VALIDATION OF HANDSET ANTENNA TEST METHODS

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***Abstract* – In this work an investigation of a test method for validating transmitted power by mobile handset proposed in [1-2] has been made for 1800 MHz GSM handsets. Test results of 8 commercially available GSM1800 handsets measured in the setup has been compared with measurements of the EIRP (Equivalent Isotropic Radiated Power), based on 3D radiation pattern measurements performned in an anechoic room. Comparing the EIRP of the phones with the results obtained in the setup a rather large deviation was observed. The principal difference between the measurement methods is the radio environment. This difference has been investigated in this paper by performing 3D radio environment measurements. The radio environment measurements has been performed at both 900 MHz and 2000 MHz.**

I. INTRODUCTION

For a GSM handset all the performance criteria are specified at the antenna connector. None of the present GSM standards include the antenna. Commercially available GSM handsets differ in transmit power and receiver sensitivity with up to 6-7 dB in free space. Including the effect of an artificial phantom head or head and hand the loss increases even further [3].

The network operators have become increasingly aware of the problems with poor antenna performance on handsets and they have an interest in avoiding the bad handsets in their network, because the performance of the handsets will have a significant effect on the quality of a cellular network.

To identify the performance of the handsets several network operators have created their own test method for evaluation of handset antenna performance. The test methods are different from one network operator to another and it is for a handset manufacturer a demanding task to keep up with all the proposed test methods and ensure that the handset will perform well in all the network operator tests. As the number of proposed test methods increase there is even the risk that one test method contradicts the results of another.

One of the network operators who have proposed a test method has been testing handset phones in a scattered field environment for some time [1-2]. The proposed measuring setup is in a room with metallic reflectors to mimic the fading and distribution of incoming fields in a real radio environment.

In [4] the test setup has been evaluated for 900 MHz handsets. In this paper a similar evaluation has been performed for 1800 MHz handsets.

Test results of 8 commercially GSM1800 handsets measured in the scattered field setup has been compared with measurements of the EIRP, based on 3D radiation pattern measurements performed in an anechoic room including a phantom head. Comparing the EIRP with results including the emulated radio environment shows a rather large difference indicating the importance of including the environment.

The radio environment was taken into account by adding the measured radio environment to the measured 3D radiation patterns by means of a MEG (Mean Effective Gain) calculation.

