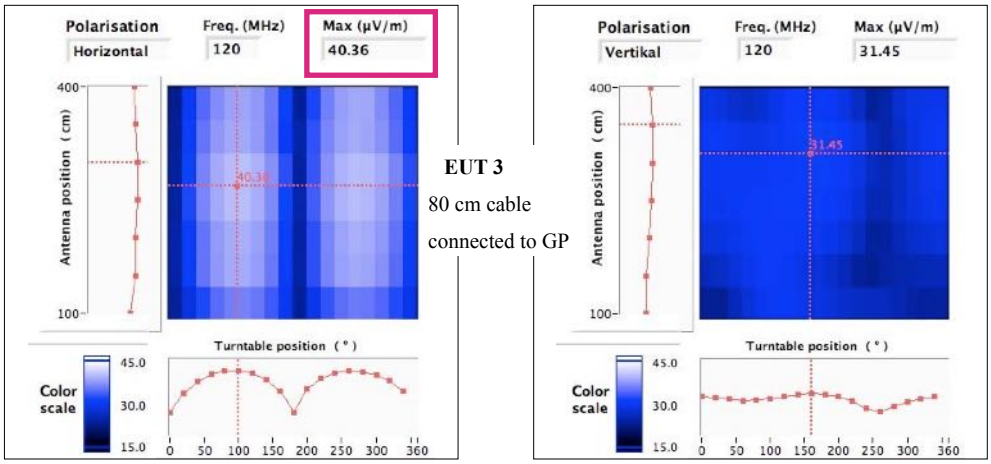
Measurement results with EUT3
Maximum results for horizontal and vertical polarisation (blue and red cross) and indication for which polarisation the maximum occurs (black points)



