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# MEASURED VARIATION IN PERFORMANCE OF HANDHELD ANTENNAS FOR A LARGE NUMBER OF TEST PERSONS

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**Abstract** - This work investigates the variation in the Mean Effective Gain (MEG) for a large number of test persons in order to find how much the difference in anatomy and persons who wear glasses etc. changes the MEG (i.e. the received signal power with respect to a reference). The evaluation was carried out in a typical GSM-1800 urban micro cell with the base station located outdoor approximately 700m from the mobile. The mobile was located in office like environments. Peak variations in the MEG among different persons of more than 10 dB were found and the difference between "no person present" and a person present is on the average 3 dB for a directive patch antenna, 6dB for a whip antenna and 10 dB for a helical antenna.

## I. INTRODUCTION

Validation of handheld antennas is becoming very important as the antenna design changes from more traditional add-on whips and normal mode helicals to custom made integrated antennas.

The MEG is a very good measure of how well the antenna performs in a specific environment but often the measurements are carried out by using only a single "test person" or with a head phantom.

This may explain why validation made by different mobile net operators of the same handset model has often led to very different performance assessment. This has led to the question: How much influence does the mobile user has on the antenna performance? To answer this question this measurement campaign was carried out.

The Mean Effective Gain (MEG) is used as the performance measure [1-4] for three candidate antennas, a  $\frac{3}{8}$  wavelength whip, a helical and a directive patch. These antenna types were selected because they are the three basic types used on today's handheld phones.

## II. MEASUREMENTS

The measurements were carried out at 1880 MHz having 200 test persons using the handsets in normal speaking position. The mock-up handheld consists of a commercially available GSM-1800 handheld equipped with a retractable whip and helical antenna which was modified to also include a back mounted patch antenna. Two 50 ohms cables were used to connect the antennas to the receiving equipment. The mock-up

consists therefore of three antennas connected to two connectors, a patch antenna on one connector and either the whip or the normal mode helical (when not retracted) on the other connector.

The measurements were carried out by asking each test person to hold the handheld in what he or she felt was a natural speaking position, see figure 1. Then the person were asked to follow a path marked by tape on the floor. The path was a square of some 2 by 4 meters and each record of data lasts one minute corresponding to 3 - 4 rounds. To record all three antennas each person had to follow the path for one minute, change the whip antenna to the helix and walk the path once again. Hence, firstly record the whip antenna and the patch and next to record the helix antenna and the patch once again.



**Figure 1** One of the test persons holding the handheld in what he feels as natural speaking position during measurement.

Altogether four locations were selected, one path on each floor and 50 test persons were used on for each floor. The windows on level 3, level 2 and the ground level were facing towards the transmitter but there was no line of sight due to higher buildings in-between. On first floor the windows were facing opposite the transmitter.

The handset was connected to a dual-channel wide-band correlation sounder in order to record two antennas at a time. The carrier frequency was 1890MHz and a bandwidth of 20 MHz was used to suppress the fast fading. The instantaneous dynamic range of the sounder was 45 dB and the over all dynamic range is 80 dB with a linearity of  $\pm 1$ dB.

To match a typical urban GSM-1800 micro cell the transmitter antenna was located approximately 700 meter away on the sixteenth level of a high building in an urban environment. The transmit antenna was a 60 degrees sector antenna with a beamwidth of 5 degrees in elevation and it was tilted mechanically some 4 degrees down. Figure 2 shows the transmit antenna together with the view of the environment [6]. The building in which the measurements were performed is hidden by other buildings on the picture and therefore no line of sight exist between the transmitter and the handheld receiver.



Figure 2 Picture of the transmitting BS antenna (the antenna is vertically mounted) and the view of the used urban area.

### III. DATA PROCESSING

Each recorded path lasts one minute and consists of 1000 impulse responses for both channels, and each impulse response has a depth of 6 micro seconds. To obtain the received power the noise power was first estimated and removed for each impulse response in similar ways as in [5]. Also the back-to-back measurements were used in equalizing the gain difference between the two channels of the sounder ( $0.3 \text{ dB} \pm 0.5 \text{ dB}$ ). Then the average of the received power for each path was taken and used as the average received power for one path, antenna and person etc.. As a reference, sets of three measurements for the same path were taken with no person present. These measurements were recorded the same way as with a

person present except that the handheld was mounted on a wooden stick with a 60 degrees tilt angle from vertical. The measurement without the person present was repeated three times in order to find the repeatability of the measured path. For each set of three measurements without a person present both the mean and the spread were calculated.

