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Absorption and body losses in mobile phones

Until now, the significance of mobile phone antennas for power density often has been neglected. Though antennas are an essential part of the device, their role in research and development has been rather small. However, since studies showed huge differences between power density provided by different antennas, they have gained greater attention as a compoment of the set-up. The way in which users hold the phone in particular is closely connected with the effective antenna characteristics. Dependent on the applied antenna type there are different receiving conditions connected with shielding and absorption effects caused by the user.

Our working group at the 'Center for Personkommunikation' of the University Aalborg has performed measurements in 200 test subjects to examine the influence of the mobile phone user and of the applied antenna type on receiving conditions in the GSM 1800 band. The phone used in experiment was equipped with three different antennas: an extendable monopole antenna, a combined helix antenna responsible for radiation when the monopole antenna is retracted, as well as a patch antenna.

During each test phase the patch antenna was examined in combination with one of the two other antennas. Test subjects were asked to hold the test phone in a natural position. Subsequently, the test subjects followed a given course within a square patch (figure 1) holding the phone close to their ear. Each measurement lasted 1 minute being equivalent to about 4 course rounds. Each individual subject had to absolve two test rounds, one with the helix antenna, the other one with the monopole antenna. In each round the patch antenna was also measured.

Measurements were made in four different floors of a multi-storey building. Per storey 50 test subjects were examined. Ground floor windows, as well as those of the second and third floor pointed to the direction of the base station antenna mounted on the roof of a sixteen-storey building at a distance of about 700 meters. The base station was not within direct sight of the test site and vice versa. The windows of the test building's first floor pointed to the opposite direction from the transmitter. The distance of 700 meters and the position of the base station antenna on top of the multi-storey building were intentionally selected to simulate a typical 1800 MHz GSM microcell in urban areas. The transmitting antenna was a high-gain sector antenna. Test site conditions are shown in figure 2.

Table 1 shows the mean values of measurement results. As is seen clearly, the power received by the helix antenna is lower than those of the other antenna types.

In summary, we can conclude as follows:

1) The differences in MEG (mean equivalent gain) between individual persons can amount to up to 10 dB.

2) Body loss, defined as the difference between the values of the two test situations 'no test person present' and 'test person present', amounts to 10 dB for the helix antenna, to 6 dB for the monopole antenna, and to 3 dB for the patch antenna.

3) The average MEG in regard to the monopole antenna for all test subjects amounts to 0.5 dB averaged for the patch antenna and to -3 dB averaged for the helix antenna.

4) The effect of test persons' body height or of spectacle frames on the MEG with less than 1 dB is very slight.

5) A huge effect on the MEG has the test subjects' left- or right-handedness. The differences between left- and right-handed

Table 1

Antenna	level 1	level 2	level 3	level 4	average	body effect
Whip no user	0	0	0	0	0	
Helical no user	0.70	0.97	0.60	0.41	0.67	
Patch no user	-3.12	-3.46	-2.69	-0.9	-2.42	
Whip with user	-6.61	-7.09	-7.04	-5.08	-6.37	-6.37
Helical with user	-9.61	-10.29	-9.54	-7.48	-9.09	-9.76
Patch with user	-6.71	-8.34	-6.24	-3.43	-5.80	-3.38

Figure 1: Test person with mobile phone held in a natural position during measurement

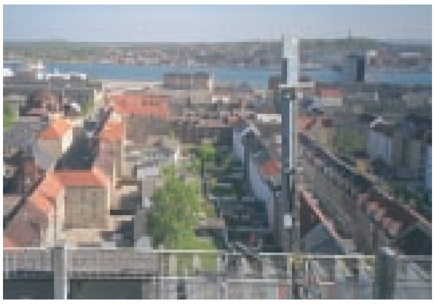

Figure 2: Photo of the transmitting base station and the environment

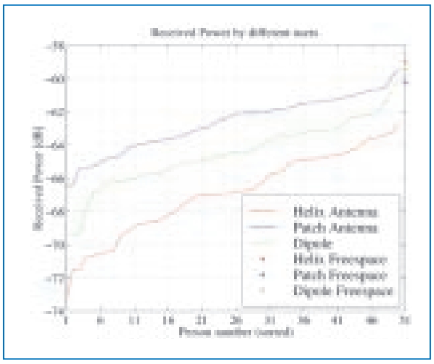

Figure 3: Power received by mobile phone for 50 different subjects inside the test building. The base station is located at a distance of about 700 meters.

Figure 4: Experimental set-up in low-reflection room

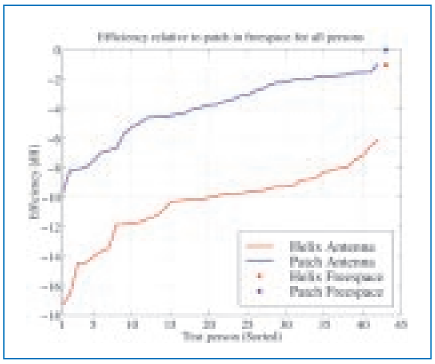

Figure 5: Power received by mobile phone for 43 different subjects in low-reflection room

persons can be relatively great, dependent on the antenna. The deviations amount to 5 dB for the patch antenna, to 3 dB for the helix antenna and to 1 dB for the monopole antenna.