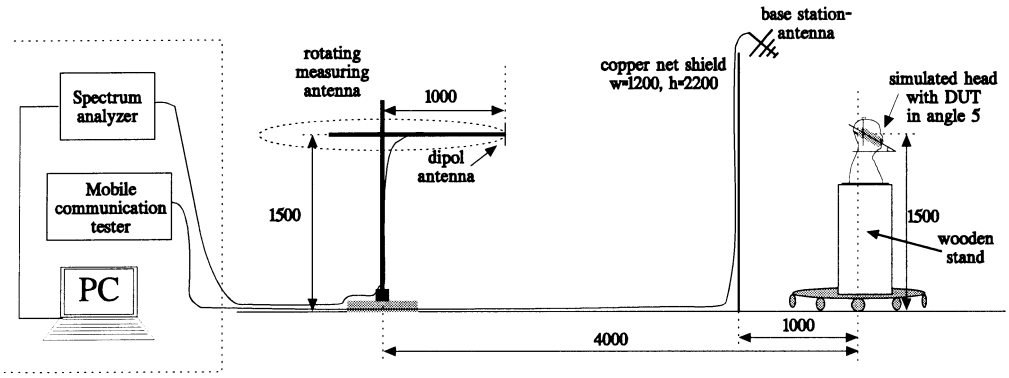

Fig.1. *Arrangement of scattered field test setup [2].*

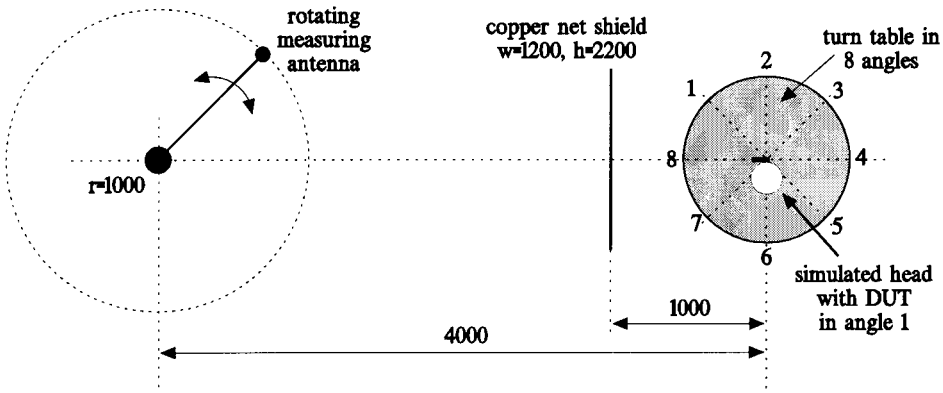

Fig.2. *Arrangement of scattered field test setup, top view [2].*

II. Measurement Setup

The test set-up for the scattered field measurements is shown in Fig. 1 and 2. In the set-up the transmitted signal of the Device Under Test (DUT) is received by the rotating measuring antenna (only the uplink is measured). The received signal power from the rotating measuring antenna is sampled 100 times for eight different angles of the DUT.

To measure the incoming multipath fields at the DUT, a dual polarised horn antenna was placed at that position.

For this measurement campaign a wideband horn antenna covering both 900 MHz and 2000 MHz was used in order to make simultaneous measurements at GSM900 and GSM1800/PCS1900/UMTS.

The horn was mounted on a “pedestal”, which can turn the horn around in every compass direction and elevate the horn from –90° to 90°, with the horizontal plane as 0°. Hereby measurements of received angular distributions of multipath fields at the DUT including both polarization’s are obtained. The spatial resolution of the measurements was 5° in azimuth and elevation.

The horn antenna was connected to a wideband four-channel correlation sounder in order to record both polarisation’s and two carrier frequencies at the same time. The carrier frequencies were 900 MHz, 2000 MHz and a bandwidth of 40 MHz was used. The instantaneous dynamic range of the sounder is 45 dB and the over all dynamic range is 80 dB with a linearity of $\pm$ 1dB.

With the pedestal replacing the DUT, channel measurements were performed for 72 equally spaced positions (5° angle resolution) of the rotating measuring antenna.

III. Scattered Field Test Room

A. Scattered Field Room

A drawing of the scattered field room is shown in Fig. 9A. In the room is a lot of corrugated sheets of metal, copper net shields and metal shelves, which together with concrete walls and window openings create a multipath environment. The direct path between the DUT and the rotating antenna is blocked by a net shield.

B. Incoming Power Distribution in the Room

In Fig. 9 and 10 the measured horizontal and vertical power are averaged across the 72 measured positions for 900 MHz and 2000 MHz.

The power distributions plots in Fig. 9 and 10 consists of a number of rectangles, the rectangles close to the center of the plot represents the measurements recorded at the highest elevation angle (90 deg.). When the horn antenna moves in azimuth it corresponds to moving the same way around on a constant radius in the plot. A change in elevation corresponds to move closer to the edge of the plot. The rectangles closest to the edge of the plot correspond to the lowest elevation angle (-90 deg.). The dynamic range is kept at 18 dB for all the power distribution plots, thereby a comparison is possible. The values in the bar are the power in dB.

By inspection of the power distributions for 900 MHz and 2000 MHz it is observed that the power distribution for 2000 MHz looks more distinct than for 900 MHz. This is due to the 3 dB beam-width of the receiving horn antenna, which is 55° for 900 MHz and 35° for 2000 MHz. Taking the beam width of the receiving horn antenna into account the power distribution looks very much alike for 900 MHz and 2000 MHz.

Looking at the vertical polarized mean power distribution it is observed that the shield in front of the DUT is blocking the direct path. For the vertical polarisation the major part of the energy comes from two strong reflections at the walls.

The horizontal polarised mean power distribution is more diffuse. This is expected since the transmitting antenna is vertically polarised and the energy in the horizontal polarisation is cross coupled by means of reflections, diffraction and scattering.

