Measurements of Radiated Power and Radiated Receiver Sensitivity in Reverberation Chambers

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Abstract

Chalmers and Bluetest AB have the last years shown that it is possible to measure radiated power and total isotropic receiver sensitivity in the statistic field environment created by a reverberation chamber. The new measurement method has been developed for mobile and wireless terminals such as mobile phones. However, the approach is also valid for measurements at higher frequencies, and e.g. to measure the performance of integrated antennas not being separable from their transmit or receive amplifiers.

The purpose of the present paper is to describe measurements of radiated power and receive sensitivity in reverberation chambers of mobile terminals, and to show that this also can be done at higher frequencies. The measurement accuracy and how this depends on frequency will be explained.

1 Introduction

The communication performance of a mobile phone is equally important in transmit and receive mode. For the antenna specialist there is also the need to get information about the radiation efficiency of the antenna on the final mobile unit and in active mode, since a soldered cable to the antenna port will to some degree change the antenna performance.

The reverberation chamber supports a uniform and isotropic field, which is useful when measuring antennas and units that are to be used in multi-path propagation environments. We have previously shown how the reverberation chamber can be used to measure the radiation efficiency of terminal antennas[1, 2] and also presented a setup to measure the total radiated power of mobile phones, described in detail in [3] with examples of measurements. In this paper we present in addition a procedure to measure the mean receiver sensitivity of mobile phones in such a chamber, since that is a convenient way to characterize the phone in receive mode. This will also make it possible to get information about the radiation efficiency of the phone antenna in the receive band.

2 Total radiated power

The setup for measuring the radiated power from active devices such as mobile phones, Blutooth units etc. is shown in the left part of figure 1. A complete description of this setup is found in [3].

3 Receiver sensitivity including the antenna

The setup used here for measurement of the mean receiver sensitivity in a reverberation chamber is similar to the setup used for measuring the total radiated power. Basically, the difference is that the phone is working as the receiver and the base station, connected to the three excitation antennas, works as transmitter. The physical setup is shown in the right part of figure 1. To calibrate the chamber a standard reference case with a dipole is used. This reference case is described with setup and calculations in [3].

3.1 Measurement procedure

The measurement procedure is done in three steps. For the first two, an arbitrary reference position for the mode stirrers is chosen. In this position the base station output power is decreased in steps (of e.g. 1 dB) from the maximum level, so that a table can be made of the reported RX-level values from the phone versus the base station output power. In the same reference position for the mode stirrers, we look for the base station output power that gives a Bit Error Rate (BER) that is equal to the limit specified in the standard, e.g.

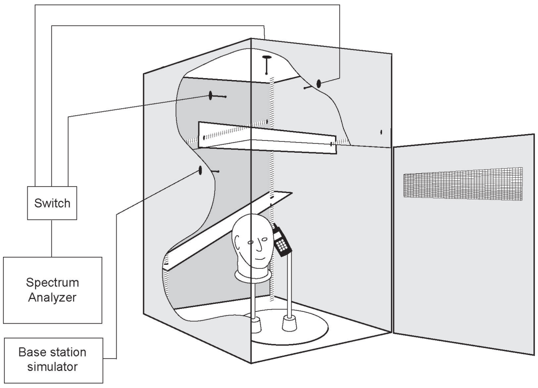

Figure 1: Setups in the reverberation chamber for measurement of total radiated power (*left*) and/or mean receiver sensitivity (*right*) of a mobile phone.

2%. Then we normalize the values in the table to this power value. By these two steps we have performed a calibration of the dB-steps of the internal power meter of the phone.

The third step is performed as follows. For a fixed output power from the base station simulator, we sample the phone received power for each position in a stirring sequence. From these sampled values we calculate the mean received power by taking the average.

3.2 Data processing

The mean received power ($\overline{A}$), in absolute terms, can be expressed as

$$\overline{A} = P_{BS,lim}^{(ref)} \cdot G^{(ref)} \cdot \overline{P} = P_{BS,used} \cdot C_c \cdot e_{rad} \tag{1}$$

where $\overline{A}$ is absolute mean received power, $P_{BS,lim}^{(ref)}$ is output power of base station for BER limit in reference position, $G^{(ref)}$ is transmission factor for the chamber in the reference position, including gain of the mobile phone antenna, $\overline{P}$ is relative mean received power of phone for a full sequence, $P_{BS,used}$ is output power of base station used during power measurement, C_c is calibration coefficient for chamber average transmission and cable losses, and e_{rad} is the radiation efficiency for the mobile phone antenna. The radiation efficiency used here (defined in [4]) is including impedance mismatch relative to 50 Ω, losses in the antenna itself and losses in the near-in environment such as a head phantom.

The mean sensitivity of a phone in a multipath environment, including the antenna, is given by $\overline{S} = S_{rec}/e_{rad}$ where $S_{rec} = P_{BS,lim}^{(ref)} \cdot G^{(ref)}$ is the receiver sensitivity, i.e. the absolute power level at the receiver of the phone, excluding any antenna, when the BER is at the specified limit. It then follows from (1) that the mean sensitivity of the phone including the antenna can be expressed as

$$\overline{S} = C_c \cdot P_{BS,used} \cdot \frac{1}{\overline{P}} \tag{2}$$

By measuring the receiver sensitivity via a cable connection (S_{cable}), possible for those units that are equipped with an external RF-connector, the radiation efficiency of the antenna can be extracted by comparing with the reverberation chamber measurement, i.e.

$$e_{rad} = \frac{S_{cable}}{\overline{S}_{chamber}} \tag{3}$$

3.3 Validation measurements

Measurements have been performed to validate the performance of the procedure. For this purpose three different, commercially available GSM phones have been used. All measurements have been performed by measuring three traffic channels (1, 62, 124) at the GSM900 frquency band, i.e. the final results are frequency stirred over a bandwidth of 25 MHz.