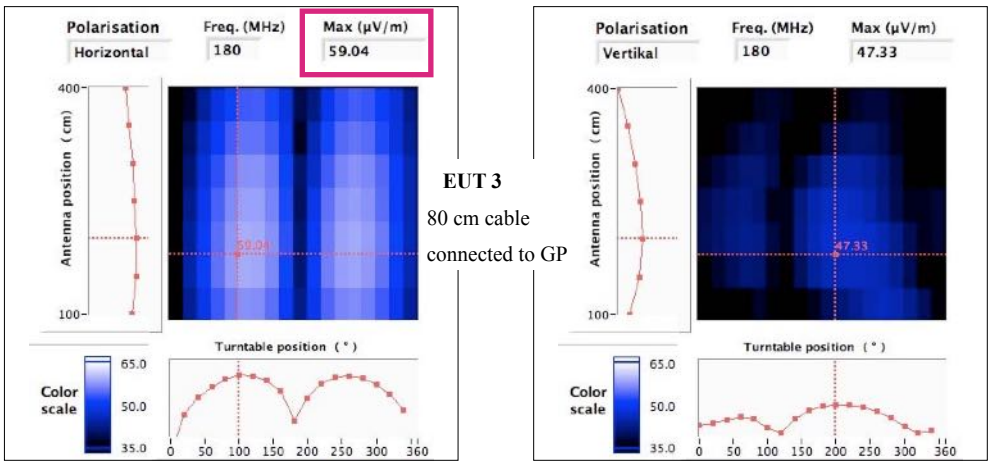
EUT 3
80 cm cable
connected to GP



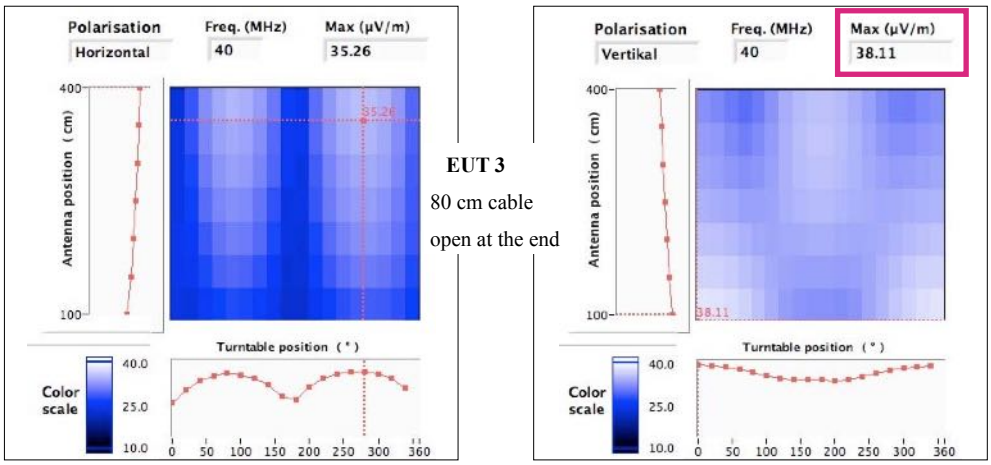
EUT 3
80 cm cable
connected to GP



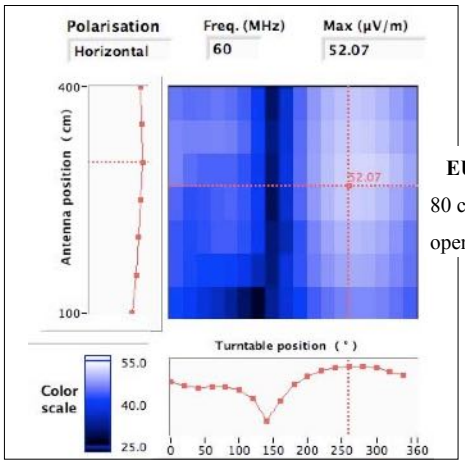
EUT 3
80 cm cable
connected to GP



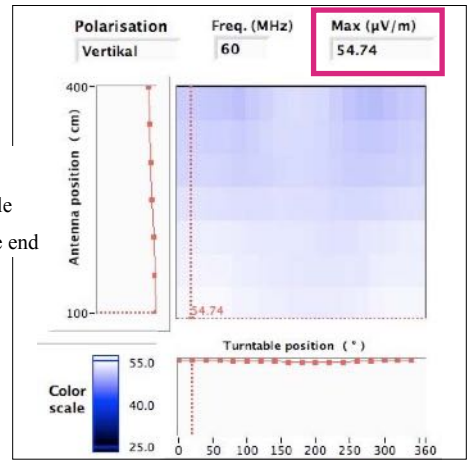
EUT 3
80 cm cable
connected to GP

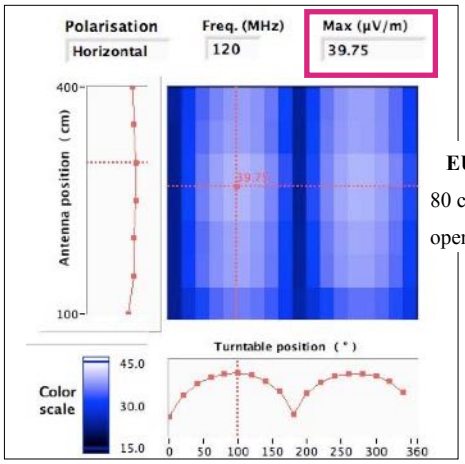