IV. Results

In this section results from the measurement campaign are presented. First the results from characterisation of the scattered field room are presented. Secondly the comparison of the calculated MEG values with the scattered field test results are presented.

A. Characterise the Scattered Field Room

As a part of a characterisation of the scattered field test room the XPD (cross polar discrimination) is computed. The XPD is obtained by integrating the power in vertical P_θ and horizontal P_ϕ polarisation.

$$XPD = \frac{P_\theta}{P_\phi}$$

For the mean power distributions plotted in Fig. 9 and 10 the XPD value is 2.6 dB for 900 MHz and 2.9 dB for 2000 MHz. In the previous measurement campaign the XPD was computed to 5.7 dB at 1890MHz [4]. In [2] an XPD value at 900 MHz has been measured by means of two dipoles to app. 8 dB.

A new horn antenna was used in this measurement campaign to cover both 900 MHz and 2000 MHz simultaneously. If the change in receiving horn antenna has any influence on the measured XPD value has to be investigated further.

The scattered field test room is also used as a storage room and the type of storage differs over time. The different XPD values are measured at three different time periods, where the content of the room was different, so changes in the room's characteristics could also contribute to the difference in measured XPD values.

B. Handset Antennas

The 3D-radiation pattern of 8 GSM 1800 phones has been measured in the uplink at the center channel (1747.4 MHz) using the torso phantom shown in Fig. 3. The phantom is a Generic Torso Phantom v3.6 from Schmid & Partner filled with a brain tissue simulating liquid.

The torso phantom used in the scattered field setup is shown in Fig. 4. It is also from Schmid & Partner, but it is a version 2.2, which is similar to the one used for the 3D-radiation pattern measurements, but not quite the same. The phantom used in the scattered field setup is filled by water with a salt concentration of 1.49 g/liter.

If the use of different versions of phantom heads and liquids have any influence on the results is still to be investigated.

The measured handset antennas are a mixture of integrated, helix and extractable monopole antennas. The 8 phones are numbered from 1 to 8.

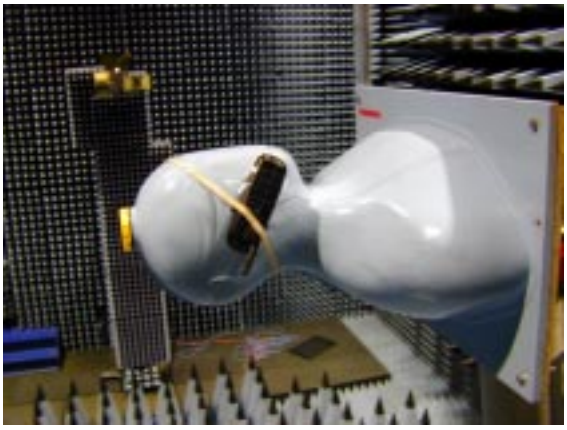

Fig.3. *Measurement setup for 3D radiation pattern measurements including torso phantom and handset.*

Fig.4. *Torso phantom used for measurements in the scattered field setup.*

The 3D radiation pattern measurements has been performed using a setup similar to the one described in [3], where the connection to the phones is established by a call from a GSM tester, so no cables are connected to the handsets.

For the handsets the EIRP is calculated by integrating the transmitted power from the measured 3D radiation pattern of the handsets including the phantom. In Fig. 5. the total EIRP is plotted together with the EIRP for the vertical and horizontal polarization. For GSM1800 handsets the nominal transmit power is specified to 30 dBm ± 2dB at the system connector [5]. It is observed that the best handset transmits with 3.1 dB less than nominal power and the worst transmits with 6.7 dB less than nominal power at the antenna. Moreover, it is observed that the handsets radiate most of the power in the vertical polarization except for handset number 5 and 6, which are extractable monopoles.

