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ANTENNA DIVERSITY ON A UMTS HANDHELD PHONE

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Abstract - **This work investigates the possible return of antenna diversity on the handheld phone in a bandwidth corresponding to UMTS. The findings are that the diversity gain will change significantly dependent on the person using the phone. The diversity gain is found to be between 2 and 7 dB.**

This is primaryly caused by different slow fading from the two different types of antennas. The investigations are based on measurements where 200 test persons have been measured.

I. Introduction

It is well known that the possible return from diversity largely depend on four parameters; The correlation between the signals, the difference in the mean power of the signals to be combined, the likelihood that the non-combined signals is below the critical level for the system and the combining scheme. All four parameters will be addressed in this investigation.

By combining the signals the likelihood that the combined signal will be below the critical level for the system investigated is reduced, which is the primarily gain obtained from diversity. In most cases the time average power of each non-combined signal is equal and the diversity only combat the fast fading, e.g. diversity on a basestation. Fast fading is the fading in the signal envelope or power due to small scale movements of the mobile antenna in the order of a fraction to a few wavelengths.

If the slow fading, i. e. the fading due to movements in the order of a few to a few hundreds of wavelengths, is different for the non-combined signals the diversity will also combat the slow fading. Signals from largely spaced antennas, e.g. signals from different basestations, can have uncorrelated slow fading. Measurements in the down-link shows that both the fast and slow fading of the two antennas placed on the mobile phone has a low correlation and the return from the diversity combining depend on both.

To investigate the possible diversity gain in the down link (from the basestation to the mobile phone) it is important to include the user of the phone due to:

1.Higher Correlation between the signals due to shadowing caused by the user, whereby the effective source spreading is lowered, [1].

2.The user change the average received power and often the average received power ratio of the non-combined signals changes[2].

3.Each user influence the received signals differently [2-4]. Therefore, the user of the phone is included in the investigation of diversity gain which can be obtained for a UMTS like scenario by having 200 persons using the phone measured.

Furthermore different type of antennas behave different and this investigation is therefor based on three antennas types, 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.

The obtained measurements is analyzed and combined off-line and both gain due to fast- and slow fading are investigated.

II. Measurements

The measurements were carried out at 1890 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 a 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 approximately 2 rounds. To record all three antennas each person had to follow the path for one minute, change from 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.

For the diversity investigations only the pair of antennas recorded at the same time can be combined and ,therefore, only the pair helix, patch, and the dipole, patch are investigated in the following.

Altogether four locations were selected, one path on each floor and 50 test persons were used on 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 the first floor the windows were facing opposite the transmitter.

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

The handset was connected to a wideband dual-channel correlation sounder in order to record two antennas at a time. The carrier frequency was 1890MHz and a bandwidth of 20 MHz was used. Measuring in this large bandwidth makes it possible to filter out the bandwidth of interest, e.g. 200 kHz for GSM and 4 MHz for UMTS etc.. The instantaneous dynamic range of the sounder was 45 dB and the over all dynamic range is 80 dB with a linearity of $\pm$1dB.

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

To match a typical urban UMTS 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. 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 phone acting as receiver.

III. DATA PROCESSING

Each recorded path lasts 30 seconds and consists of 1000 impulse responses for both channels, and each impulse response has a depth of 6 micro seconds. The back-to-back measurements of the measuring equipment were used in equalizing the gain difference between the two channels of the sounder (0.3 dB $\pm$0.5 dB).

To fit UMTS signals the measured signals were filtered to 4MHz bandwidth. Altogether three band-pass filters were used to obtain three filtered signals from the 20MHz wide measured data. Hereby obtaining higher statistic, which is used in the further investigations. All calculations of correlation, diversity gain, branch power ratios etc. are made on the filtered signals

To investigate the potential diversity gain the filtered signals are both combined directly, i.e. including the measured branch power ration, fast- and slow fading, as well as compensated for either slow-fading or fast-fading.

To compensate for the slow fading a rectangular window with a time-length corresponding to 25 impulse responses (a distance of some 3 to 4 wavelengths) were used as a sliding window on the calculated RSSI values of each filtered signal. The length of the window were found from inspections of the filtered signals and from the CDF of the fast-fading.

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

This section is based on the first results (covering 150 persons) and will in the final version of the paper be presented in a more compact way.

