

# ACCURATE MEASUREMENTS OF SMALL ANTENNAS AND RADIATION FROM MOBILE PHONES IN SMALL REVERBERATION CHAMBERS

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## ABSTRACT

The paper gives a summary of the work that has been performed in the Antenna group at Chalmers University of Technology and the start-up company Bluetest AB ([www.bluetest.se](http://www.bluetest.se)) on measuring radiated power from mobile phones in reverberation chambers. Reverberation chambers were originally developed for EMC measurements. We have shown that it also can be used to accurately measure performance of antennas that are designed for use in multipath propagation environment, as well as the total radiated power of complete phones. The antennas and phones can be measured with or without the presence of a head phantom or other objects. In the present paper we describe the measurements of the total radiated power and provide results for phones with different types of antennas. We will also show results of validation against measurements of the total radiated power by integration of three-dimensional far field patterns measured in anechoic chambers.

## INTRODUCTION

A mobile phone must radiate in order to work. Thereby it is also unavoidable that part of the radiated power is absorbed in the human head. This absorption is characterized in terms of a Specific Absorption Rate (SAR), and there exist requirements to the maximum allowed value of the SAR. These values have been determined by considering the possibility of health hazards. It has therefore been an issue that the SAR value should be as low as possible, without actually mentioning the fact that a phone must radiate in order to work satisfactory. It is therefore necessary to introduce a complement to the SAR value. This is the maximum power the phone can utilize for communication in the presence of the human head. This radiated power can be measured in many ways. E.g., it can be measured in a standard anechoic chamber. The purpose of the present paper is to describe measurements of the radiated power in a reverberation chamber. The reverberation chamber has many advantages over an anechoic chamber. The anechoic chamber needs to be several meters in cross section, whereas the reverberation chamber we use is much smaller, only 0.8m x 1.05m x 1.6m in size (Figure 1). The measurements take also much shorter time. We will in this paper also show that the measurement accuracy is comparable with that of a good anechoic chamber. The present paper is a summary of results from [1].

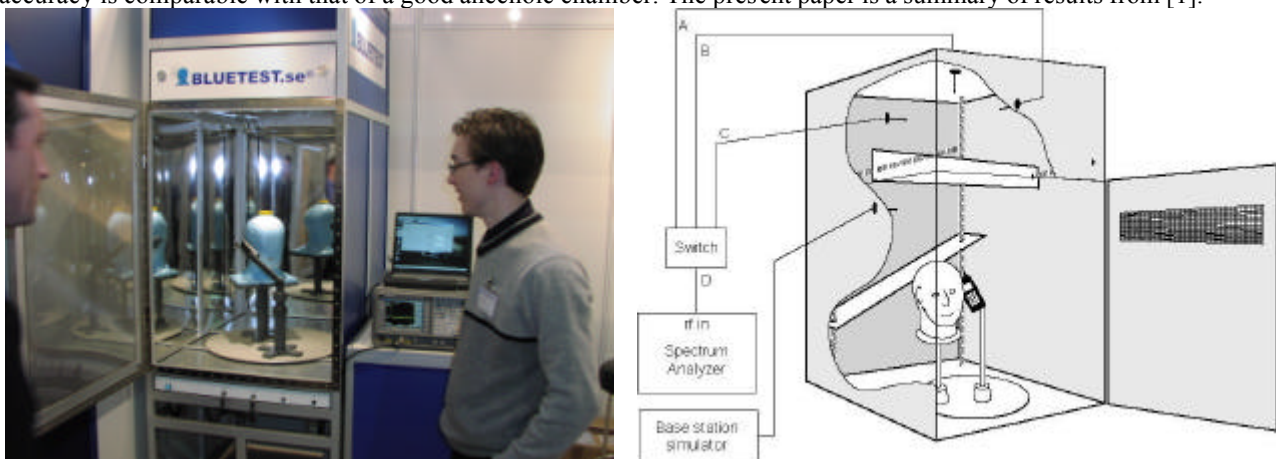


Figure 1. Photo (left) of Bluetest's reverberation chamber RC800 with open door, and drawing (right) of measurement setup with base station simulator and spectrum analyzer used in pulse power mode. The two plate shaped mechanical stirrers, the platform stirrer and the three antennas for polarization stirring are shown.