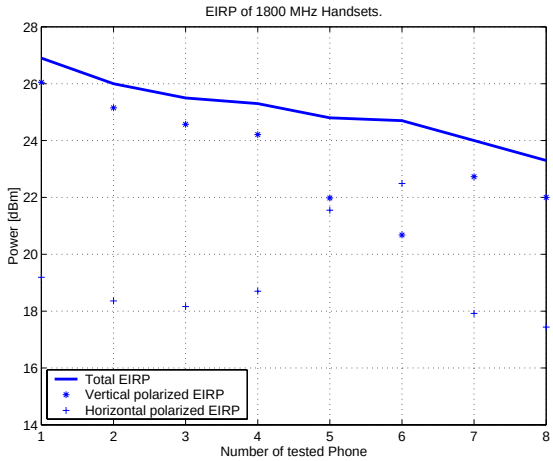

Fig.5. *Test of 8 standard 1800 MHz GSM handsets. The solid line shows the total EIRP. The '+' shows the EIRP in the horizontal polarisation and the '*' shows the EIRP in the vertical polarisation.*

The handsets tested in the scattered field setup are measured relative to a 60-degree tilted dipole transmitting the nominal power of 30 dBm. In Fig. 6. the test results of the 8 GSM1800 handsets from the scattered field set-up are plotted relative to a 60-degree tilted dipole. In the same plot is the total EIRP plotted relative to the nominal power of 30 dBm. From those two curves it is observed that mean and max difference in dB between the scattered field results and the EIRP is 1.3 dB and 2.0 dB, respectively.

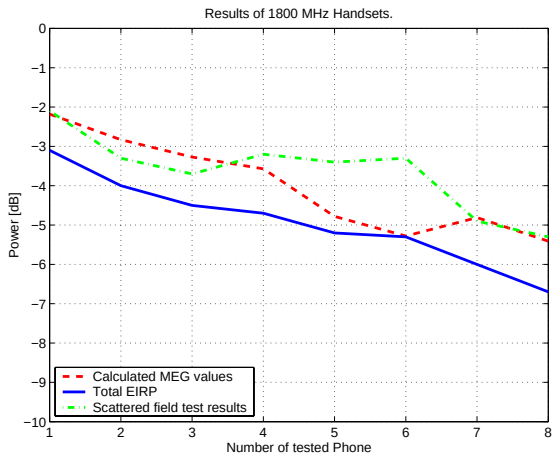

Fig.6. *Test of 8 standard 1800 MHz GSM handsets models. The handsets are sorted relative to the phone with the highest EIRP. The solid line shows the EIRP. The dot-dash line is the results obtained in the scattered field test set-up. The dashed lines are the MEG values calculated using the measured 3D power distribution of the room at 2000 MHz and the measured 3D radiation patterns of the handset antennas.*

The principal difference between the results obtained in the scattered field test setup and the EIRP is the radio environment included in the scattered field test room. This difference can be investigated by adding the measured radio environment to the measured 3D radiation patterns by means of a MEG calculation [6].

$$MEG = \oint \left[\frac{XPD}{XPD+1} G_\theta(\Omega) \cdot P_\theta(\Omega) + \frac{1}{XPD+1} G_\phi(\Omega) \cdot P_\phi(\Omega) \right] d\Omega$$

As mentioned earlier, a 60-degree tilted dipole is used as reference for the measured scattered field measurements. Calculating the MEG for a 60-degree tilted dipole in the measured 3D environment gives a value of –3.0 dB, which has been added to the calculated MEG values to have a commend reference for the scattered field results and the calculated MEG values.

The calculated MEG values are plotted in Fig. 6. as well. The difference in dB between the scattered field results and the calculated MEG values is mean 0.6 dB and max 2.0 dB. It is observed that the scatted filed results and the calculated MEG values deviates with less than 0.5 dB except for handset 5 and 6, which are extractable monopoles. The large difference for the extractable monopole antenna could be due to different size of torso phantoms or positioning errors of the handset. For monopole antennas the performance is influenced on how large a portion of the whip that is hidden behind the head. If less of the whip is covered by the phantom, when measuring in the scattered field setup, it can explain why the scattered field results are 1.4 and 2.0 dB higher for the two measured whip antennas.