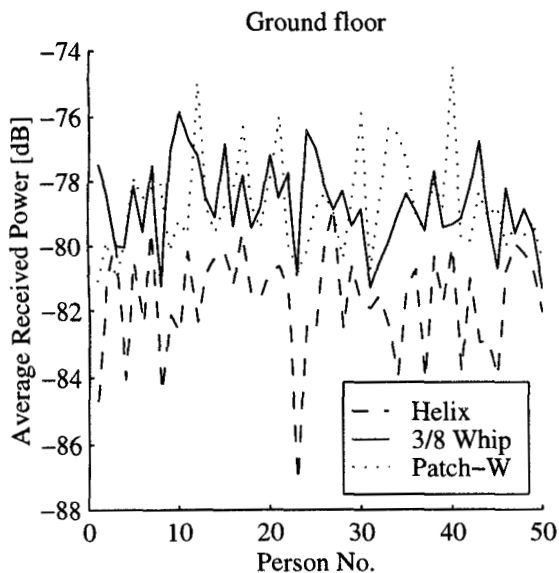
### IV. RESULTS

The measured received power for 50 persons on each of the four levels are shown in figure 3 to 6. The results are also summarized in table 1. From the results it is clear that the helix performs worse than the two other antennas both concerning the average and the spread values. From the figures peak values of 10 dB can be found (between the highest received power and the lowest received power) for the helix antenna. For the whip and patch antenna peak difference in the order of 5 to 7 dB can be found. These values are somewhat surprisingly high.

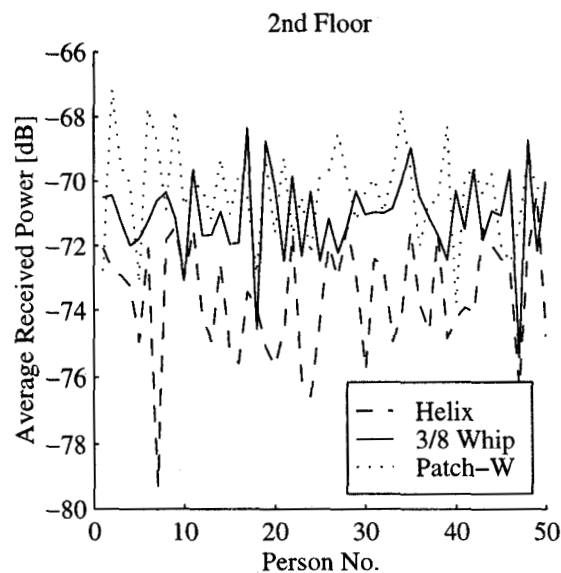
On floor 3 (figure 6) it can be noted that the first 16 test persons seems to receive a few dB less on average than the last 34 test persons which explain the higher spread values in table 1. The first 16 measurements were all performed on the first day and it is possible that the attenuator in the transmitter was 3 dB higher that day but as we are not sure we have not changed the values.

Antenna	Floor			
	Ground	First	Second	third
whip	$-78.7 \pm 1.3$	$-64.7 \pm 1.2$	$-71.1 \pm 1.3$	$-64.5 \pm 2.1$
Patch W	$-78.8 \pm 1.5$	$-65.9 \pm 1.9$	$-70.3 \pm 1.4$	$-62.7 \pm 1.7$
Patch H	$-78.8 \pm 1.5$	$-66.0 \pm 1.7$	$-70.3 \pm 1.3$	$-63.0 \pm 1.7$
Helix	$-81.7 \pm 1.6$	$-67.9 \pm 1.9$	$-73.6 \pm 1.8$	$-66.9 \pm 2.5$

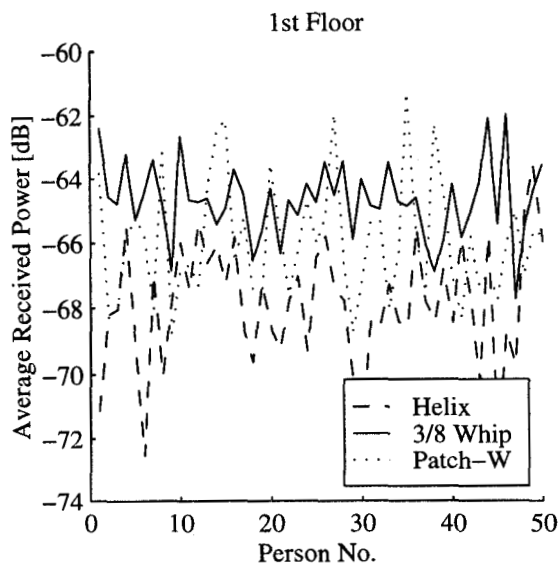
Table 1 Averaged received power in dB and standard deviation for each antenna on each floor. Patch W is the patch recorded at the same time as the whip and Patch H is the same patch recorded at the same time as the Helix.