First the **c**orrelation **c**oefficients (cc) for both pairs of antennas are calculated for all persons. The cc for the helix and patch antennas are presented in Figure 3, and Figure 4 shows the cc for the dipole and patch antenna. The cc are sorted to ease the readability. The cc in Figure 3 and 4 are the highest values found for each of the three 4 MHz filtered signals. Normally a cc of 0.7 is taken as sufficient for diversity actions and it here both antenna configurations will pass. For comparisons the cc for the freespace measurements performed in the same way are below o.2 (on average below o.o7).

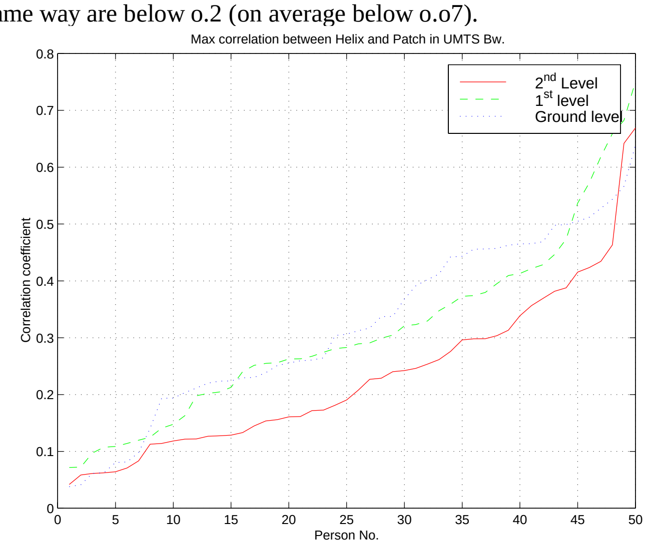

Figure 3. Highest correlation coefficient for the helix and patch antenna in the three 4MHz bands investigated. The results are sorted to ease the readability.

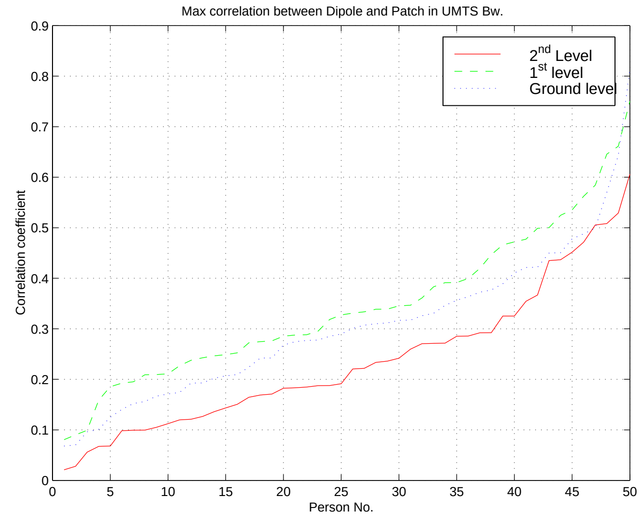

Figure 4. Highest correlation coefficient for the dipole and patch antenna in the three 4MHz bands investigated. The results are sorted to ease the readability.

Haven seen that the cc are sufficiently low to make diversity actions worthwhile the branch power ratio is investigated. Figure 5 and 6 shows the branch power ratios between the helix and patch and between the dipole and the patch, respectively. From the figure it is seen that especially the helix patch configuration results in a branch power ratio larger than 2 dB for approximately half of all users. This will degrade the diversity performance by some 2 dB or more and the diversity gain will be significantly different from one user to another.

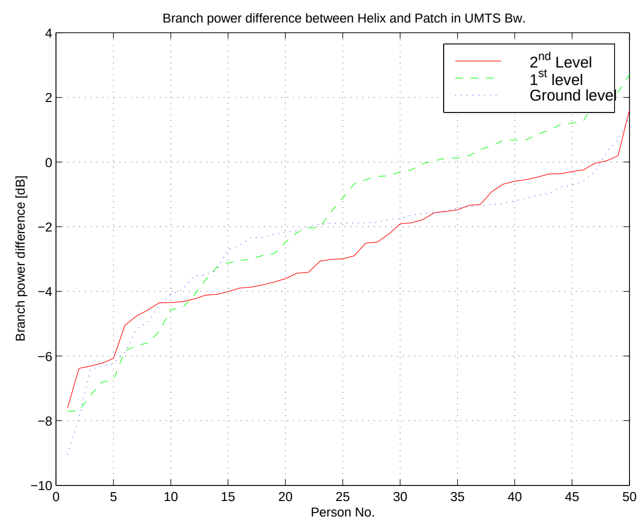

Figure 5. The Branch power difference for the helix and patch antenna. The results are sorted to ease the readability.