In Fig. 7 the results of a MEG calculation for 1800 MHz handsets using both the measured radio environments at 900 MHz and 2000 MHz is plotted. It is observed that the calculated MEG values are very similar using the power distributions for 900 MHz and 2000 MHz, which indicates that the power distribution is similar for 900 MHz and 2000 MHz in the test room.

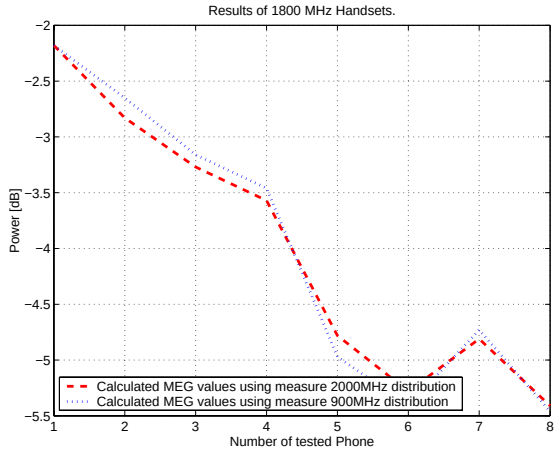

Fig.7. *Test of 8 standard 1800 MHz GSM handsets models. The dashed and dotted lines are the MEG values calculated using the measured 3D power distribution of the room at 900 MHz, 2000 MHz respectively and the measured 3D radiation patterns of the 1800 MHz handset antennas.*

It also indicates that the beam-width of the receiving horn antenna has limited influence on the MEG values obtained for 1800 MHz handset antennas using the measured power distribution.

It is expected that the beam width of the receiving horn antenna is of less importance for the MEG calculations of handsets due to the low gain of handset antennas, which can be seen by a typical 3D radiation pattern of a standard 1800 MHz handset in Fig.8.

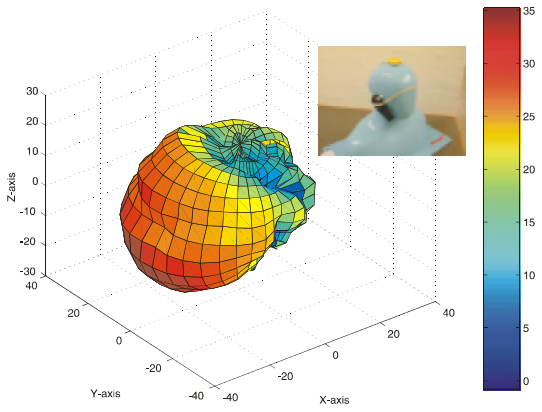

Fig.8. *Typical 3D power gain of a standard GSM1800 handset including torso phantom. The picture of a phantom head in the upper right corner shows the orientation of the radiation pattern.*

V. Conclusions

3D radio environment measurements have been performed in a scattered field test room at both 900 MHz and 2000 MHz. An XPD value of 2.6 dB for 900 MHz and 2.9 dB for 2000 MHz is obtained, which is very different from the XPD value obtained in [2] of app. 8 dB. The difference could be due to changes in the characteristics of the room over time or the use of different probe antennas for each measurement.

Results of MEG calculation based on measured 3D antenna patterns of 1800 MHz handsets and the measured 3D incoming power distribution of the scattered field room are compared with results obtained with the same handsets measured in scattered field set-up. The comparison showed that the difference between the scattered field set-up and the MEG calculations is mean 0.6 dB, while the difference between the scattered field results and the EIRP is mean 1.3 dB. Hence, the mean difference is reduced from 1.3 dB to 0.6 dB by including the environment.

The mean power distribution at 900 MHz and 2000 MHz is similar. Using the measured mean power distributions together with 3D radiation patterns for handset antennas to calculate the MEG gives similar results for both frequencies. Hence, it seems like it is possible to use the same 3D radio environmental model of the scattered field room for both 900 MHz and 2000 MHz to calculate the MEG of the handset antennas.

