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Abstract

This document presents results of the benchmarking of test facilities for small terminal antennas that were conducted during the periods December 2004 to June 2005 and September to December 2005, respectively.

Keyword List

Antenna measurement, Benchmarking, Antenna test facility, Round robin, Radiation efficiency, Diversity gain, Total radiated power, Total isotropic sensitivity

Contents

1 Introduction

This report describes the benchmarking of test facilities for small terminal antennas, which were conducted between December 2004 and June 2005 and September 2005 to December 2005, respectively. The test devices used for the comparison were both passive antennas and active devices chosen to cover the most popular communications frequency bands. Measured parameters were those judged to be relevant for small terminal antennas and small active devices. The test devices are described in more detail in chapter 3, the different test cases in chapter 4 and the results in chapter 6.

In order to guarantee comparable results the test devices were put together in a test kit that was sent around to the participants of the benchmarking. This means e.g. that the same lossy cylinder filled with liquid and the same active devices were measured at all participating facilities. All defined test cases were measured by the first organisation in the round robin and relevant test cases were repeated once again after the two measurement periods to check the status of the test devices after the completed periods. Results from these investigations can be found in chapter 7. The round robin was organised in such a way that the participants would not know which organisations had already performed their measurement, in order to guarantee that no one had access to results beforehand.

2 Organisation of the benchmarking

2.1 Participants

Table 2.1 lists the participants of the benchmarking together with the responsible person(s) at each organisation.

Organisation	Responsible person(s)	Address
CHALMERS	Charlie Orlenius	Chalmers University of Technology Department of Signals and Systems Antenna Group SE-412 96 Göteborg, SWEDEN
SP	Kristian Karlsson	SP Swedish National Testing and Research Institute Brinellgatan 4 Box 857 SE-501 15 Borås, SWEDEN
IMST	Andreas Winkelmann	Department of Antennas & EM Modelling IMST GmbH Carl-Friedrich-Gauß Str. 2 D-47475 Kamp-Lintfort, GERMANY
HUT	Clemens Icheln	Radio Laboratory Helsinki University of Technology P.O.Box 3000 Otakaari 5a FI-02015 Espoo, FINLAND
LEMA-EPFL	Anja Skrivervik	LEMA EPFL-STI-ITOP Station 11 CH1015 Lausanne, SWITZERLAND
SATIMO	B. Bencivenga / S.Gaymay / L. Duchesne	SATIMO 22, avenue de la Baltique F-91953 Courtaboeuf Cedex, FRANCE
UoB	Phill Rogers	University of Bristol Wireless and Networks Research Labs Merchant Venturers Building, Woodland Road Bristol, ENGLAND, BS8 1UB
IETR	Ala Sharaiha	IETR Groupe Antennes & Hyperfréquences UMR CNRS 6164 Université de Rennes 1 Campus de beaulieu- Bat 11D 263, Avenue General Leclerc CS 74205, 35042, Rennes Cedex / FRANCE
SES	Johan Andersson	Sony Ericsson Mobile Communications AB Nya Vattentornet 221 88 LUND, SWEDEN
BenQ	Werner Schroeder	BenQ Mobile GmbH & Co. OHG Neutorplatz 3-4 D-46395 Bocholt, GERMANY

Table 2.1. Participating organisations.

2.2 Measurement schedule

The measurement schedule was set up and supervised by Jan Carlsson at Chalmers, and kept secret to the participants until the round robin was completed. Each participant was only informed of their allocated time slot, and to whom the test devices had to be send after completion of the measurements. The reason for this arrangement was that no participant should have access to results beforehand.

During the first measurement period the test devices were sent to the participating organisations in the following order:

December 2004

Mo	Tu	We	Th	Fr	Sa	Su
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

January 2005

Mo	Tu	We	Th	Fr	Sa	Su
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

February 2005

Mo	Tu	We	Th	Fr	Sa	Su
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28						

March 2005

Mo	Tu	We	Th	Fr	Sa	Su
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

April 2005

Mo	Tu	We	Th	Fr	Sa	Su
				1	2	3
4	5	6	7	8	9	
11	12	13	14	15	16	
18	19	20	21	22	23	24
25	26	27	28	29	30	

May 2005

Mo	Tu	We	Th	Fr	Sa	Su
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

CHALMERS[1], SP, IMST, HUT, LEMA-EPFL, SATIMO, UOB, LU[2], Sony Ericsson[3]

Note 1: Chalmers measured once again during June 2005, to check that nothing had been modified in the test devices during the measurement period. Results from this investigation can be found in chapter 7.

Note 2: The University of Lund (LU, Sweden) was not able to measure during the allocated time period due to technical problems with their equipment.

Note 3: Sony Ericsson Mobile Communications (SES, Sweden) was delayed due to technical problems with their equipment. They were re-scheduled to the second measurement period.

Measurements during the second benchmarking period were conducted in the following order:

September 2005

M	T	W	T	F	S	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30		

October 2005

M	T	W	T	F	S	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	
31						

November 2005

M	T	W	T	F	S	S
	1	2	3	4	5	
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

December 2005

M	T	W	T	F	S	S
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

SATIMO[1], RENNES, SONY-ERICSSON[2], BenQ, VTT[3]

Note 1: Satimo performed a complete re-measurement. Satimo have stated the following reasons for erroneous results in the first measurement round: *"The major inaccuracies were coming from the calibration data file of our reference horn which was corrupted during the first measurement of ACE antennas. The minor inaccuracies were coming from the calibration of our probe array. This calibration is performed every year and was a bit old when we have measured the first benchmarking".*

On 20th September Satimo reported that the special 1.785 GHz active device was damaged. Since it couldn't be repaired it had to be removed from the remaining part of the benchmarking.

Note 2: On 28th October Sony Ericsson Mobile Communications (SES, Sweden) reported that the dipole holder on the lossy cylinder was damaged when the devices arrived. This meant that they were not able to measure the cases of dipoles close to the lossy cylinder. After completed measurements the devices were sent to BenQ since they couldn't measure the lossy cylinder in any case.

Note 3: Due to the damaged holder on the lossy cylinder (see Note 2) the devices had to be returned to Chalmers for repair meaning that VTT was not able to perform their scheduled measurements. VTT will have the opportunity to measure in the next coming ACE.

Note 4: Chalmers measured once again during December 2005, to check that nothing had been modified in the test devices during the measurement period and that the repaired lossy cylinder gave the same results as before. Results from this investigation can be found in chapter 7.

3 Test devices

All test devices for the benchmarking were collected in a suitcase, Fig. 3.1. The suitcase is padded with foam, so that it is possible to send it as a normal package without any special arrangements to protect the different devices. In addition, two CD-ROMs are included in the kit that was sent around, which contain the documentation necessary for handling of the devices, the description of the different test cases and templates for reporting of results.