EUT 3
80 cm cable
open at the end

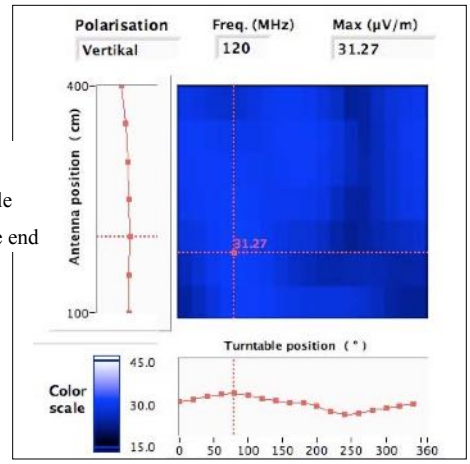


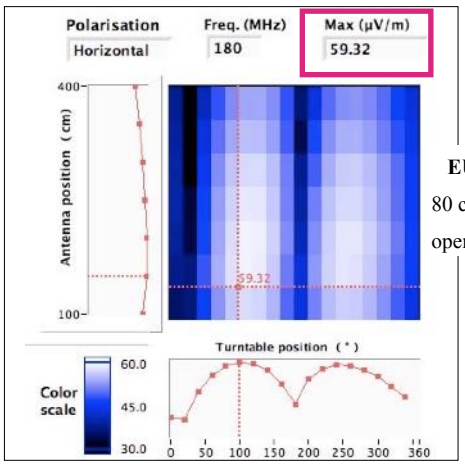
EUT 3
80 cm cable
open at the end



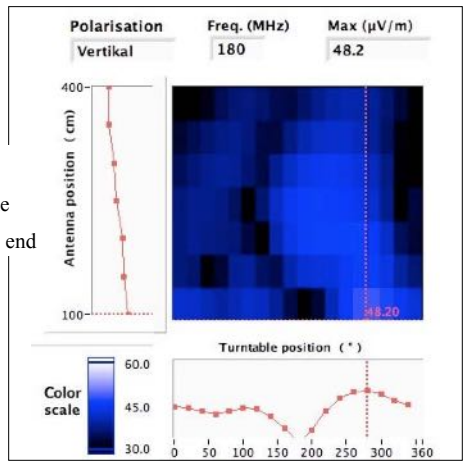


EUT 3
80 cm cable
open at the end

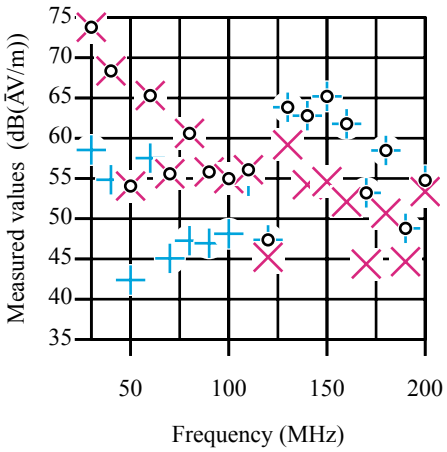




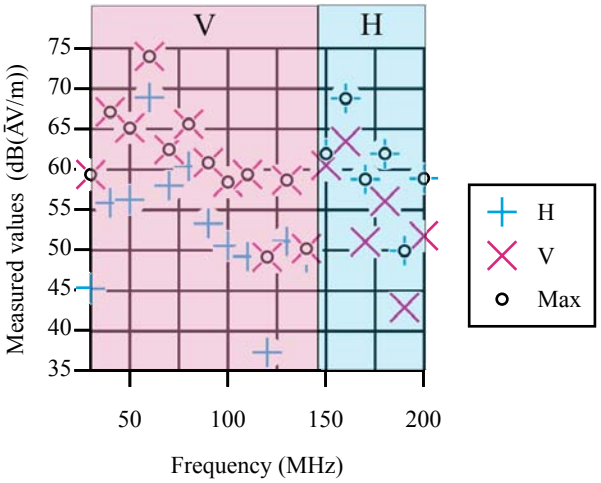
EUT 3
80 cm cable
open at the end



