CHARACTERIZATION OF MOBILE TERMINALS IN RAYLEIGH FADING BY USING REVERBERATION CHAMBER

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Introduction

The reverberation chamber is a metal cavity which is large enough to support several cavity modes at the frequency of operation. The modes can be stirred to create a Rayleigh distributed transfer function between two antennas inside the chamber. The Q of the chamber is affected by wall losses, leakage, lossy objects as well as the antennas, and can be used to control the average power level of the transfer function. This average level is produced by measuring the transfer function for several stirrer positions and averaging these levels. Reverberation chambers with high Q have for a couple of decades been used for EMC measurements [1]. The Rayleigh statistics is also present in chambers with low Q (down to 100). This makes them possible to use for testing of mobile terminals designed for use in fading environments.

The last four years the capabilities of reverberation chambers have been extended to accurate measurements of small antennas and active terminals that are designed for use in Rayleigh fading environment. The new measurement capabilities include radiation efficiency of small antennas [2], diversity gain of diversity antennas [3], maximum available capacity of multiport antennas for MIMO systems [4], radiated power of active terminals [5][6][7], diversity gain of active terminals [8], and receiver sensitivity [9]. All the measurements can readily be done with the terminal located in a position inside the chamber corresponding to free space as well as in talk positions near a head phantom or close to other near-field objects.

The present paper will summarize the new measurement capabilities that have been developed as collaboration between the antenna group at Chalmers University of technology and the spin-off company Bluetest AB (www.bluetest.se). The active measurements can be done for mobile communication systems such as GSM, PDC, TDMA, IS-95, EDGE, UMTS, 3G, CDMA2000, Bluetooth, WLAN and similar.

The reverberation chamber

Measurements in a reverberation chamber are performed by measuring the transfer function between an antenna or terminal under test and some fixed wall antennas. When the power of this transfer function is averaged over the stirrer positions, the averaged level is proportional to the radiated power of the terminal under test or the radiation efficiency of the antenna under test. The work to make the reverberation chamber a practical measurement instrument for mobile terminals started by developing a small chamber which could be used with reasonable measurement accuracy (0.5 dB standard deviation of average levels of transfer function) down to 900 MHz (Figure 1). This was enabled by more field stirring methods than those used before, which were limited to mechanical stirring and frequency stirring [1], the new methods being referred to as platform stirring [10] and polarization stirring [11]. The standard size chamber shown in the figure is moveable on wheels (when lifted down from its support frame), and it can pass through a door of 80 cm width. The chamber can also be extended to larger widths and heights. The chamber comes today with control software for the different types of measurements described below.

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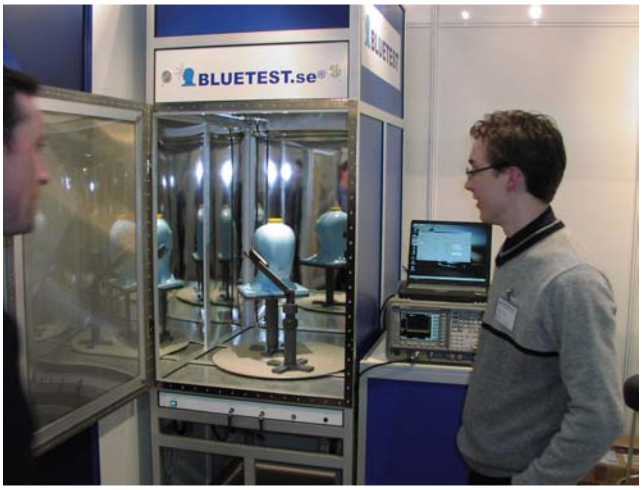

Figure 1. The Bluetest reverberation chamber shown with open door with a setup for measuring radiated power of mobile phone close to head phantom. The chamber size shown allow for use down to 850 MHz. The camber and control software is available from Bluetest AB (www.bluetest.se).