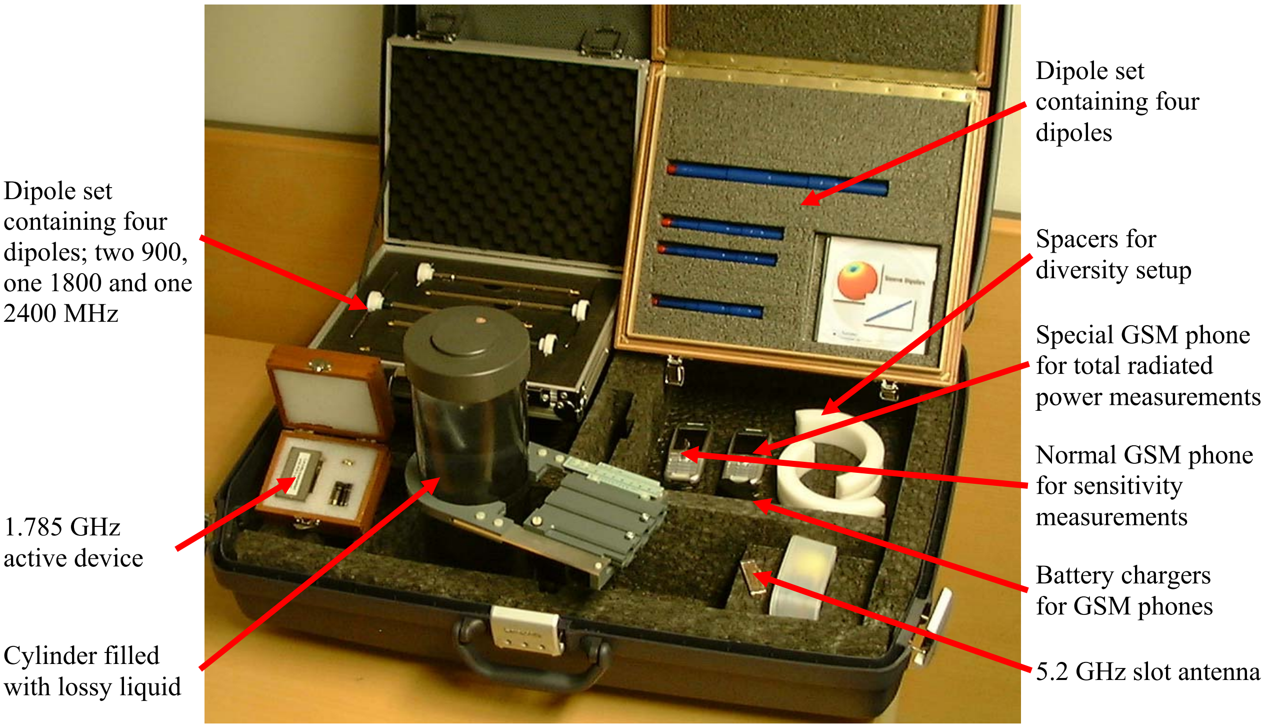

Fig. 3.1. The suitcase containing all test equipment.

Table 3.1 lists the test devices and their identification numbers. A complete list of contents of the test kit is available in Annex I, while detailed handling instructions for the test devices can be found in Annex II (reference [1]).

Description	Purpose	Identification	Supplied by
900 MHz dipole	Efficiency, diversity	Id. 8.9	Bluetest AB
900 MHz dipole		Id. 10.9	
1800 MHz dipole	Efficiency	Id. 8.18	
2400 MHz dipole		Id. 8.24	
Sealed plastic cylinder containing lossy liquid	Control of efficiency for dipoles	-	
900 MHz dipole	Reference, supplied as a courtesy	Id. 900-16	SATIMO
1800 MHz dipole		Id. 1800-13	
1900 MHz dipole		Id. 1900-14	
2450 MHz dipole		Id. 2450-13	
Special GSM phone	Total radiated power	IMEI 35441600-275762-3	Sony Ericsson Mobile Communications AB
Standard GSM phone	Total isotropic sensitivity	IMEI 35441600-275764-9	
1.785 GHz active device	Total radiated power, efficiency	-	LEMA-EPFL
5.2 GHz slot antenna	Efficiency, gain	-	University of Bristol

Table 3.1. Test devices included in the test kit.

The organisations that supplied the necessary devices for the test kit are gratefully acknowledged.

4 Test cases

Detailed descriptions of the test cases are together with priorities given in Annex III (reference [2]). For convenience, a brief description is also included in the following section.

4.1 Efficiency

Efficiency measurement test cases were defined for three dipoles and one slot antenna. For the dipoles, test setups in free space and close to the lossy cylinder were defined, while the slot antenna was only measured in free space. However, for the slot antenna both efficiency and peak gain should be measured.

The test setup for the dipole close to the lossy cylinder is shown in Fig. 4.1.1, and the defined test cases are summarized in Table 4.1.1. For each test case both the radiation efficiency and the total radiation efficiency (see definition below) should be measured at five discrete frequencies centred on the free space resonance of the dipoles.

The *radiation efficiency* is here defined as the ratio of the radiated power to the net power delivered to the antenna. The *total radiation efficiency* is defined as the ratio of the radiated power to the maximum available power from a 50 ohm source. Thus, this includes losses in the antenna itself, losses in the near-in environment of the antenna, and impedance mismatch. The definitions are given by:

$$\begin{cases} Radiation\ Efficiency = \dfrac{P_{rad}}{P_{in}} \\ Total\ Radiation\ Efficiency = \dfrac{P_{rad}}{P_{\max}} = \left(1-\left|S_{11}\right|^2\right)\dfrac{P_{rad}}{P_{in}} \end{cases}$$

Fig. 4.1.1. Test setup for efficiency measurement – Single dipole close to lossy cylinder.

Dipole	Free space					20 mm between dipole & cyl.					10 mm between dipole & cyl.				
Id. 8.9	800	850	900	950	1000	800	850	900	950	1000	800	850	900	950	1000
Id. 8.18	1700	1750	1800	1850	1900	1700	1750	1800	1850	1900	1700	1750	1800	1850	1900
Id. 8.24	2300	2350	2400	2450	2500	2300	2350	2400	2450	2500	2300	2350	2400	2450	2500

Highest priority	2nd highest priority	Lowest priority

Table 4.1.1. Test cases for dipoles. Frequencies in MHz.

4.2 Diversity

Since diversity measurements normally are quite time consuming, only one test case was defined. The test setup consists of two dipoles mounted at specified distances from the cylinder and from each other as described in [1], see also Fig. 4.2.1. The parameters considered for the measurements were the *effective, actual* and *apparent diversity gains* at 900 MHz and at a cumulative probability level (CDF) of 1 % when selection combining is used. The environment is assumed to be isotropic, i.e. equal probability for all angles of arrival.

By *effective diversity gain* we mean here the gain relative to what is obtained by using a separate single antenna with 0 dB radiation efficiency, i.e. compared to an ideal reference in free space. *Actual diversity gain* is defined as the gain relative to a single dipole placed close to the cylinder and *apparent diversity gain* is defined as relative to the strongest branch. These definitions can be found in references [3], [4] and [5].

Fig. 4.2.1. Test setup for diversity gain measurement – Two dipoles close to lossy cylinder.

The dipole with identification number 8.9 is the one in the centre and is also used as the reference for effective and actual diversity gain measurements. The other dipole has the identification number 10.9.

4.3 Total radiated power

Total radiated power (TRP) should be measured for a special triple band GSM phone and the specially designed active device radiating at 1.785 GHz. Measurements should be done for free space conditions. In the case of the GSM phone, measurements were also performed for a talk position close to a head phantom. The head phantom and the talk position “cheek right” that should be used are in agreement with what is described in [6]. The idea behind the use of the head phantom was to get a measure of the variations between different laboratories due to the use of different phantoms and the positioning of the phone by different operators.