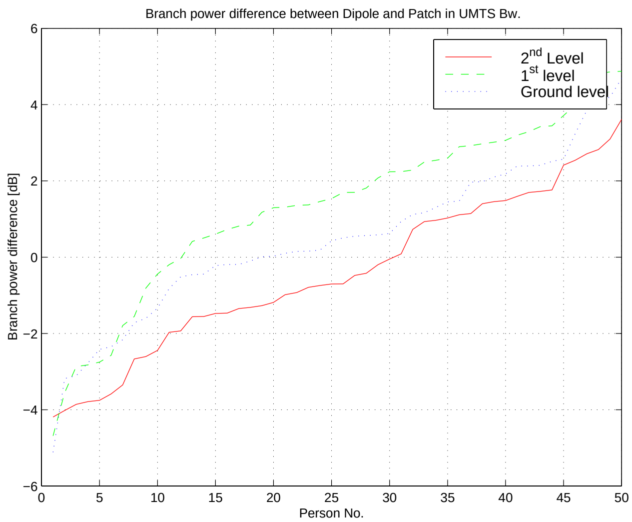

Figure 6. The Branch power difference for the dipole and patch antenna. The results are sorted to ease the readability.

In Figure 7 and 8 the CDF of the RSSI (Received Signal Strength Indicator) w.r.t. each users mean received power is shown for all 50 test persons on level 3. Figure 7 shows the CDFs for the helix and Figure 8 the CDFs for the patch antenna measured at the same time, and it is clear that also the distribution of the received signals has a large spread for the helix antenna. At the 1% level the spread is approximately 7 dB for the helix and 4 dB for the dipole whereas the patch only has a spread of one dB. This is somewhat surprisingly that the that the distribution of the received signals are influenced very differently depending on the antenna type used on the handset.

The possible explanation is that especially the helix which is located relatively close to the users head and has an omnidirectional like radiation pattern has a high degree of interactions with the head of the user whereas the patch antenna which is placed on the back of the phone is less sensitive to the location of both hand and head.

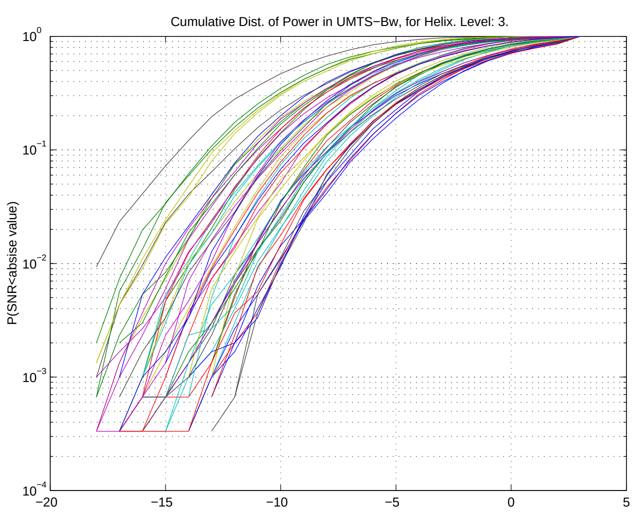

Figure 7. CDFs of the RSSI w.r.t. each users mean received power for all 50 test persons on level 3 for the helix antenna.

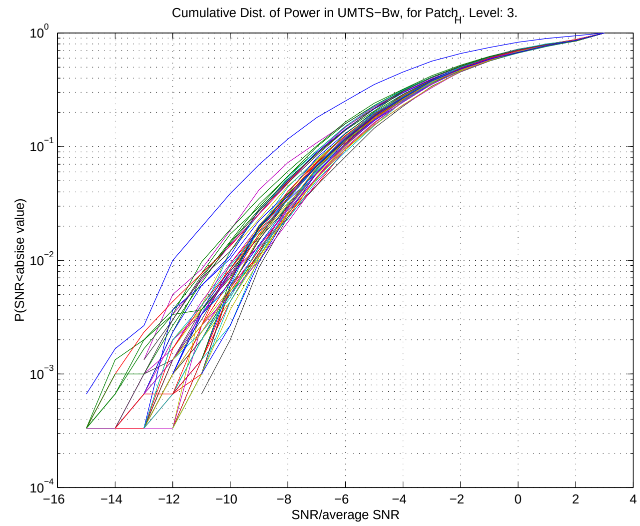

Figure 8. CDFs of the RSSI w.r.t. each users mean received power for all 50 test persons on level 3 for the patch antenna.