Radiation efficiency measurements and diversity gain

The average transfer function of the chamber is proportional to the radiation efficiency of the antennas. Therefore, the chamber can be used to measure radiation efficiency by comparison with a calibration antenna with known radiation efficiency. The radiation efficiency includes contributions due to input port reflections. Antenna diversity is allowed in UMTS, CDMA2000 and some Japanese and Korean systems. This requires special measurements to be able to quantify and optimize the antenna performance. The reverberation chamber is well suited for this as its environment has a similar Rayleigh distribution as actual urban and indoor environments for mobile communication. The measurement procedures as well as theories for antenna diversity performance have been developed, and the set-up is in principle the same as for radiation efficiency measurements. Some initial results are given in [3], see also [4].

Total radiated power and implemented diversity gain of active mobile terminal

The measurements of total radiated power of mobile phones in “free space” position as well as different talk positions close to a human head is described in [6]. This way of measuring total radiated power is included in the TCO’01 Mobile Phones quality labeling, see www.tcodevelopment.com. The procedures have been extended to mobile systems of different standards, also Bluetooth [7]. The reverberation chamber is in particular attractive for measuring implemented diversity gain in active terminals, such as in the measured DECT phones described in [8]. The measured results from the latter are shown in Figure 2. We see that the implemented diversity in the phone gives a diversity gain of 5 dB at 1% cumulative level, compared to the level when the strongest antenna (diversity branch) is used. The maximum available diversity gain from the two implemented antennas in the phone when selection combining is used is seen to be 2 dB larger.

Receiver sensitivity of active terminals

The quality of a received signal in a mobile terminal is characterized by the bit error rate (BER), or by the corresponding frame error rate (FER) in CDMA systems. The sensitivity is normally quantified in terms of the input signal level at a certain BER or FER level, for FER often chosen to be 0.5%. This sensitivity will depend on the level of the radiation pattern in the direction of the incoming wave. Therefore, it is common to specify a so-called total isotropic sensitivity (TIS) that is the averaged of the sensitivity over all directions of incidences of waves. This is theoretically equal to the sensitivity in dBm measured directly on the receiver input port, degraded by the radiation efficiency of the antenna. The TIS can be measured both in an anechoic chamber and in a reverberation chamber, but the procedure is laborious. The reverberation chamber offers in addition the possibility of a much faster measurement in an actual fading environment, with a continuously fading signal present at the terminal. This is a way of characterizing mobile terminals on reception that is very realistic compared to an actual operation of the terminal. However, this Average Fading Sensitivity (AFS) gives a theoretically larger dBm value than TIS (for the same BER or FER). The difference seems to be constant in dB, and we are working to theoretically evaluate this constant. At the moment it is sufficient to point out that the differences (in dBm) between the AFS of different phones seem to be the same as between the TIS of the same phones, see Figure 3. More results can be found in [9]. A mobile communication tester is needed for both TIS and AFS measurements.