The TRP is defined as the integral of the power transmitted in different directions over the entire radiation sphere, [7]. For the GSM phone the power level should be determined as the average of the samples over the 147 useful bits, i.e. the useful part, of the GSM pulse, [8]. A special GSM phone, with identification IMEI 35441600-275762-3, was used for the TRP measurements.

The test cases are summarized in Table 4.3.1.

Device	**Free space**			**Head phantom**		
Special GSM phone	880.2	897	914.8	880.2	897	914.8
	1710.2	1747	1784.8	1710.2	1747	1784.8
	1850.2	1880	1909.8	1850.2	1880	1909.8
Special active device	TRP @ 1785		Eff. @ 1785			

Highest priority	2nd highest priority	Lowest priority

Table 4.3.1. Test cases for total radiated power. Frequencies in MHz.

4.4 Total isotropic sensitivity

Sensitivity measurements should be done for a standard triple band GSM phone in free space and in a talk position close to a head phantom. Again, the head phantom and the talk position "cheek right" should be considered. Since the phone used for these measurements is a standard GSM phone, a base station simulator is needed.

The sensitivity level to be measured is defined as the total isotropic sensitivity at a BER of 2.4 % (± 0.1 %), see [7] and [9]. The standard GSM phone with identification IMEI 35441600-275764-9 should be used for the sensitivity measurements.

The test cases are summarized in Table 4.4.1.

Device	Free space	Head phantom
GSM phone	897	897
	1747	1747
	1880	1880

Highest priority	2nd highest priority	Lowest priority

Table 4.4.1. Test cases for total isotropic sensitivity. Frequencies in MHz.

5 Methods of measurements

In the following the methods of measurements used by the participants are briefly described. For further information contact the responsible person at the participating organisation as given in Table 2.1. More detailed descriptions of the different methods used can also be found in [10].

5.1 CHALMERS

Measurements were done in a reverberation chamber with dimension 0.8 m by 1.0 m by 1.6 m equipped with two plate stirrers, platform stirring and three orthogonal wall mounted antennas, Fig. 5.1.1. In addition frequency stirring was used.

The claimed uncertainties are given in Table 5.1.1.

Test case	Total expanded uncertainty, 2σ (dB)
Efficiency, 900 MHz	1
Efficiency, 1800 MHz	1
Efficiency, 2400 MHz	1
Efficiency, 5200 MHz	1
Diversity gain, 900 MHz	1
Peak gain, 5200 MHZ	-
TRP, 900 MHz	1
TRP, 1800 MHz	1
TRP, 1900 MHz	1
TIS, 900 MHz	-
TIS, 1800 MHz	-
TIS, 1900 MHz	-

Table 5.1.1. Claimed total expanded uncertainties - CHALMERS.

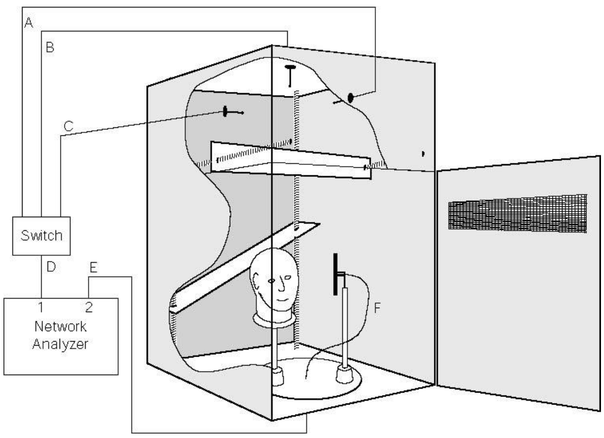

Fig. 5.1.1. Schematic drawing of the reverberation chamber used by CHALMERS.

5.2 IMST

Measurements were done in an anechoic chamber with dimension 12 m by 8 m by 5.5 m equipped with foam absorbers, which provide good absorption down to 400 MHz, Fig. 5.2.1.

The claimed uncertainties are given in Table 5.2.1.

Test case	Total expanded uncertainty, 2σ (dB)
Efficiency, 900 MHz	2
Efficiency, 1800 MHz	2
Efficiency, 2400 MHz	2
Efficiency, 5200 MHz	2
Diversity gain, 900 MHz	-
Peak gain, 5200 MHZ	2
TRP, 900 MHz	2
TRP, 1800 MHz	2
TRP, 1900 MHz	2
TIS, 900 MHz	2
TIS, 1800 MHz	2
TIS, 1900 MHz	2

Table 5.2.1. Claimed total expanded uncertainties – IMST.

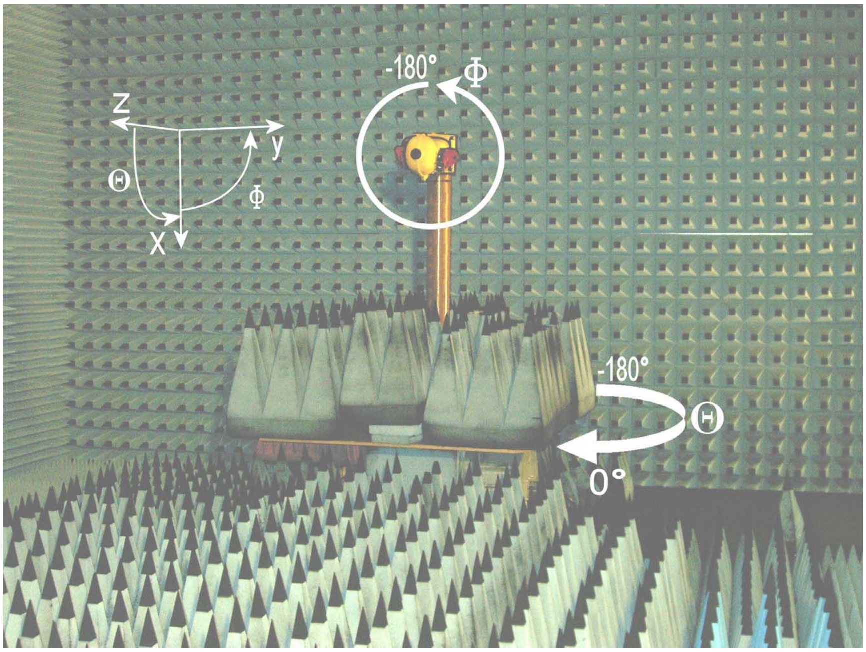

Fig. 5.2.1. Anechoic chamber used by IMST.

5.3 HUT

Measurements were done using the rapid antenna measurement system of TKK/Radiolab (experimental in-house system), Fig. 5.3.1. The total radiated power of the antenna under test (AUT) was determined by comparing the integrated 3-D radiation pattern of the AUT to that of the reference sleeve dipoles in free space (efficiency is known), i.e. the ratio of the integrated 3-D patterns yields the relative efficiency. With the known efficiency of the reference dipoles the total efficiency of the AUT was found. With the measured matching of the AUT its radiation efficiency was determined. For active devices the total radiated power was determined by comparing the integrated 3-D radiation pattern to that of a known radiator (output power and efficiency are known), i.e. the integrated 3-D pattern was used as a reference level for the total power.