## RADIATED POWER, HEAD LOSS AND SAR; THREE QUALITY MEASURES OF MOBILE PHONES

The total radiated power in the presence of the head is the figure of merit of a mobile phone, when it is transmitting. The higher the radiated power, the better the phone will work in the transmit mode. On the other hand, the possible radiation hazards are characterized in terms of a Specific Absorption Rate (SAR) distribution that should be as low as possible or at least below some standardized limits, see e.g. [2]. Both the radiated power and the SAR are proportional to the maximum power that can be radiated by the phone. Therefore, a high quality phone must provide a good compromise between high radiated power and low SAR. This is possible by using an antenna that directs the radiation from the phone away from the head. In practical measurements the human head is replaced by a head phantom with similar characteristics as the human head.

The radiated power is proportional to the radiation efficiency of the antenna on the phone, measured with a head phantom present. The radiation efficiency as defined in [3] has three contributions: The reflections due to impedance mismatch between the phone antenna and the transmission line that connects the phone antenna to the receive and transmit amplifiers inside the phone, the absorption in the phone antenna itself including the chassis of the phone, and the absorption in the phantom.

The less absorption in the head, the lower is the SAR. Thus, the best compromise between high radiated power and low SAR is to make the antenna radiate away from the phantom (head). Thereby, the absorption in the phantom will decrease so that the radiation efficiency increases.

In a setup for measuring the radiated power it is not possible to separate the power absorbed in the head from the results. However, we can measure the total loss in radiated power when we move the phone from a position far from the head to one of the talk positions defined in [2]. This loss we refer to as head loss, i.e. loss due to the presence of the head phantom. It is caused by both mismatch of the antenna on the phone and absorption, and we cannot separate the two. A good phone has low head loss. A good phone has low head loss.

## IMPROVEMENTS OF REVERBERATION CHAMBER

The present tests make use of a so-called reverberation chamber. The reverberation chamber is well known within the EMC area. Its theory is described in detail in [4]-[8]. It has recently also been used to characterize antennas. The reverberation chamber is also called a mode stirred chamber, as it contains several cavity modes, which are stirred mechanically to provide several statistically independent field distributions. These field distributions correspond to what in mobile communications result from multipath propagation, as shown in [9]. The mechanical stirrers can have many forms. The reverberation chamber at Chalmers makes use of two plate stirrers. One of these can be moved across the back wall of the chamber, and the other can be moved over a complete horizontal cross section in the upper part of the chamber (see Figure 1).

The antenna group at Chalmers has shown that reverberation chambers can be used to measure radiation efficiency of antennas. In order to improve accuracy we have developed platform stirring [10] and polarization stirring [11], see Figure 1. We have also shown that it can be used to measure the “free space” input reflection coefficient of small antennas in the vicinity of some object such as a head phantom [12]. With “free space” reflection coefficient we mean the reflection coefficient, as it would be seen if the antenna and the object were located in free space. We have also shown that reverberation chambers can be used to measure effective diversity gain very accurately, if the phone has more than one antenna and makes use of diversity [13]. Measurements of both radiation efficiency and radiated power in Bluetest’s chamber are in [14] validated against measurements in another reverberation chamber and in two anechoic chambers. Table 1 shows the validation results.

	Radiation efficiency		Radiated power	
	900 MHz	1800 MHz	900 MHz	1800 MHz
GSM band				
Mean Deviation	0.01 dB	-0.18 dB	0.00 dB	0.00 dB
Standard Deviation	0.72 dB	0.55 dB	0.57 dB	0.87 dB
Maximum Deviation	1.43 dB	-1.54 dB	-1.00 dB	-1.57 dB

Table 1. Statistical deviations between measured results in reverberation chamber and anechoic chamber [14].

## RESULTS FOR RADIATED POWER

We will here give some results for measured radiated power and head loss of 20 phones, see Figure 2. The complete results including validation measurements are given in [1]. The radiated power at 900 MHz is shown in Fig. 2. We have chosen to letter-code the phones because we want to study the effect of different antennas types and not the different phone models. The phone code contains even an antenna code that is an abbreviation for external (E), built-in (BI) and extractable (EL).

We have measured the radiated power in dBm for all the talk positions of the phones defined in the new European Standard for SAR measurements developed by CENELEC [2]; free space, cheek right, cheek left, tilt right and tilt left.

We see that all phones have free space radiated power at 900 MHz in the range 29-32.2 dBm, whereas the GSM standard is 33 dBm +/- 2 dB. At 1800 MHz all phones except two have values between 27 and 29.3 dBm when the GSM standard is 30 dBm +/- 2dB. The head loss, which is a quality measure of the antenna on the phone, is the difference in dB between the radiated power in free space and in a talk position. We see that the extractable antennas are very good at 900 MHz. There is not much difference between built-in and external antennas at 900 MHz, whereas the built-in antennas have typically 1 dB smaller head loss at 1800 MHz. The radiated powers vary much more with phone position for phones with external antennas than for phones with built-in antennas. The built-in antenna seems to be less sensitive to how the phone is used. The head loss is between 2.5 and 9 dB at 900 MHz, whereas it is between 1 and 4 dB at 1800 MHz. We must here note that the present results do not take into account the effect of a users hand.