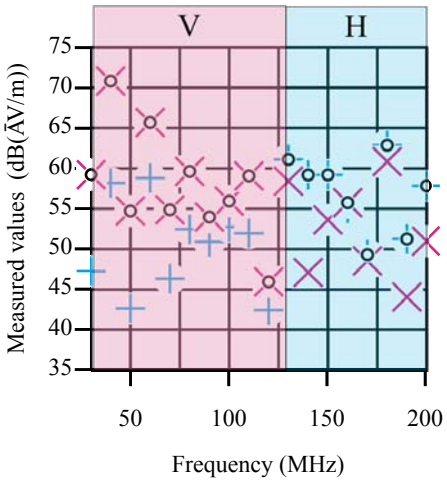
EUT4 80 cm cable, connected to GP



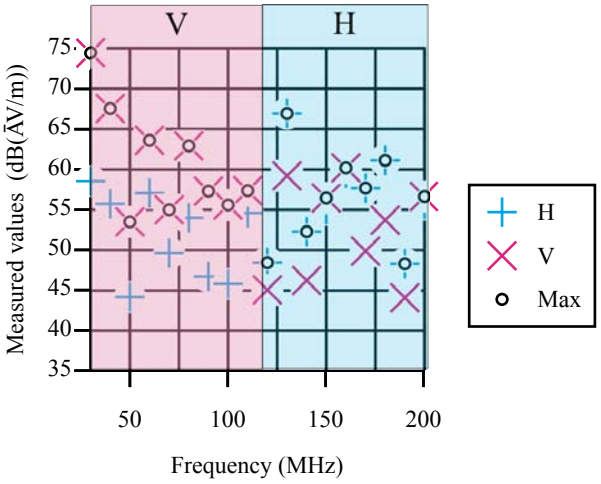
EUT4 80 cm cable, open at the end



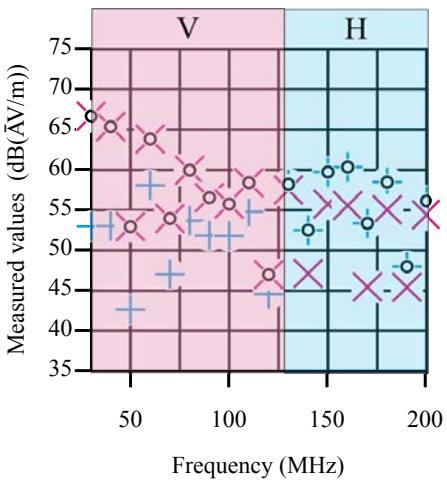
EUT4 230 cm cable, connected to GP



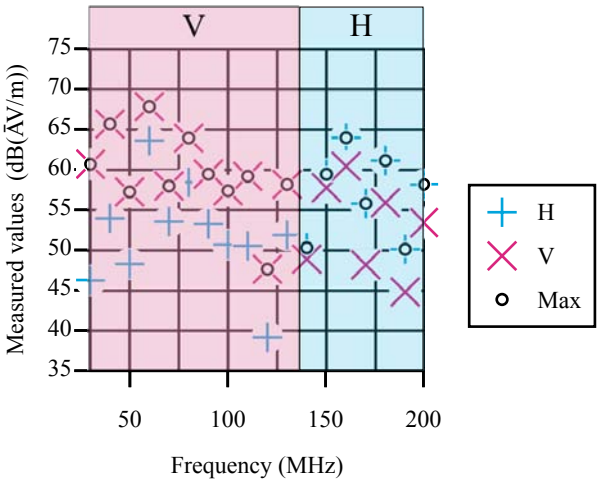
EUT4 230 cm cable, open at the end



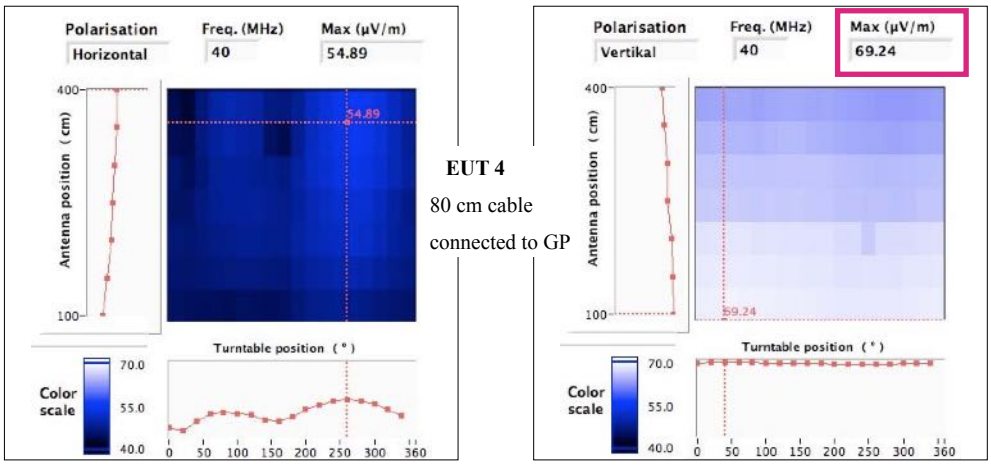