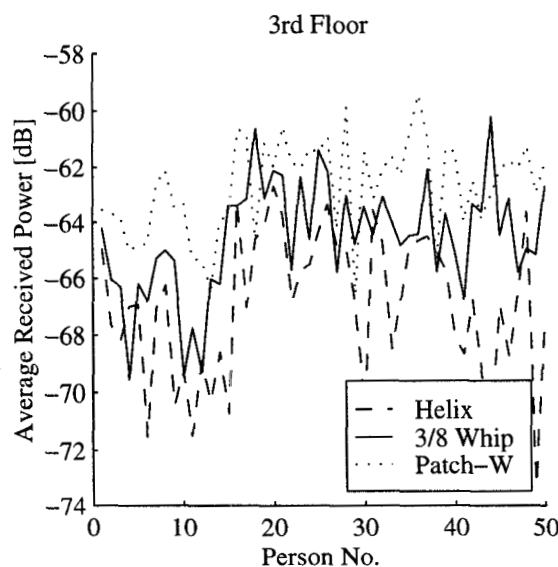
**Figure 3** Received power by three antennas on a handheld for 50 different persons on the ground level.



**Figure 5** Received power by three antennas on a handheld for 50 different persons on second floor.



**Figure 4** Received power by three antennas on a handheld for 50 different persons on first floor.



**Figure 6** Received power by three antennas on a handheld for 50 different persons on third floor.

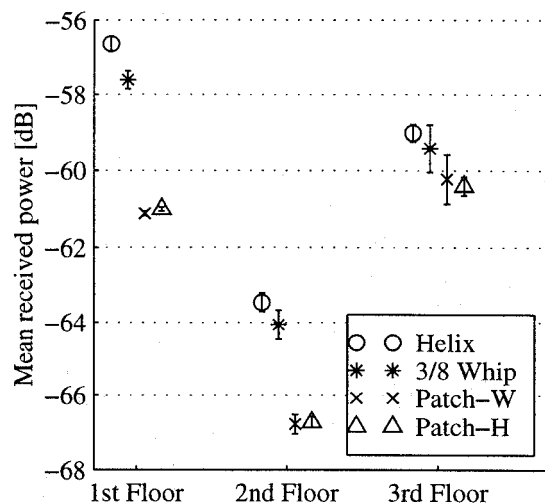
Having found that the variation in received power from one person to another can be very high possible explanations were investigated. The first parameter to investigate is the repeatability (or uncertainty) of the measurement. In figure 7 the received power in "free space" is shown for all antennas on floor one to three. Three measurements for each path were recorded in order to examine the repeatability. Both the mean and spread is plotted on the figure. From the figure it is clear that the spread is only  $\pm 0.5$  dB. Even when a person is present the spread is very small as can be found from the fact that the patch antenna was recorded twice for each person, see table 1 for patch-W and patch-H.

Next the influence of the heights of the test persons was investigated by taking the same path for three heights, 1.5 meters, 1.6 meters and 1.75 meters. The results are shown in fig-

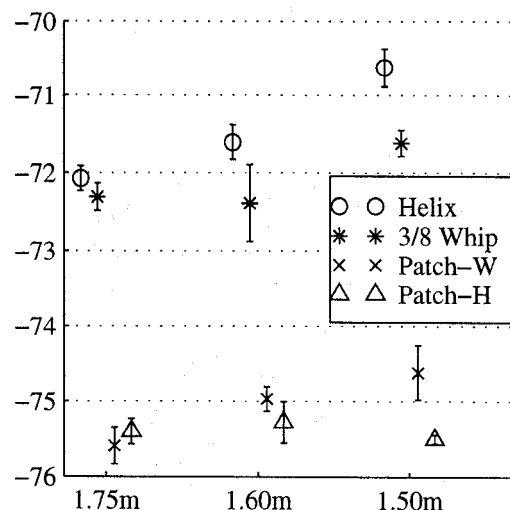
ure 8 and a small difference of 1 dB is found but this is just a minor contribution to the explanation and does not by itself explain the large variation.