The claimed uncertainties are given in Table 5.3.1.

Test case	Total expanded uncertainty, 2σ (dB)
Efficiency, 900 MHz	1
Efficiency, 1800 MHz	1
Efficiency, 2400 MHz	1
Efficiency, 5200 MHz	1
Diversity gain, 900 MHz	-
Peak gain, 5200 MHZ	1
TRP, 900 MHz	1
TRP, 1800 MHz	1
TRP, 1900 MHz	1
TIS, 900 MHz	-
TIS, 1800 MHz	-
TIS, 1900 MHz	-

Table 5.3.1. Claimed total expanded uncertainties – HUT.

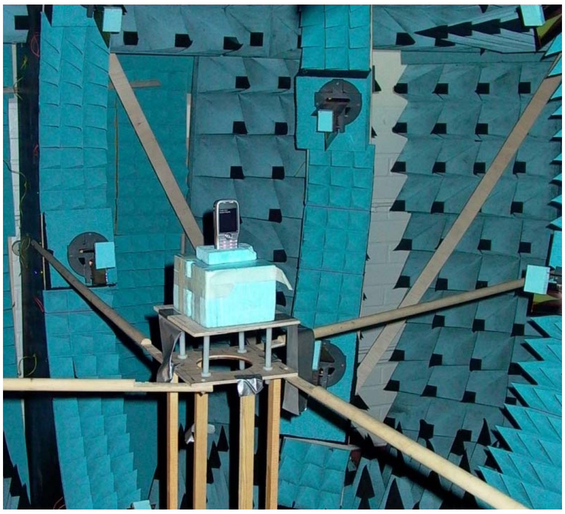

Fig. 5.3.1. The rapid antenna measurement system used by HUT.

5.4 LEMA-EPFL

Measurements were done using a random positioner system [11], Fig. 5.4.1. Efficiency for the slot antenna at 5.2 GHz was obtained by integrating the measured 3D pattern. A broadband reference was used as a reference.

The claimed uncertainties are given in Table 5.4.1.

Test case	Total expanded uncertainty, 2σ (dB)
Efficiency, 900 MHz	-
Efficiency, 1800 MHz	0.4
Efficiency, 2400 MHz	-
Efficiency, 5200 MHz	1
Diversity gain, 900 MHz	-
Peak gain, 5200 MHZ	1
TRP, 900 MHz	-
TRP, 1800 MHz	0.4
TRP, 1900 MHz	-
TIS, 900 MHz	-
TIS, 1800 MHz	-
TIS, 1900 MHz	-

Table 5.4.1. Claimed total expanded uncertainties – LEMA-EPFL.

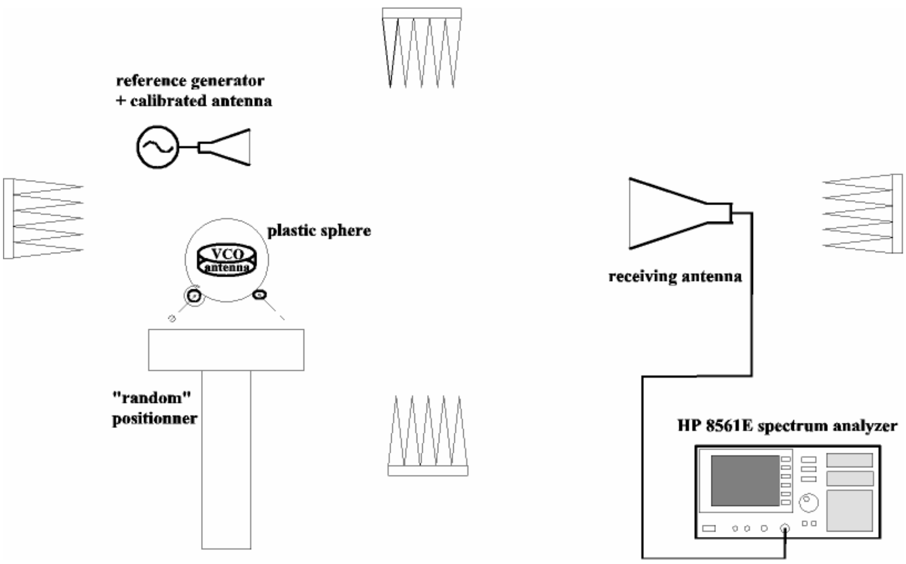

Fig. 5.4.1. Schematic drawing of the random positioner system used by LEMA-EPFL.

5.5 SATIMO

Measurements were done in a SATIMO STARGATE 64 spherical near field facility, Fig. 5.5.1.

The claimed uncertainties are given in Table 5.5.1.

Test case	Total expanded uncertainty, 2σ (dB)
Efficiency, 900 MHz	0.5
Efficiency, 1800 MHz	0.5
Efficiency, 2400 MHz	0.5
Efficiency, 5200 MHz	0.5
Diversity gain, 900 MHz	-
Peak gain, 5200 MHZ	0.5
TRP, 900 MHz	0.5
TRP, 1800 MHz	0.5
TRP, 1900 MHz	0.5
TIS, 900 MHz	-
TIS, 1800 MHz	-
TIS, 1900 MHz	-

Table 5.5.1. Claimed total expanded uncertainties – SATIMO.

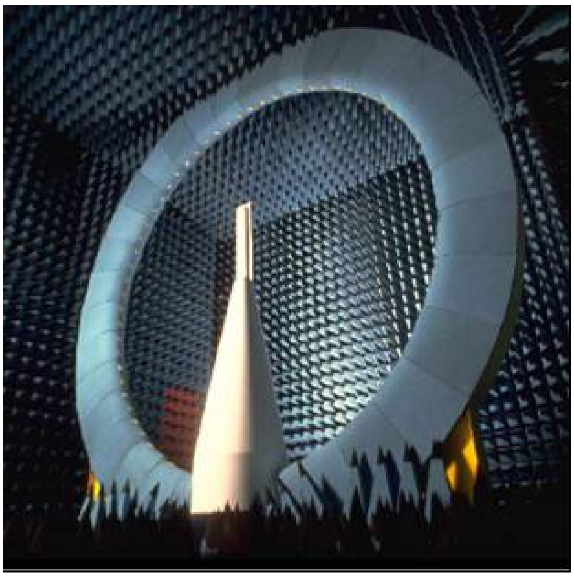

Fig. 5.5.1. The STARGATE 64 spherical near field facility used by SATIMO.

5.6 UoB

Efficiencies were obtained by measuring the full 3D patterns at the desired frequency. From this the maximum value of directivity is determined. Then the gain is obtained by using a sliding range method [12]. Using the relationship $G = \eta D$ (η being efficiency), η is determined.

The claimed uncertainties are given in Table 5.6.1.

Test case	Total expanded uncertainty, 2σ (dB)
Efficiency, 900 MHz	-
Efficiency, 1800 MHz	0.2
Efficiency, 2400 MHz	-
Efficiency, 5200 MHz	0.2
Diversity gain, 900 MHz	-
Peak gain, 5200 MHZ	0.2
TRP, 900 MHz	0.2
TRP, 1800 MHz	0.3
TRP, 1900 MHz	0.05
TIS, 900 MHz	-
TIS, 1800 MHz	-
TIS, 1900 MHz	-

Table 5.6.1. Claimed total expanded uncertainties – UoB.