For phones that are equipped with an external RF-connector it is possible to extract information about the radiation efficiency of the phone antenna, as mentioned in section 3.2. Figure 2 shows the measured values for the three phones used (D, E and F) measured both in the chamber and with a cable connection via the RF-contact. The values compare well to what is expected for these types of phones, which shows that the method can be used for the claimed purpose.

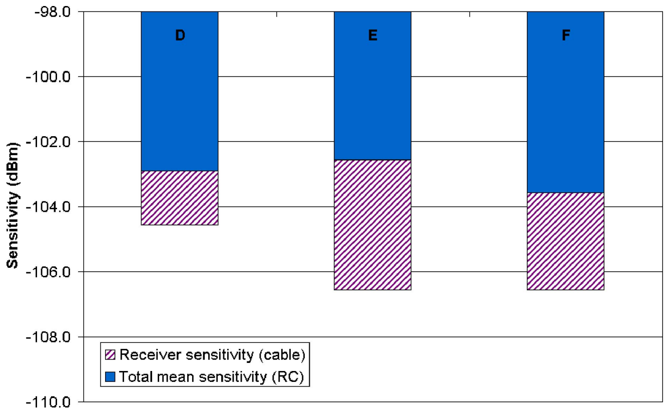

Figure 2: Mean sensitivity and receiver sensitivity for three GSM phones. The mean sensitivity values are measured in free space location inside the reverberation chamber, i.e. mounted far away from the head phantom, whereas receiver sensitivity values are measured through a cable connection to the phone. The difference between the two values for each phone corresponds to the radiation efficiency.

4 Extension to higher frequencies

An important contribution to the measurement accuracy in the case of the reverberation chamber is the mode statistics. From the reverberation theory we know that the average received power by the antenna under test will be normally distributed with a standard deviation that is inversely proportional to the square root of the number of independent power samples acheived during the measurement [5], i.e.

$$\sigma_{rel} = \frac{1}{\sqrt{N_{indep}}} \tag{4}$$

The goal with the mode stirring in the chamber is then to create as many independent samples as possible. Generally, the upper limit for the number of independent samples is regarded to be determined by the number of modes excited in the chamber at the particular measurement frequency, but it is also possible to extend this limit further by using e.g. platform stirring [6].

The present chamber used in this study is of size 1.0x0.8x1.6m^3, which is a relatively small sized chamber at the GSM900 frequency band. Several improvements have been done to this chamber in order to achieve the preferred measurement accuracy [1, 6, 7]. Since the mode density of the chamber increases with frequency, we have a more favourable situation, with regard to the number of modes excited, the higher up in frequency we go. A thorough study of the mode density in reverberation chambers is given in [1], but we can estimate the mode density with the following equation, derived from the so called Weyl's formula,

$$\frac{\partial M}{\partial f} = \frac{8\pi}{c^3} LWHf^2 \tag{5}$$

where the squared dependency on the frequency clearly can be seen. The total number of modes excited can then be calculated as the product of the mode density and the average mode bandwidth (Δf) of the chamber, i.e.

$$M_{tot} = \frac{\partial M}{\partial f} \Delta f \tag{6}$$

If we limit the number of independent samples (N_{indep}) to the total number of modes excited (M_{tot}) we can use eq. 4 together with eqs. 5 and 6 to estimate the expected confidence interval for the mean received power of the antenna under test. Figure 3 shows an example of this for the case with a 25 MHz frequency stirring, which is the amount used for measurements in the present chamber at frequencies around 900 MHz.

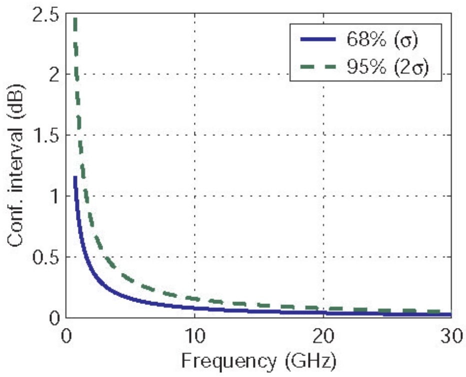

Figure 3: Confidence intervals for the mean received power of an antenna under test in a 1.0x0.8x1.6m^3 large chamber with a frequency stirring of 25 MHz.

From the reasoning above the conclusion can be drawn that there is a fundamental gain in accuracy when going up in frequency. For active tests though, there might on the contrary be problems arising when increasing the frequency which have to be taken care of when implementing setups. For instance the average transmission function of the chamber becomes lower with higher frequency, which means that the communication channel between the controller unit and the unit under test may be poorer.

5 Conclusion

Procedures for measuring the radiated power and mean receiver sensitivity for active mobile phones including the antenna in a reverberation chamber have been developed. The methods have been validated and show good agreement with what can be expected.

References

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