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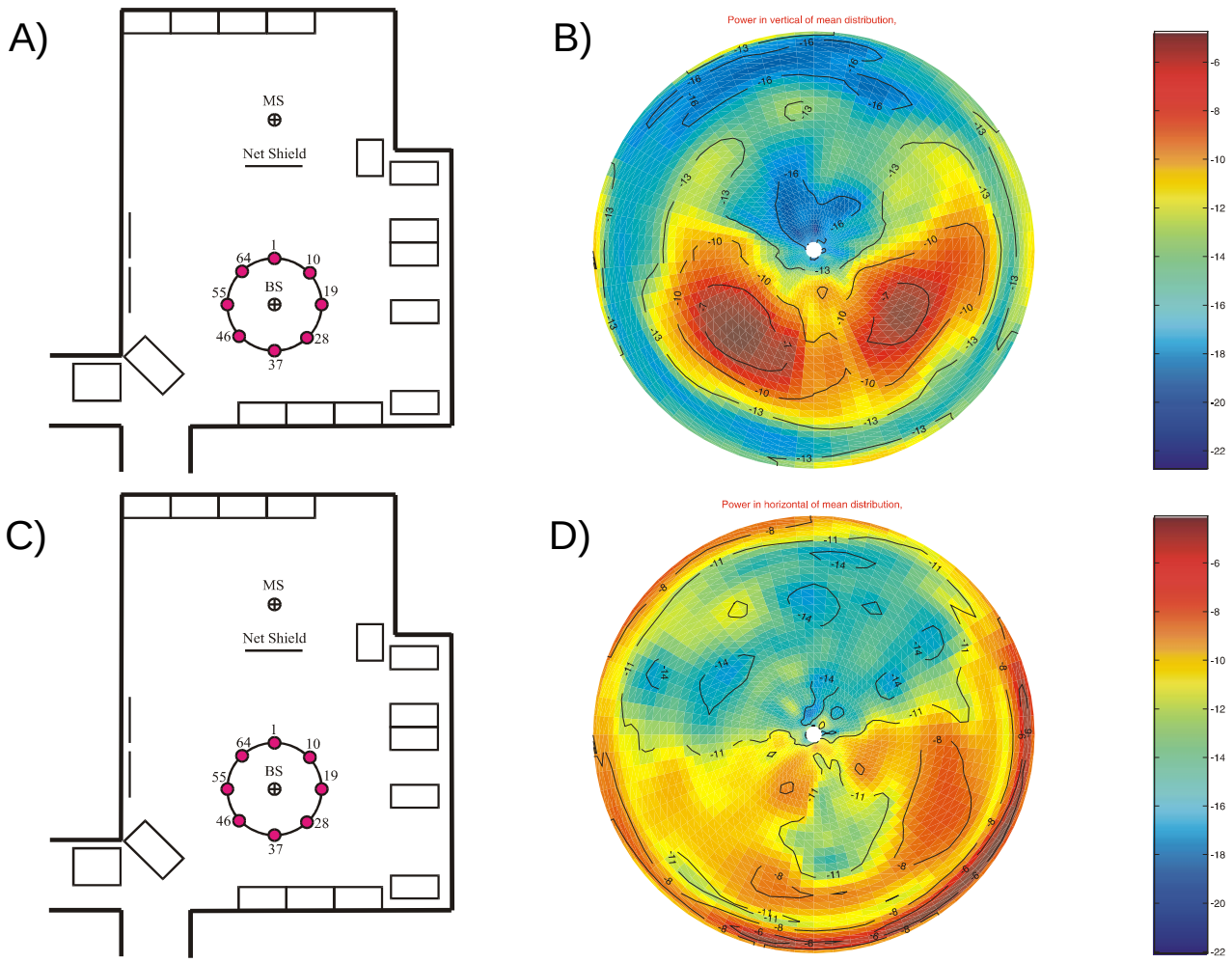

Fig. 9. *Measurement at 900 MHz of the mean power distribution for the vertical and horizontal polarisation's. A), C) Drawing of the scattered field room. The dots indicating positions of the transmitting measuring antenna. B) Plot of the mean power distribution in the vertical polarisation. D) Plot of the mean power distribution in the horizontal polarisation.*