Also the influence of persons wearing glasses were investigated but once again the variation was less than  $\pm 0.5$  dB in 6 measurements with glasses and 6 measurements without glasses for the same person.

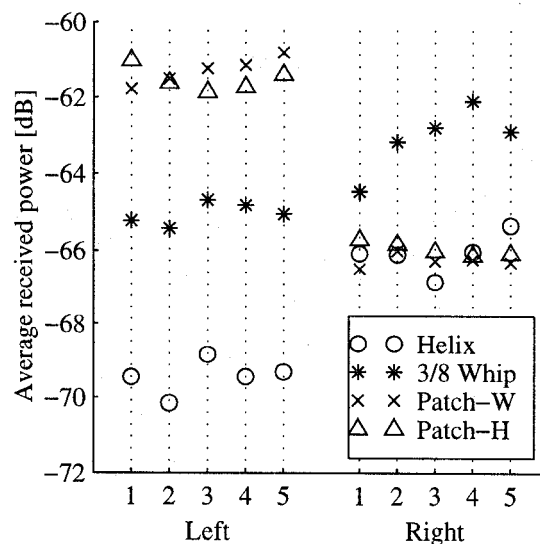
Last, the influence of left handed and right handed persons was investigated. Two persons were recorded on the same path (first floor) 20 times each, 10 times with the whip and patch (5 with left hand and 5 with right hand) and 10 with the helix and patch. Figure 9 shows the results for person A and it is clear that there is a major difference between left handed and right handed. The difference is most significant for the patch antenna (some 5 dB) and less significant for the whip (some 1 dB). In table 2 the results for both persons are shown and the results for person B are similar to the person A shown in the figure. It can also be noted that the spread is low especially for person A and B among the 5 repeated measurements.



**Figure 7** Received power when no person is presence. Both average values and spread among 3 measurements are shown for each antenna and on each floor.



**Figure 8** Received power when no person is presence on the ground floor for three different heights of the hand-held. Both average values and spread among 3 measurements are shown for each antenna.



**Figure 9** Received power in dB for person A when using left hand and right hand to hold the handset towards the head. The measurements are repeated 5 times to allow calculation of the spread.

Antenna	Person	
	A	B
Whip Left	$-65.0 \pm 0.3$	$-64.3 \pm 0.4$
Whip Right	$-63.1 \pm 0.9$	$-63.2 \pm 0.3$
Patch-H Left	$-61.5 \pm 0.3$	$-60.8 \pm 0.2$
Patch-W Left	$-61.3 \pm 0.4$	$-60.7 \pm 0.2$
Patch-H Right	$-66.0 \pm 0.2$	$-66.2 \pm 0.4$
Patch-W Right	$-66.3 \pm 0.2$	$-65.3 \pm 0.3$
Helix Left	$-69.4 \pm 0.5$	$-68.2 \pm 0.4$
Helix Right	$-66.1 \pm 0.5$	$-64.4 \pm 0.4$

**Table 2 Average received power in dB for three persons when using the left hand (and left side of head) and the right hand.**

## V. CONCLUSIONS

For 200 test persons in a typical GSM-1800 micro cell located in urban area a handheld with three antennas was validated in terms of received power or mean effective gain (MEG). The validated antennas are a whip, a helix and a patch antenna (FS-PIFA [3]) which were selected in order to match the types of antennas used on today's handheld. The findings are as follows:

- The Variations in MEG from one person to another person can vary up to 10 dB
- The difference between "no person present" and a person present is on the average 10 dB for a helical antenna, 6 dB for a whip antenna and 3 dB for a directive patch antenna.
- The average MEG for all test persons with respect to the patch antenna are -1 dB for the whip and -3 dB for the helical antenna.
- The influence on the MEG from difference in heights of persons and from persons who wear glasses is small (less than one dB).
- The influence on the MEG from persons who use the left hand or the right hand can be large depending on the antenna, 5 dB for the patch antenna, 3 dB for the helix antenna and 1 dB for the whip antenna.
- The performance of the patch antenna is best for left handed persons indication that the performance can be even higher than the 1 dB with respect to the whip antenna if most persons use the left hand - or the patch antenna is rotated 180 degrees.
- It is possible to reproduce the MEG results with in  $\pm 0.5$  dB

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