EUT4 90 cm cable, connected to CDN



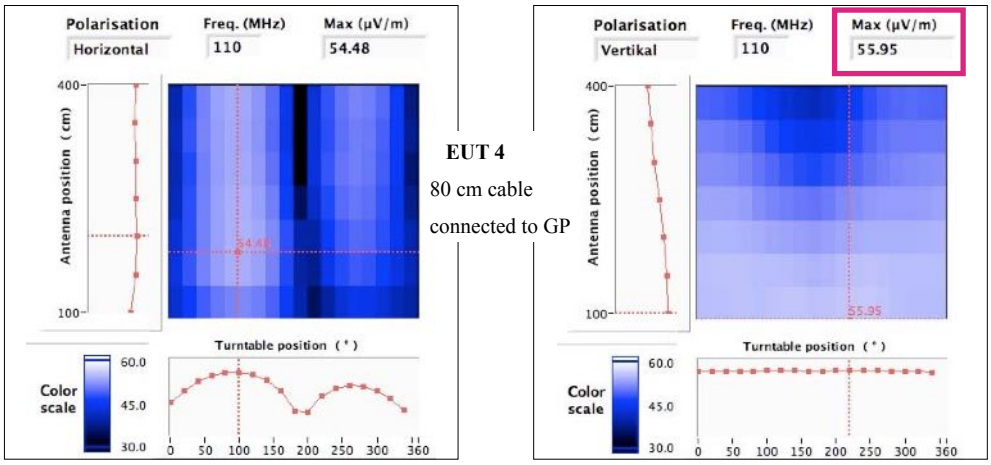
EUT4 90 cm cable, connected to CMAD



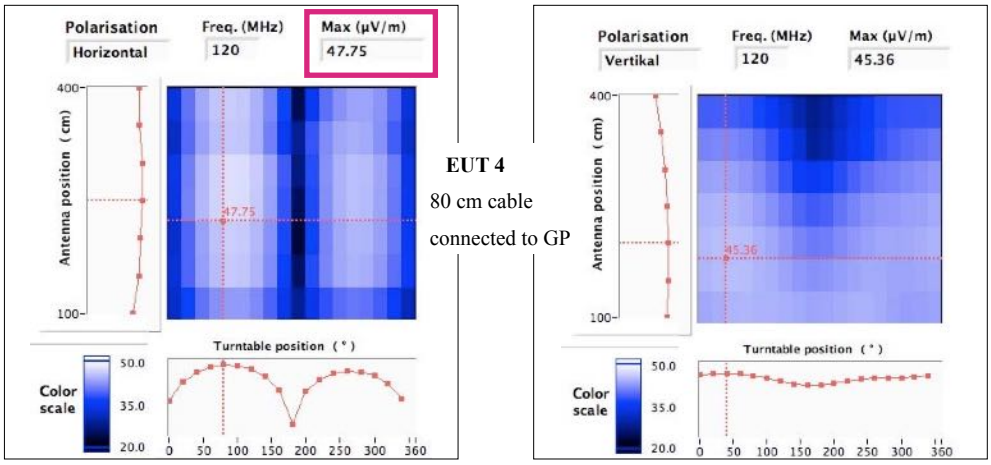
Measurement results with EUT4
Maximum results for horizontal and vertical polarisation (blue and red cross) and indication for which polarisation the maximum occurs (black points)