Figure 9 shows the maximalratio combined signal and with respect to the best of the single antenna (the patch) the diversity gain is in the order of 1 to 6 dB. The variation from one user to another is very large. The corresponding figures for the dipole and patch also at the 1% probability level are 2 - 7 dB.

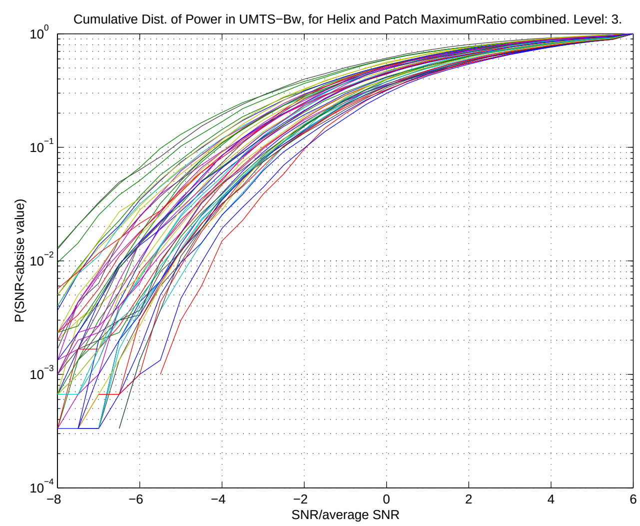

Figure 9. CDFs of the RSSI w.r.t. each users mean received power for the patch antenna (the best single element) after maximalratio combining of the helix and patch antenna on level 3 for all 50 test persons.

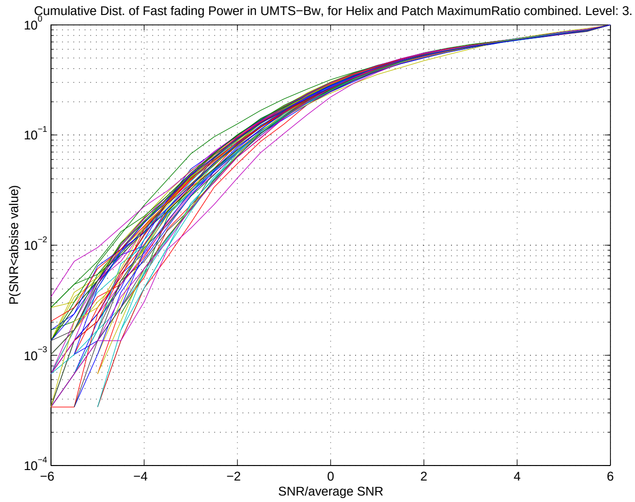

Figure 10. CDFs of the RSSI w.r.t. each users mean received power for the patch antenna (the best single element) after maximalratio combining of the helix and patch antenna on level 3 for all 50 test persons. The combining is done after the non-combined signals are compensated for slowfading.

If the non-combined signals are compensated for slow variation for each user the difference in diversity gain among users is only 1dB, see Figure 10 as an example.

From the above it is clear that the individual antennas have an somewhat uncorrelated slow fading and Figure 11 and 12 shows the CDFs of the RSSI for the slow fading compensated signals from the helix and the patch antenna, and it is clear that the difference in the diversity is primaraly caused by the large spread in the slow fading.

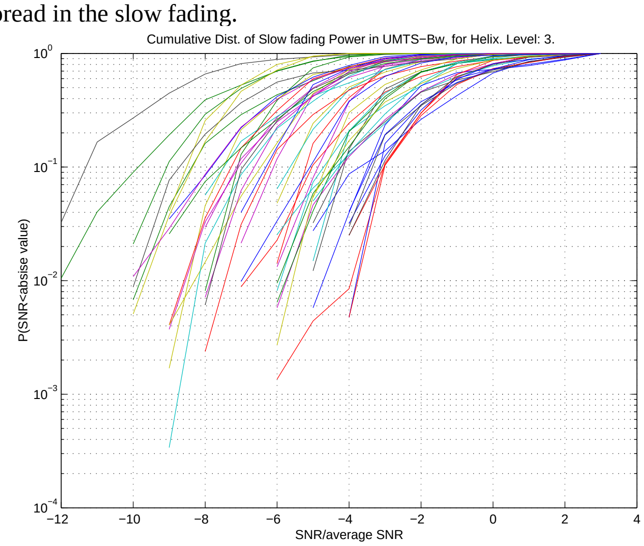

Figure 11. CDFs of the fast fading compensated RSSI w.r.t. each users mean received power for all 50 test persons on level 3 for the helix antenna.