5.7 SP

Measurements were done in a reverberation chamber with dimension 2.48 m by 3.07 m by 2.45 m equipped with a rotating mechanical stirrer, platform stirring and three orthogonal wall mounted antennas, Fig. 5.7.1. In addition frequency stirring was used.

The claimed uncertainties are given in Table 5.7.1.

Test case	Total expanded uncertainty, 2σ (dB)
Efficiency, 900 MHz	0.6
Efficiency, 1800 MHz	0.6
Efficiency, 2400 MHz	0.6
Efficiency, 5200 MHz	0.6
Diversity gain, 900 MHz	-
Peak gain, 5200 MHZ	-
TRP, 900 MHz	0.8
TRP, 1800 MHz	0.8
TRP, 1900 MHz	0.8
TIS, 900 MHz	-
TIS, 1800 MHz	-
TIS, 1900 MHz	-

Table 5.7.1. Claimed total expanded uncertainties – SP.

Fig. 5.7.1. Reverberation chamber used by SP.

5.8 IETR

Measurements were done in a reverberation chamber equipped with a rotating mechanical stirrer, Fig. 5.8.1.

The claimed uncertainties are given in Table 5.8.1.

Test case	Total expanded uncertainty, 2σ (dB)
Efficiency, 900 MHz	0.5
Efficiency, 1800 MHz	0.5
Efficiency, 2400 MHz	0.5
Efficiency, 5200 MHz	0.5
Diversity gain, 900 MHz	0.5
Peak gain, 5200 MHZ	-
TRP, 900 MHz	-
TRP, 1800 MHz	-
TRP, 1900 MHz	-
TIS, 900 MHz	-
TIS, 1800 MHz	-
TIS, 1900 MHz	-

Table 5.8.1. Claimed total expanded uncertainties – IETR.

Fig. 5.8.1. Reverberation chamber used by IETR.

5.9 SES

All measurements except TIS were done in a scattered field chamber, Fig. 5.9.1. TIS measurements were done in an anechoic chamber.

The claimed uncertainties are given in Table 5.9.1.

Test case	Total expanded uncertainty, 2σ (dB)
Efficiency, 900 MHz	0.5
Efficiency, 1800 MHz	0.5
Efficiency, 2400 MHz	0.5
Efficiency, 5200 MHz	-
Diversity gain, 900 MHz	-
Peak gain, 5200 MHZ	-
TRP, 900 MHz	0.5
TRP, 1800 MHz	0.5
TRP, 1900 MHz	0.5
TIS, 900 MHz	1
TIS, 1800 MHz	1
TIS, 1900 MHz	-

Table 5.9.1. Claimed total expanded uncertainties – SES.

Fig. 5.9.1. Scattered field chamber used by SES.

5.10 BenQ

Measurements were done using a calorimetric radiation efficiency measurement method after [13]. The power P_{acc} accepted by the antenna and the power P_{diss} dissipated in the antenna are measured and radiation efficiency calculated as $1 - P_{diss} / P_{acc} + K2$, where K2 is a correction term for power dissipated in the feed line. P_{acc} is measured using a 20 dB coupler and a power meter. P_{diss} is measured in a heat flow comparator, a thermally insulated box immersed into a constant temperature heat bath. The insulated box is pre-heated with a DC fed resistor. When RF power is supplied to the AUT the additional heat from the AUT is compensated for by reduction of DC power so as to keep temperature constant. The amount of reduction is equated to the dissipated power from the AUT. The known heat contribution from the feed line within the box is removed from the result by addition of $K2 = P_{diss,\ feed\text{-}line} / P_{acc}$ in the above equation. Accepted power is referred to the antenna port and frequency dependent values of S_{11} are included in the calculation of K2. Total radiation efficiency is calculated as $\eta = (1- |S_{11}|^2)\ \eta_{rad}$ using S_{11} data from an NWA measurement in the same environment.

The claimed uncertainties are given in Table 5.10.1.

Test case	Total expanded uncertainty, 2σ (dB)
Efficiency, 900 MHz	-
Efficiency, 1800 MHz	-
Efficiency, 2400 MHz	-
Efficiency, 5200 MHz	0.1
Diversity gain, 900 MHz	-
Peak gain, 5200 MHZ	-
TRP, 900 MHz	-
TRP, 1800 MHz	-
TRP, 1900 MHz	-
TIS, 900 MHz	-
TIS, 1800 MHz	-
TIS, 1900 MHz	-

Table 5.10.1. Claimed total expanded uncertainties – BenQ.

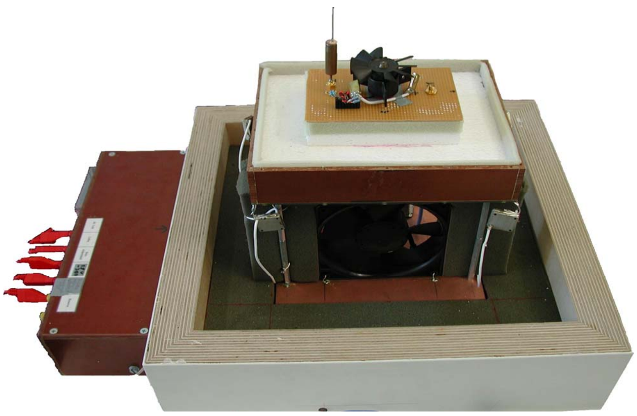

Fig. 5.10.1. Calorimetric measurement device used by BenQ.

6 Benchmarking results

The results from the benchmarking are presented in this chapter. The results from the control measurements performed by Chalmers after the completed benchmarking periods are together with results from the first measurements presented in Chapter 7.

Mean values presented in tables in this section is calculated from linear values and then converted to decibels. Red numbers in tables denote a deviation from mean value of more than the claimed expanded uncertainty as given in Chapter 5 for the various participants. It should be noted that the claimed uncertainties are different for different participants and also that the mean value is not necessarily the "true" value.

6.1 Radiation efficiency – 900 MHz dipole

The radiation efficiency for the 900 MHz dipole was measured by the participants as given in Table 6.1.1.

	Radiation Efficiency – Dipole & Cylinder		
	Free space	20 mm	10 mm
CHALMERS	X	X	X
IMST			
HUT	X		
EPFL			
SATIMO	X	X	X
UoB			
SP	X	X	
IETR	X	X	X
SES	X		
BenQ			

Table 6.1.1. Measured radiation efficiency for the 900 MHz dipole.

6.1.1 Free space

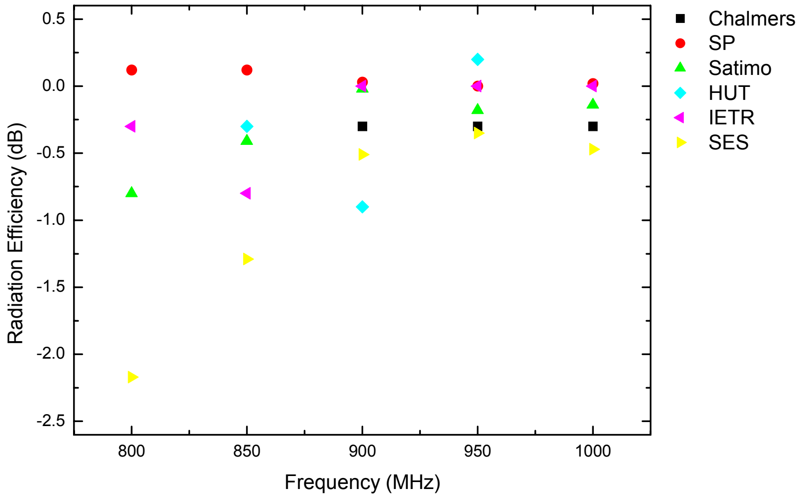

Fig. 6.1.1.1. Measured radiation efficiency for the 900 MHz dipole in free space.