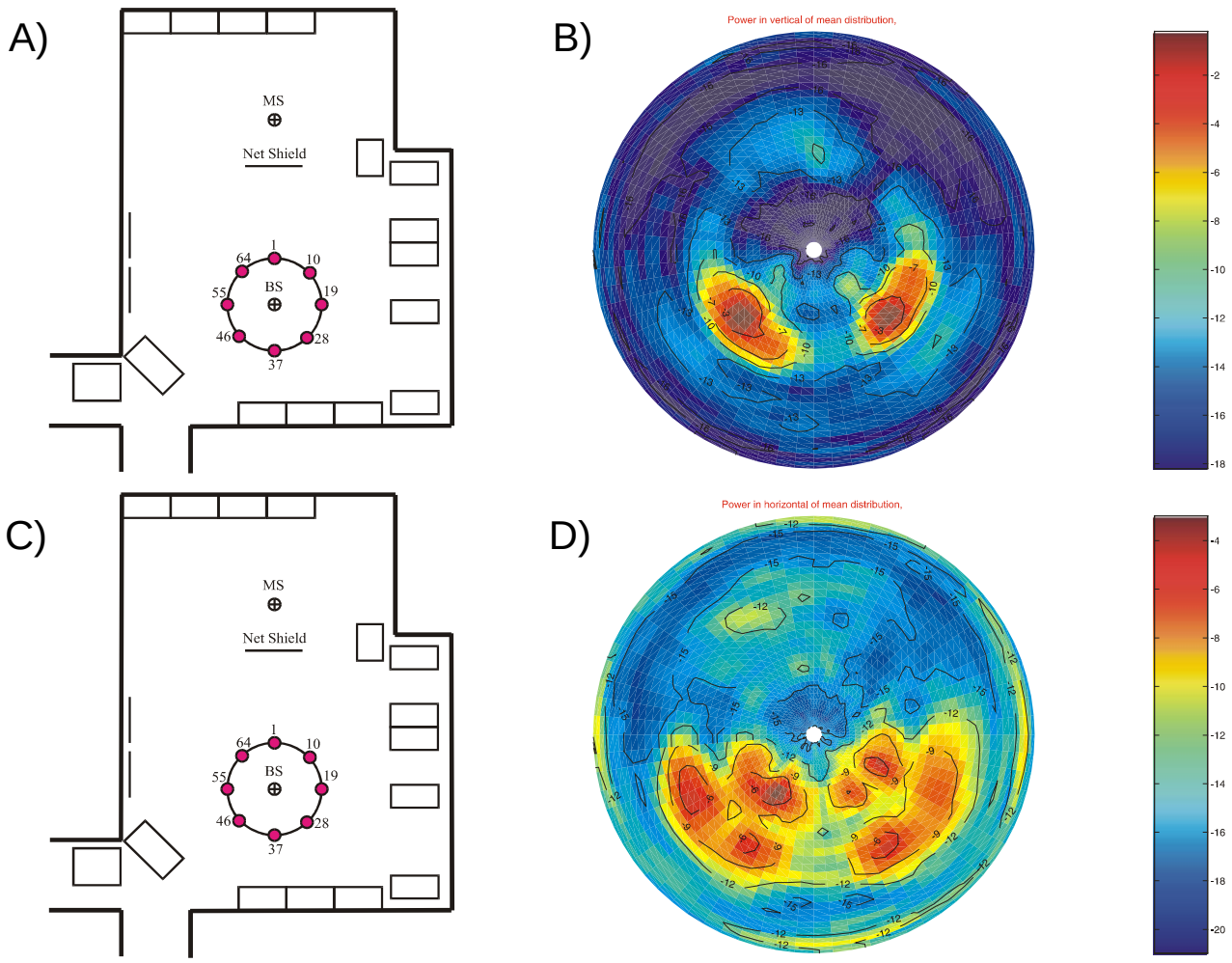

Fig. 10. *Measurement at 2000 MHz of the mean power distribution for the vertical and horizontal polarisation's. A), C) Drawing of the scattered field room. The dots indicating positions of the transmitting measuring antenna. B) Plot of the mean power distribution in the vertical polarisation. D) Plot of the mean power distribution in the horizontal polarisation.*