6) MEG values are reproducable in the range of + 0.5 dB.

Whole body absorption

Further tests were performed in a low-reflection absorber room to find out why the losses of mobile radio connections differ clearly from one individual user to the other and how such losses occur. During measurements, all factors having to do with body losses were supervised. The rectangular measurement site had a base of 7 x 10 meters and a height of 7 meters. All walls, the ceiling and the floor were equipped with HF-absorbers. Reflection attenuation at 2 GHz exceeds 40 dB.

Basically, during use of a mobile phone four factors contribute to body losses:

- the absorption in the human body,
- mismatch of the antenna,
- changes in radiation characteristics and
- changes in polarisation direction.

A specific measurement set-up was installed in the absorber room aimed to capture the significance of each individual factor. As is shown in figure 4, a test person sat on a special structure above an azimuth rotary stand holding a mobile phone transmitting at 1.89 GHz in a normal phoning position. By means of two vertically polarised receiving antennas fixed to a frame swivelling during elevation, the electric field strength was measured at a sphere surface (radius 2.1 m) around the test mobile phone. Thus, via integration across the sphere surface the total radiated power can be calculated, body losses being the difference between the power input of the mobile phone antenna and radiated power. A directional coupler added to the mobile phone antenna allowed us to measure power input and reflected power caused by antenna mismatch.

The losses caused by user influence on antenna characteristics and polarisation can be detected by comparing the radiation diagrams measured for both polarisation directions via a reference field equivalent to the field of a realistic environment with multi-directional propagation.

The reflected power measured by the directional coupler on the one hand was used to determine mismatch and actual radiated power. On the other hand it showed whether the test person changed the mobile phone's position towards the head. Even finger movements across the back of the phone were identifiable as a change in reflected power.

The electric fields were measured in 43 test subjects for each of both antenna types. The power losses caused by antenna mismatch for both antenna types amounted to less than 2 dB in all test persons. Several repeated test measurements showed that measurement inaccuracies lay below 1 dB. As the radiated power can vary by up to 10 dB from one individual to the other, the measurement set-up was evaluated as sufficiently exact.

Figure 5 shows the radiated power in relation to the individual test person. The test persons are sorted by their radiation losses. To the far right of the diagram the free space measurements (without test person) are listed. Radiation losses in the helix antenna with average 9.7 dB are significantly higher as in the patch antenna with 3.4 dB.

Absorption in phantom hand and phantom head

From the tests in the absorber room we can conclude that above all absorption is responsible for radiation losses. To find out why absorption is so hugely dependent on the phoning person and which parameter ultimately has the greatest effect, further tests using a phantom model as a replacement for test persons were carried out.

Particularly the following parameters seemed to be of importance for absorption:

- hand position at the phone,
- distance between head and phone,
- angle of phone position,
- head/hand shape,
- body height of the subject,
- skin humidity of the subject,
- further parameters such as age, sex, amalgam in the teeth, glasses, hair growth in head area, etc.

The studies carried out on the first 3 parameters are listed in entry (5) of literature references. Measurements were made applying the same test phone, however in connection with simple head and hand models. The head model consisted of a thin-walled synthetic shell phantom filled with liquid. The liquid had the electric properties of brain/muscle tissue. As a hand model served a thin rubber glove filled with the same liquid. To obtain the typical

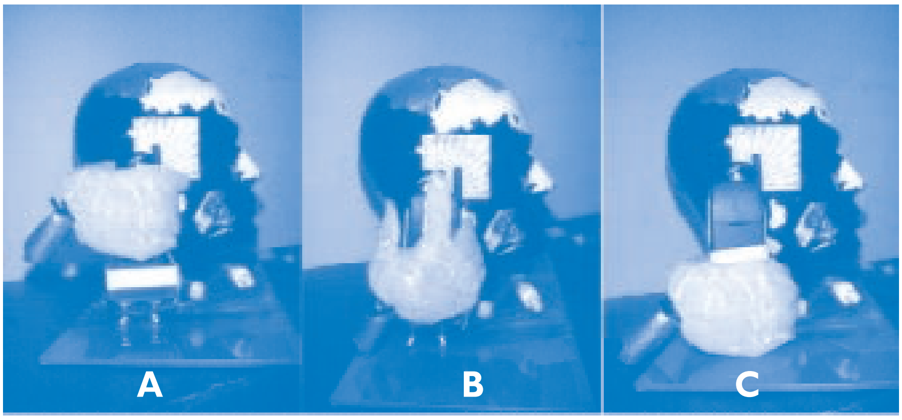

Figure 6: Phantom model 'head - hand'; A) hand in position 'top', B) hand in position 'near top', C) hand in position 'bottom'

shape of a hand, a thin adhesive tape was wrapped around the palm and each finger. The models are shown in figure 6.