		Frequency (MHz)				
		800	850	900	950	1000
	Mean (dB)	-0.71	-0.51	-0.27	-0.10	-0.17
Deviation from mean (dB)	CHALMERS	-	-	-0.03	-0.20	-0.13
	IMST					
	HUT	-	0.21	-0.63	0.30	-
	EPFL					
	SATIMO	-0.09	0.10	0.25	-0.08	0.03
	UoB					
	SP	0.83	0.63	0.30	0.10	0.19
	IETR	0.41	-0.29	0.27	0.10	0.17
	SES	-1.46	-0.78	-0.24	-0.25	-0.30
	BenQ					

Table 6.1.1.1. Deviation from mean radiation efficiency for the 900 MHz dipole in free space.

6.1.2 20 mm distance between dipole and cylinder

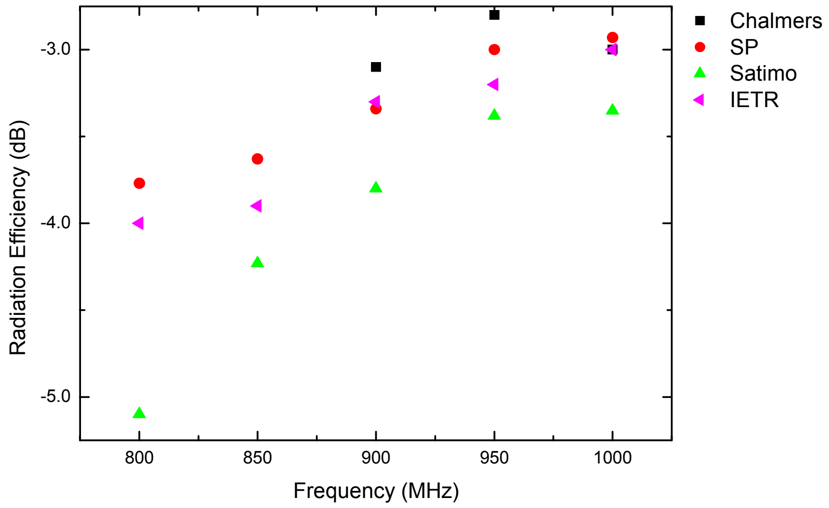

Fig. 6.1.2.1. Measured radiation efficiency for the 900 MHz dipole at a distance of 20 mm from the lossy cylinder.

		Frequency (MHz)				
		800	850	900	950	1000
	Mean (dB)	-4.25	-3.91	-3.38	-3.09	-3.07
Deviation from mean (dB)	CHALMERS	-	-	0.28	0.29	0.07
	IMST					
	HUT					
	EPFL					
	SATIMO	-0.85	-0.32	-0.42	-0.29	-0.28
	UoB					
	SP	0.48	0.28	0.04	0.09	0.14
	IETR	0.25	0.01	0.08	-0.11	0.07
	SES					
	BenQ					

Table 6.1.2.1. Deviation from mean radiation efficiency for the 900 MHz dipole at a distance of 20 mm from the lossy cylinder.

6.1.3 10 mm distance between dipole and cylinder

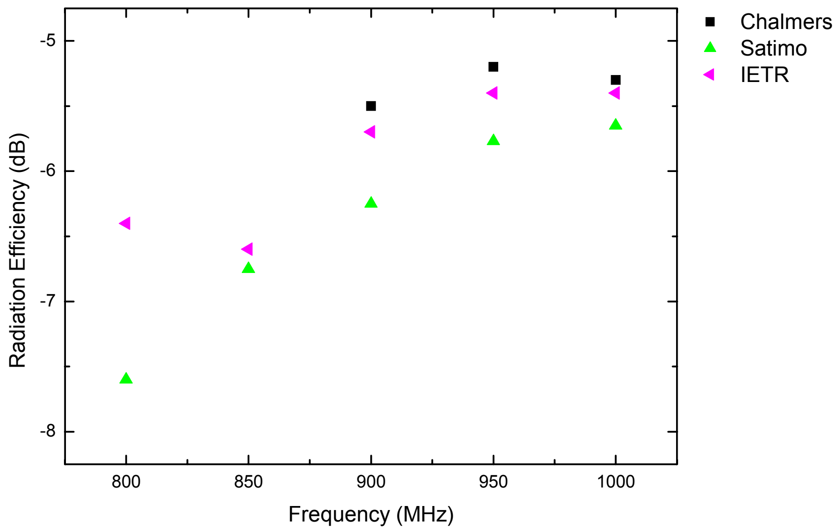

Fig. 6.1.3.1. Measured radiation efficiency for the 900 MHz dipole at a distance of 10 mm from the lossy cylinder.

		Frequency (MHz)				
		800	850	900	950	1000
	Mean (dB)	-6.96	-6.67	-5.81	-5.45	-5.45
Deviation from mean (dB)	CHALMERS	-	-	0.31	0.25	0.15
	IMST					
	HUT					
	EPFL					
	SATIMO	-0.64	-0.08	-0.44	-0.32	-0.20
	UoB					
	SP					
	IETR	0.56	0.07	0.11	0.05	0.05
	SES					
	BenQ					

Table 6.1.3.1. Deviation from mean radiation efficiency for the 900 MHz dipole at a distance of 10 mm from the lossy cylinder.

6.2 Total radiation efficiency – 900 MHz dipole

The total radiation efficiency for the 900 MHz dipole was measured by the participants as given in Table 6.2.1.

	Total Radiation Efficiency – Dipole & Cylinder		
	Free space	**20 mm**	**10 mm**
CHALMERS	X	X	X
IMST	X	X	X
HUT	X	X	X
EPFL			
SATIMO	X	X	X
UoB			
SP	X	X	
IETR	X	X	X
SES	X		
BenQ			

Table 6.2.1. Measured total radiation efficiency for the 900 MHz dipole.

6.2.1 Free space

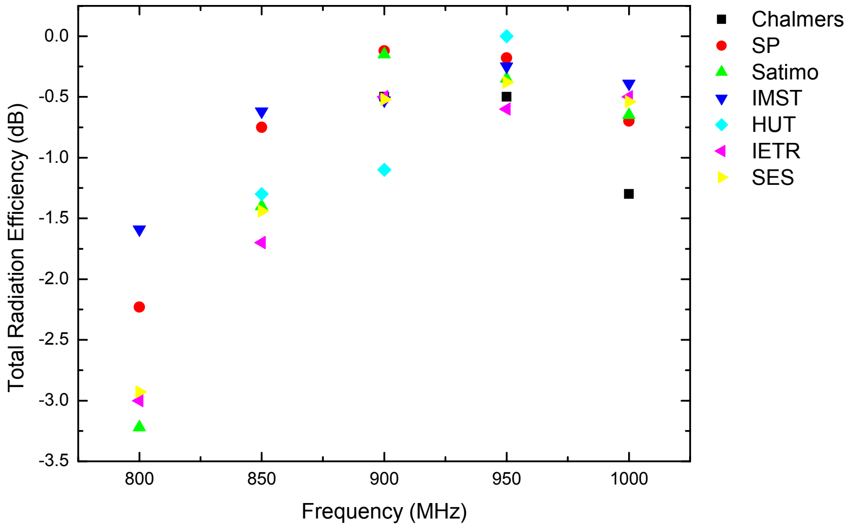

Fig. 6.2.1.1. Measured total radiation efficiency for the 900 MHz dipole in free space.