The measurement accuracy has been investigated in detail in [1], by using the European recommendations. The result is an expanded uncertainty of less than 1 dB in both the 900 and 1800 MHz bands. Expanded accuracy means two standard deviations. This value agrees well with the validation results in the previous section.

## ACKNOWLEDGEMENTS

The Swedish Strategic Research Foundation (SSF) has supported the theoretical part of the research associated with the development of the reverberation chamber for measuring small antennas, under a program related to antenna technology. The measurements of the 20 phones have been supported by TCO Development AB. TCO has adopted the present measurement method for radiated power in their new quality marking of mobile phones. The radiated power is there referred to as TCP (telephone Communication Power), which is a copyrighted trademark of TCO Development.

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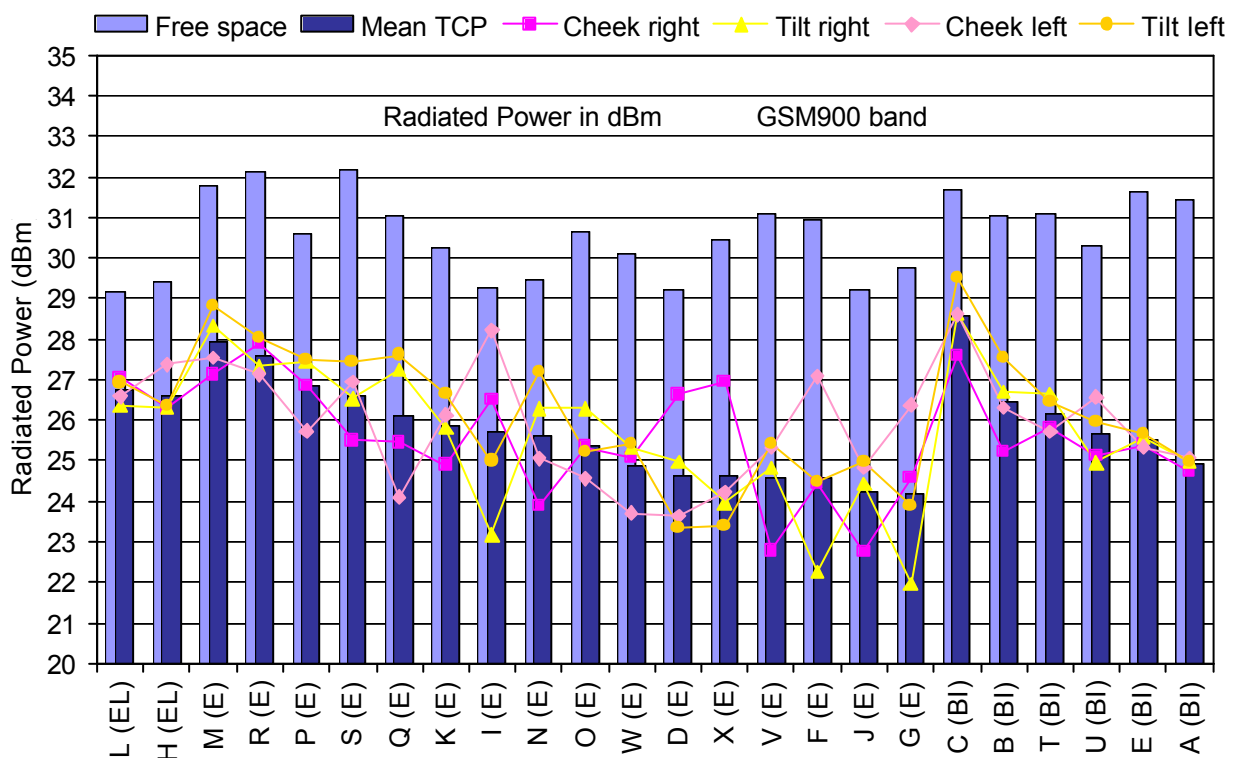


Figure 5. Measured radiated power in Bluetest's reverberation chamber in the transmit GSM 900 MHz band of 20 phones with extractable antenna (EL), external antenna (E) and built-In antenna (BI), for different positions relative to head phantom. The results are obtained with 50 platform positions and 2 stirrer positions per platform position. The frequency stirring is 25 MHz.