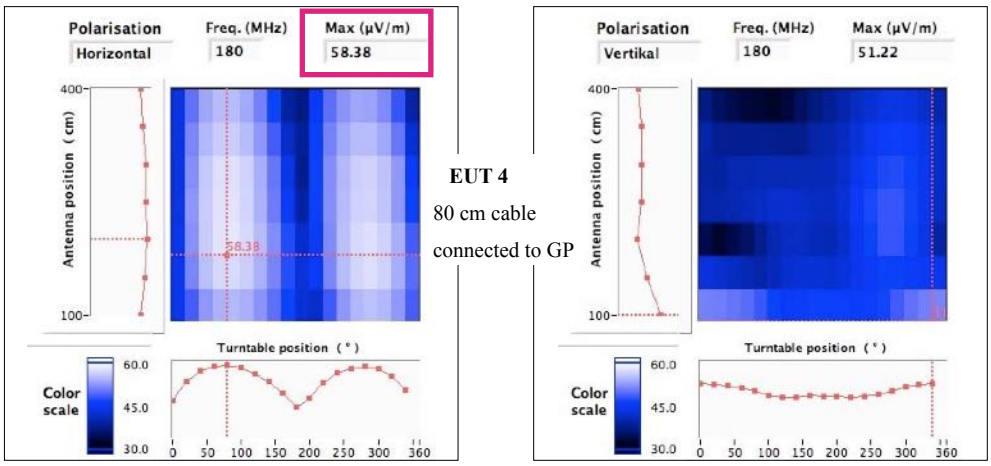
EUT 4
80 cm cable
connected to GP



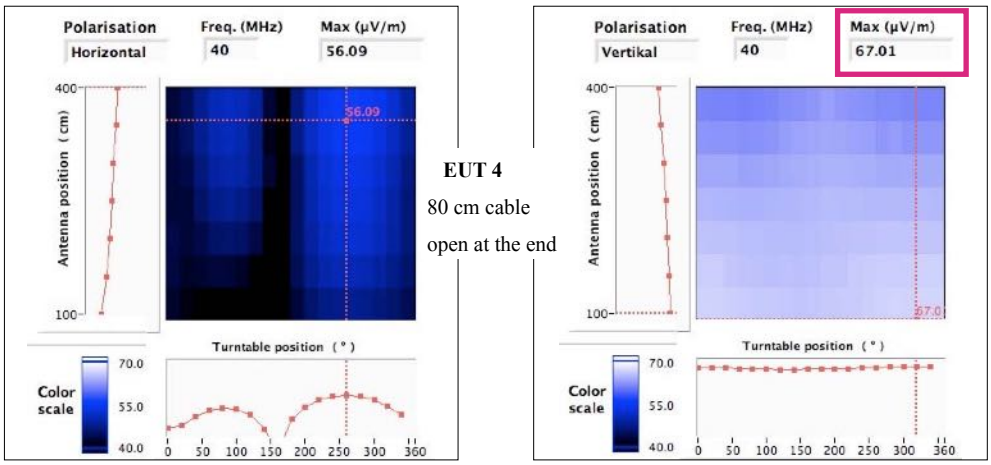
EUT 4
80 cm cable
connected to GP



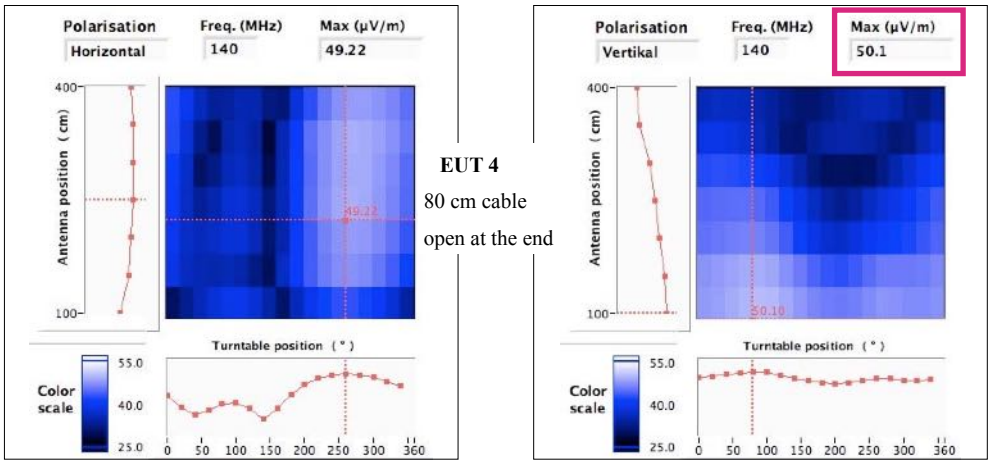
EUT 4
80 cm cable
connected to GP



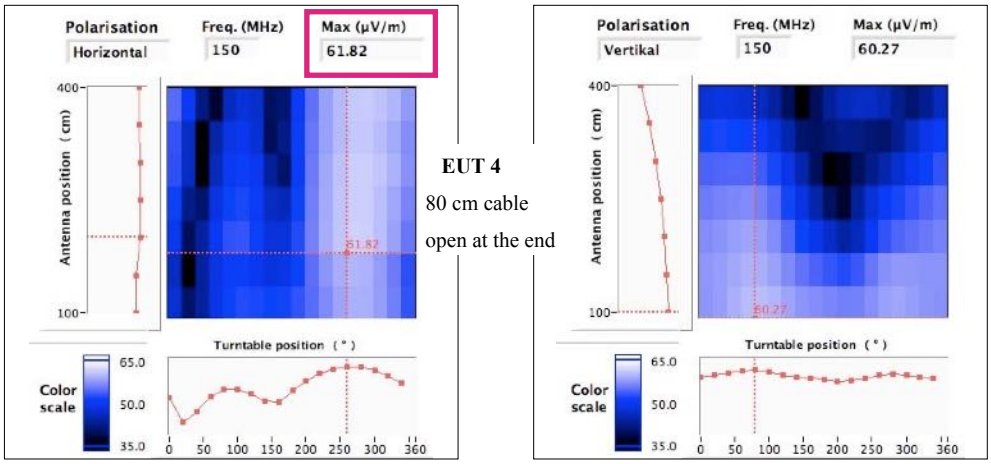
EUT 4
80 cm cable
connected to GP



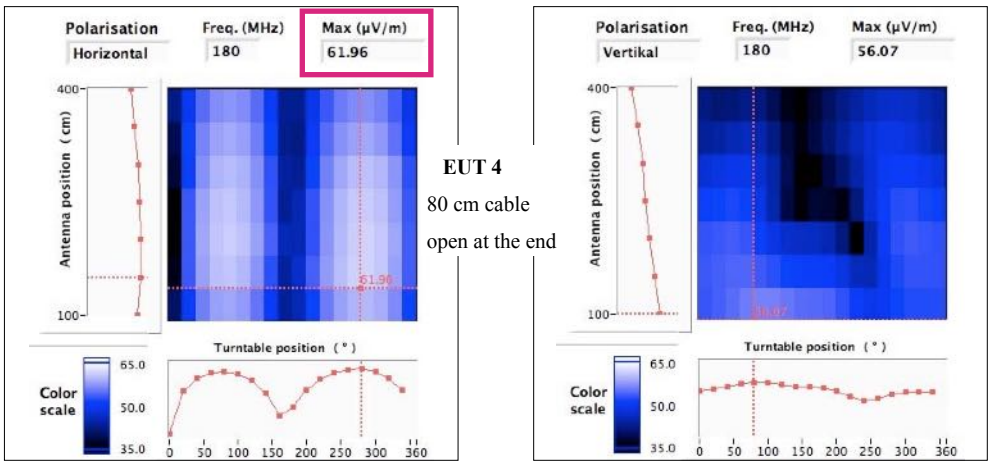
EUT 4
80 cm cable
open at the end



EUT 4
80 cm cable
open at the end



EUT 4
80 cm cable
open at the end



EUT 4
80 cm cable
open at the end

7. Conclusions

- The influence of the cable connection at the ground plane is most severe with small EUT's and one cable (EUT1 and EUT5, older results Example 1 on page 19). In these cases, the deviation from the average can be up to 15 dB in the frequency range 30 MHz to 80 MHz and up to 10 dB in the frequency range 80 MHz to 180 MHz.

- For EUT's with higher dimensions (EUT2, EUT3, EUT4, older results Example 3 and 7 on page 20), the deviations are about half the values compared to the most severe examples.

- The CMAD can reduce the compliance uncertainty of the radiated emission measurement significantly for some sensitive types of EUT's (See examples on page 19 and 20).

- The test set up with CMAD should describe the position of the CAMAD in such a way that the cable leaving the test volume is entering the CMAD at the point where it reaches the grond plane.

- If CDN's (with 150Ā common mode impedance) are used instead of the ferrite clamp type CMAD's with the specification according to CISPR/A/754/CDV, the measurement result of radiated emission can be up to 5 dB different (See Fig 8b, 9b, 10b, 11b and 12b).

- An adjustment of limits for the case that CMAD are systematically applied is not justified