		Frequency (MHz)				
		800	850	900	950	1000
	Mean (dB)	-2.55	-1.18	-0.48	-0.32	-0.67
Deviation from mean (dB)	CHALMERS	-	-	-0.02	-0.18	-0.63
	IMST	0.96	0.56	-0.05	0.07	0.28
	HUT	-	-0.12	-0.62	0.32	-
	EPFL					
	SATIMO	-0.67	-0.22	0.33	-0.03	0.02
	UoB					
	SP	0.32	0.43	0.36	0.14	-0.03
	IETR	-0.45	-0.52	-0.02	-0.28	0.17
	SES	-0.38	-0.26	-0.04	-0.06	0.13
	BenQ					

Table 6.2.1.1. Deviation from mean total radiation efficiency for the 900 MHz dipole in free space.

6.2.2 20 mm distance between dipole and cylinder

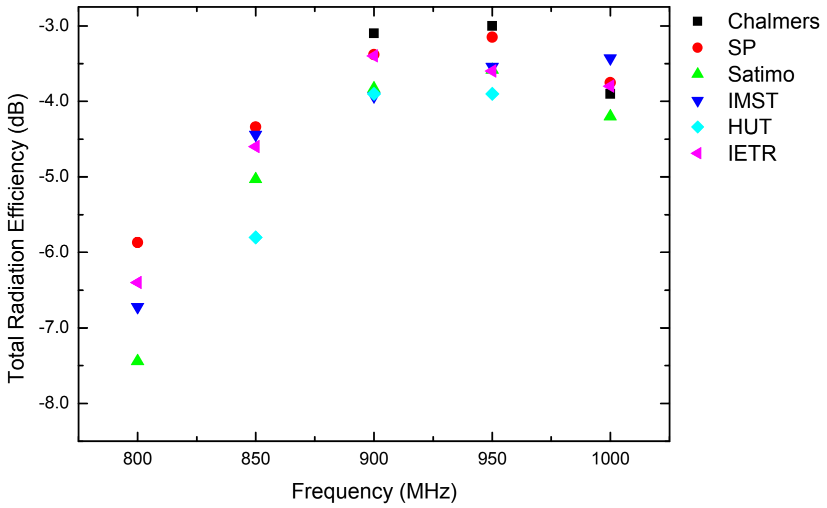

Fig. 6.2.2.1. Measured total radiation efficiency for the 900 MHz dipole at a distance of 20 mm from the lossy cylinder.

		Frequency (MHz)				
		800	850	900	950	1000
	Mean (dB)	-6.57	-4.81	-3.58	-3.45	-3.81
Deviation from mean (dB)	CHALMERS	-	-	0.48	0.45	-0.09
	IMST	-0.15	0.37	-0.35	-0.09	0.38
	HUT	-	-0.99	-0.32	-0.45	-
	EPFL					
	SATIMO	-0.87	-0.22	-0.25	-0.13	-0.39
	UoB					
	SP	0.70	0.47	0.20	0.30	0.06
	IETR	0.17	0.21	0.18	-0.15	0.01
	SES					
	BenQ					

Table 6.2.2.1. Deviation from mean total radiation efficiency for the 900 MHz dipole at a distance of 20 mm from the lossy cylinder.

6.2.3 10 mm distance between dipole and cylinder

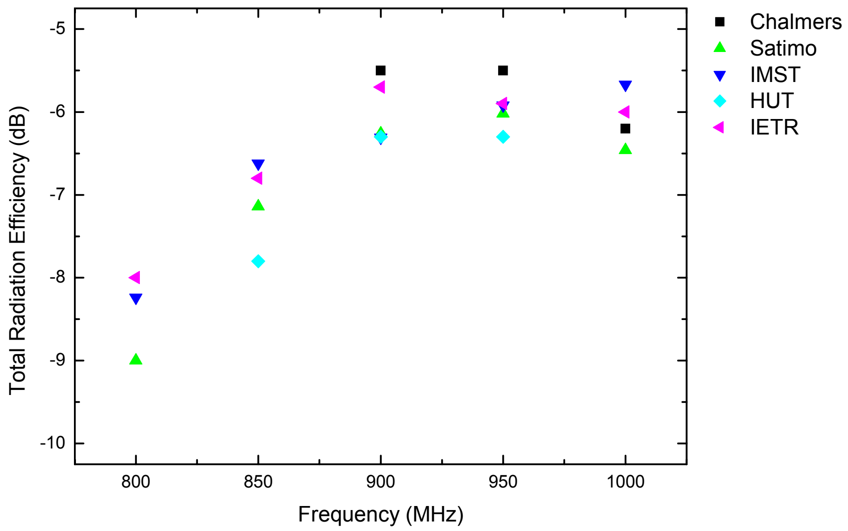

Fig. 6.2.3.1. Measured total radiation efficiency for the 900 MHz dipole at a distance of 10 mm from the lossy cylinder.

		Frequency (MHz)				
		800	850	900	950	1000
	Mean (dB)	-8.39	-7.07	-6.00	-5.92	-6.07
Deviation from mean (dB)	CHALMERS	-	-	0.50	0.42	-0.13
	IMST	0.15	0.45	-0.31	0.00	0.40
	HUT	-	-0.73	-0.30	-0.38	-
	EPFL					
	SATIMO	-0.61	-0.07	-0.26	-0.10	-0.39
	UoB					
	SP					
	IETR	0.39	0.27	0.30	0.02	0.07
	SES					
	BenQ					

Table 6.2.3.1. Deviation from mean total radiation efficiency for the 900 MHz dipole at a distance of 10 mm from the lossy cylinder.

6.3 Radiation efficiency – 1800 MHz dipole

The radiation efficiency for the 1800 MHz dipole was measured by the participants as given in Table 6.3.1.

	Radiation Efficiency – Dipole & Cylinder		
	Free space	20 mm	10 mm
CHALMERS	X	X	X
IMST			
HUT	X	X	X
EPFL			
SATIMO	X	X	X
UoB			
SP	X	X	
IETR	X	X	X
SES	X		
BenQ			

Table 6.3.1. Measured radiation efficiency for the 1800 MHz dipole.