The angle in which hand and phone were fixed to the head, has scant impact on total losses. Measured differences of 0.6 dB are close to measurement exactness.

Some mobile phone users hold their phone at a small distance from their head, others press them close to their head. If the phone is pressed close to the head, tissue shape changes slightly and absorption losses can increase. If a hard shell phantom is used, such changes naturally can not occur. Radiation losses are shown in figure 7 as a function of the distance between head model and phone. Though the distance between head and handheld device is important for local SAR values (specific absorption rates), it has only a slight effect on total absorption.

Different simulation experiments show that the losses caused by the hand are considerably smaller than head losses.

To demonstrate how radiation losses are related to hand positions measurements were made at four different holding positions of the hand (figure 6). The results are shown in figure 8. As is seen clearly, radiation losses in the hand in bottom holding position scarcely differ from those without hand. However, if the hand holds the phone close to its upper edge and thus close to the antenna, the losses for both antenna types rise up to 8 dB. The way in

ABSORPTION

measurements

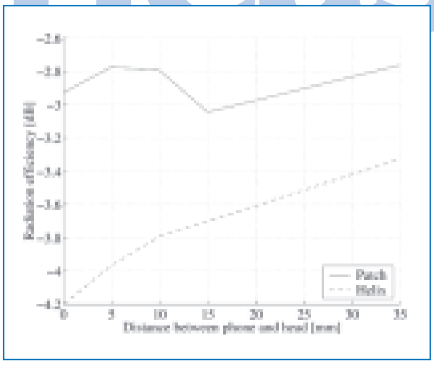

Figure 7: Curve of radiation losses as a function of the distance between phone and head model

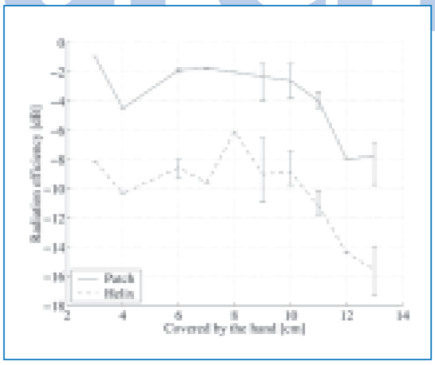

Figure 9: Radiation losses at different holding positions of the mobile phone

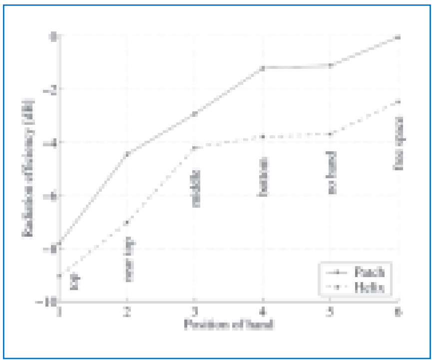

Figure 8: Radiation losses at different hand positions

which the phone is held in the hand, therefore is a crucial influence factor for losses of the combined head/hand model. The differences of up to 10 dB at measurements of radiation losses of different mobile phone users mainly are due to hand positions at the phone. If the holding position has such an essential effect on absorption, it should be possible to draw a connection between absorption and hand positions of the test persons during measurements in the absorber room.

Absorption in the hand of the test subject

During the above described measurements in test subjects, each test person was filmed per video camera. A black and white square pattern was added to the back of the phone, with a square size of 10 mm x 10 mm. Thus, by means of the video recording each holding position could rather precisely be determined. Each person holds the phone in its own specific way. In order to simplify tests holding positions were identified by detecting the space remaining uncovered by the fingers.

Results are shown in figure 9. As can be seen clearly, radiation losses are related to the holding position of the phone. The interaction coefficient between the attenuation and the position of the hand amounts to 0.7 for the patch antenna and to 0.67 for the helix antenna. It must be mentioned that only one test person held the phone at positions 3, 4, 8, 12 cm. All other holding positions each were used by in the least 3 persons. Radiation losses mainly remain constant if the hand covers the phone up to position 10 cm. The critical area are the upper three centimeters of the phone. 40% of the test persons touched this area, 66% touched the upper four cm of the device. Using the relatively large test phone (height = 13 cm) only 1/6 of the test persons caused high radiation losses. However, with up-to-date smaller mobile phones increased radiation losses are to be expected for most users, if nothing is done to prevent this. With a mobile phone of 10 cm height, the test persons touching the upper 4 cm of the 13-cm test mobile phone with their fingers, would be even nearer than 2 cm to the antenna. This is the length of the most new mobile phones being on the market.

Literature

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