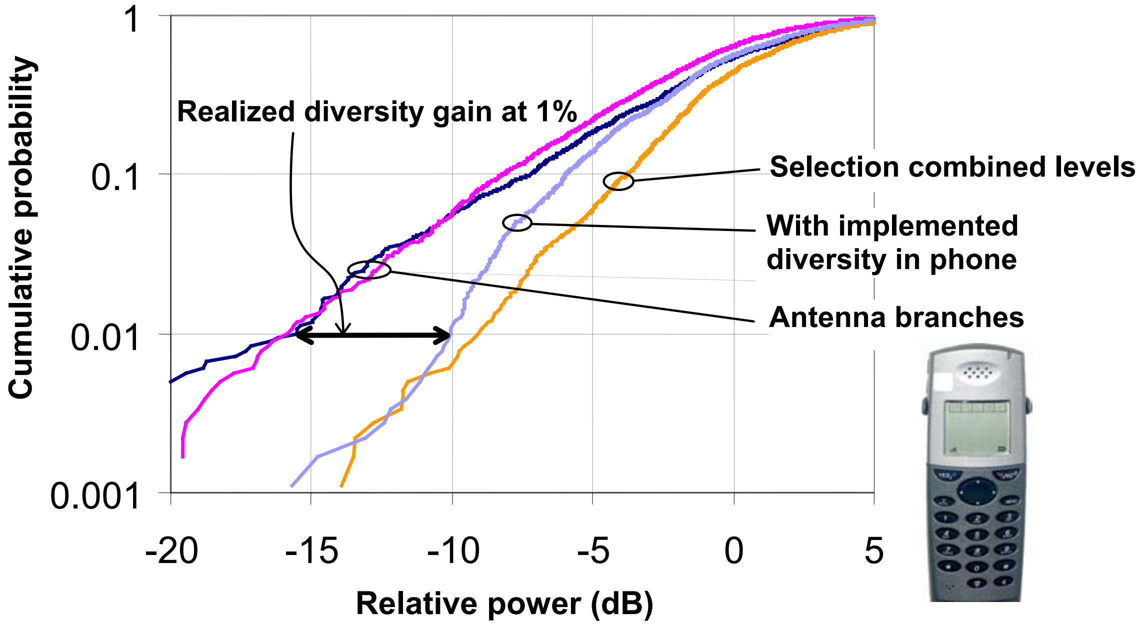

Figure 2. Measured cumulative distribution of signal amplitudes when an active DECT phone with implemented antenna diversity is used in reverberation chamber. The implemented/realized diversity gain is seen to be about 2 dB lower than the theoretical maximum by selection combining.

Terminals for future diversity and multiport MIMO systems

There is presently a lot of attention given to the research on future communication systems which continuously adapt to fading. A popular candidate for such is a so-called MIMO system (Multiple Input Multiple Output), where multiple ports on both the transmitting and receiving sides are used to generate several communication channels between which the signals are distributed in an optimum manner. MIMO antennas and terminals require special testing instrumentation. The quality of a MIMO system in a fading multipath environment is characterized by the maximum available capacity in bits/sec/Hz. Antennas for MIMO systems degrade the capacity due to both their radiation efficiency and correlation between received signals, of which the former is a dominating factor. The reverberation chamber offers a unique opportunity to experimentally characterize MIMO systems in a controllable fading environment. Results of such characterizations are already being published and compared with theoretical results [4].

Conclusion

The reverberation chamber has been proven to be able to characterize both antennas and mobile terminals that are designed for use in a Rayleigh fading environment. The alternative is often laborious and expensive field measurements. There is a large potential in further developments of the technique, which is underway at Chalmers in collaboration with Bluetest AB.

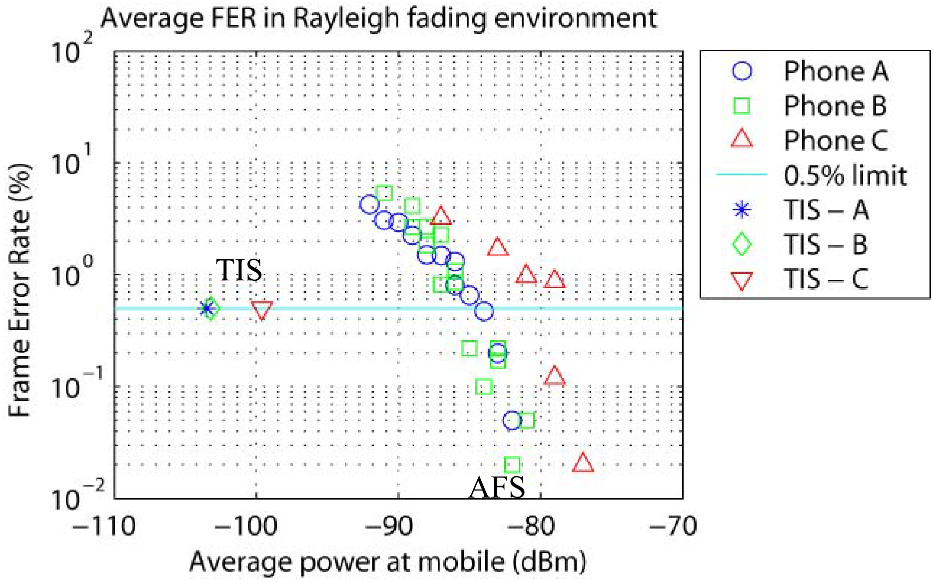

Figure 3. Frame Error Rates (FER) measured in reverberation chamber for three different CDMA2000 phones A, B and C, where phones A and B are the same model. The AFS levels of the three phones are marked with red arrows (where the three FER curves pass the 0.5% level). These are to be compared with the three marks to the left, corresponding to the TIS levels at 0.5% level. The difference between the TIS and AFS levels of the three phones are the same.

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