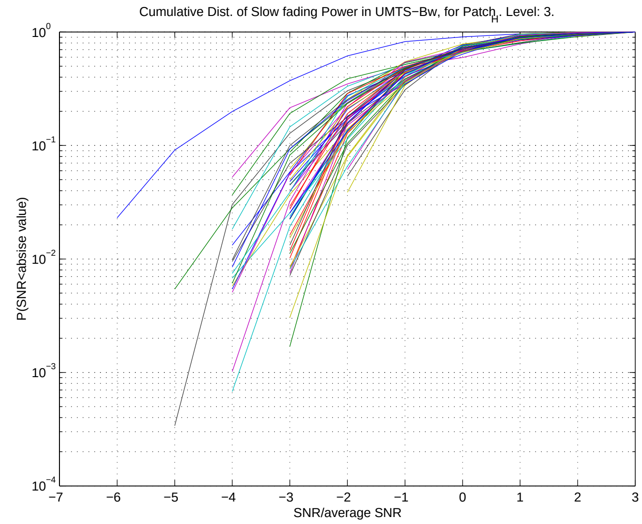

Figure 12. CDFs of the fast fading compensated RSSI w.r.t. each users mean received power for all 50 test persons on level 3 for the patch antenna.

To investigate how uncorrelated the slow fading on the antenna pairs are, the cc are calculated based on the fast fading compensated signals for each user and presented in figure 13 and 14, for the helix, patch and dipole, patch configuration, respectively. It is seen that the slow fading of each antenna pair has a low level of correlation. This is at a first glance surprisingly but can be explained by the difference radiation patterns of the individual antennas. The radiation pattern are different for the antennas and the antennas do not "see" the same signals and the local mean power will therefore vary difrent.

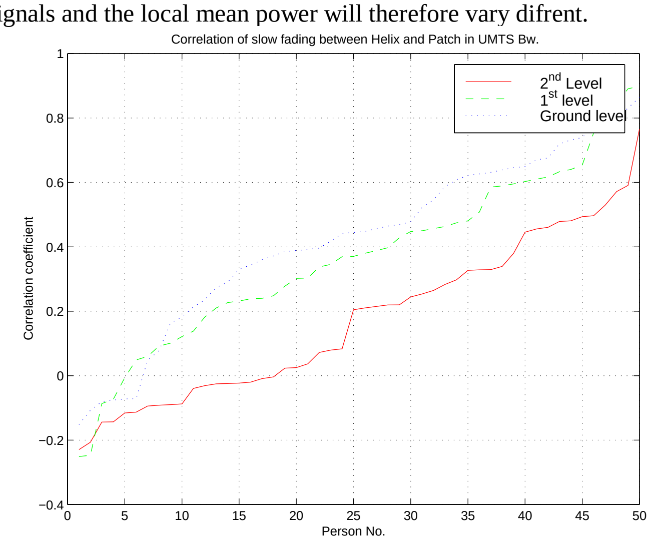

Figure 13. Correlation of the fast fading compensated RSSI values between the helix and patch antenna.

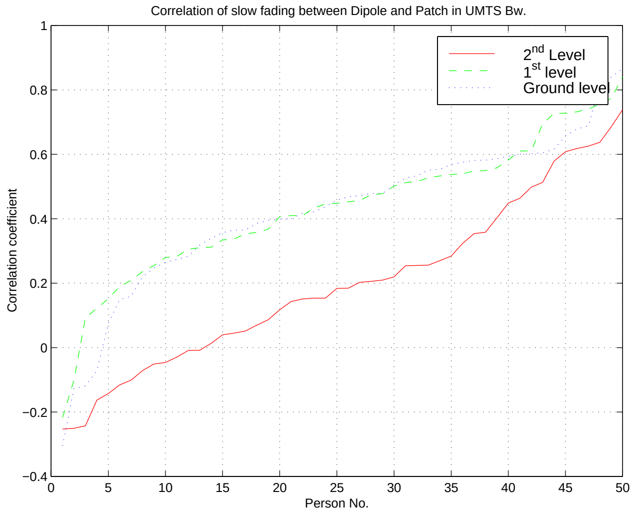

Figure 14. Correlation of the fast fading compensated RSSI values between the helix and patch antenna.

V. Conclusions

To be drawn later when all data is analysed.

VI. Acknowledgments

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