6.3.1 Free space

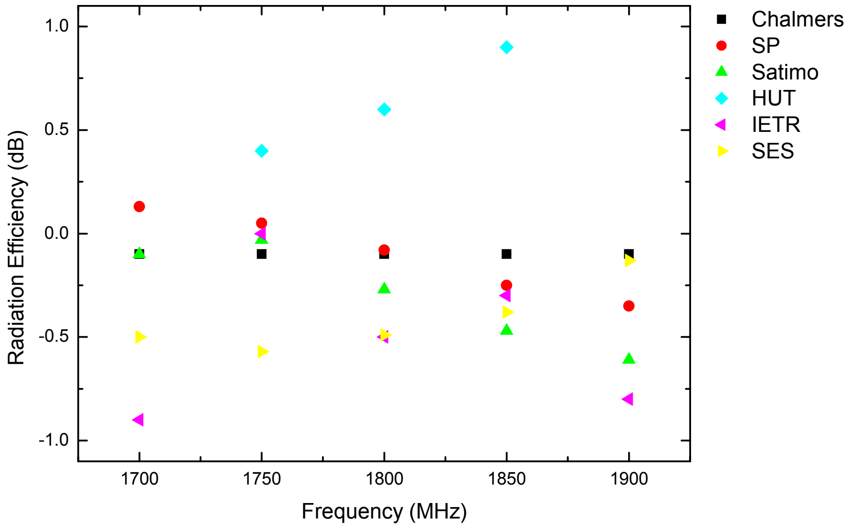

Fig. 6.3.1.1. Measured radiation efficiency for the 1800 MHz dipole in free space.

		Frequency (MHz)				
		1700	1750	1800	1850	1900
	Mean (dB)	-0.28	-0.03	-0.12	-0.07	-0.39
Deviation from mean (dB)	CHALMERS	0.18	-0.07	0.02	-0.03	0.29
	IMST					
	HUT	-	0.43	0.72	0.97	-
	EPFL					
	SATIMO	0.18	0.00	-0.15	-0.40	-0.22
	UoB					
	SP	0.41	0.08	0.04	-0.18	0.04
	IETR	-0.62	0.03	-0.38	-0.23	-0.41
	SES	-0.22	-0.54	-0.37	-0.31	0.26
	BenQ					

Table 6.3.1.1. Deviation from mean radiation efficiency for the 1800 MHz dipole in free space.

6.3.2 20 mm distance between dipole and cylinder

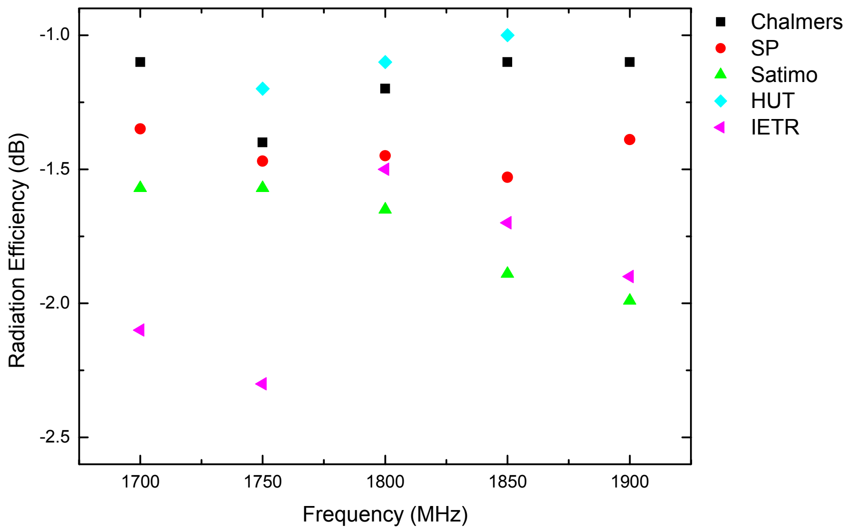

Fig. 6.3.2.1. Measured radiation efficiency for the 1800 MHz dipole at a distance of 20 mm from the lossy cylinder.

		Frequency (MHz)				
		1700	1750	1800	1850	1900
	Mean (dB)	-1.51	-1.57	-1.38	-1.43	-1.58
Deviation from mean (dB)	CHALMERS	0.41	0.17	0.18	0.33	0.48
	IMST					
	HUT	-	0.37	0.28	0.43	-
	EPFL					
	SATIMO	-0.06	0.00	-0.27	-0.46	-0.41
	UoB					
	SP	0.16	0.10	-0.07	-0.10	0.19
	IETR	-0.59	-0.73	-0.12	-0.27	-0.32
	SES					
	BenQ					

Table 6.3.2.1. Deviation from mean radiation efficiency for the 1800 MHz dipole at a distance of 20 mm from the lossy cylinder.

6.3.3 10 mm distance between dipole and cylinder

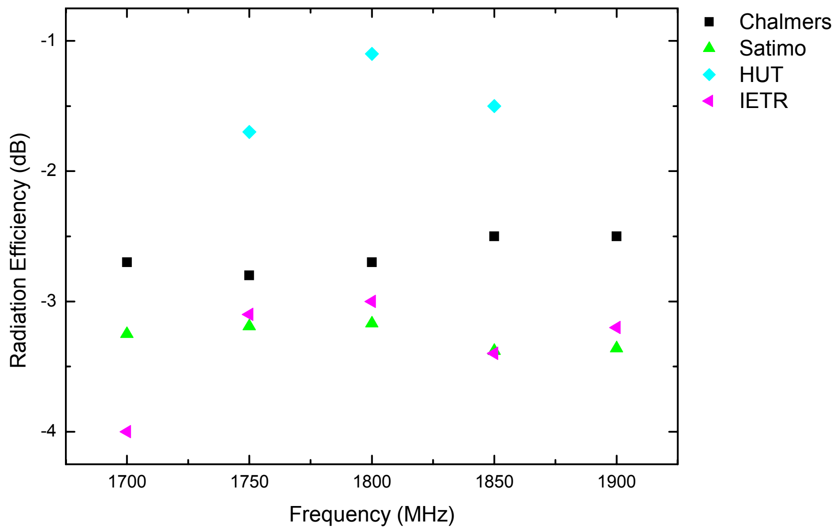

Fig. 6.3.3.1. Measured radiation efficiency for the 1800 MHz dipole at a distance of 10 mm from the lossy cylinder.

		Frequency (MHz)				
		1700	1750	1800	1850	1900
	Mean (dB)	-3.28	-2.66	-2.41	-2.62	-3.00
Deviation from mean (dB)	CHALMERS	0.58	-0.14	-0.29	0.12	0.50
	IMST					
	HUT	-	0.96	1.31	1.12	-
	EPFL					
	SATIMO	0.03	-0.53	-0.76	-0.76	-0.36
	UoB					
	SP					
	IETR	-0.72	-0.44	-0.59	-0.78	-0.20
	SES					
	BenQ					

Table 6.3.3.1. Deviation from mean radiation efficiency for the 1800 MHz dipole at a distance of 10 mm from the lossy cylinder.

6.4 Total radiation efficiency – 1800 MHz dipole

The total radiation efficiency for the 1800 MHz dipole was measured by the participants as given in Table 6.4.1.

	Total Radiation Efficiency – Dipole & Cylinder		
	Free space	**20 mm**	**10 mm**
CHALMERS	X	X	X
IMST	X	X	X
HUT	X	X	X
EPFL			
SATIMO	X	X	X
UoB			
SP	X	X	
IETR	X	X	X
SES	X		
BenQ			

Table 6.4.1. Measured total radiation efficiency for the 1800 MHz dipole.

6.4.1 Free space

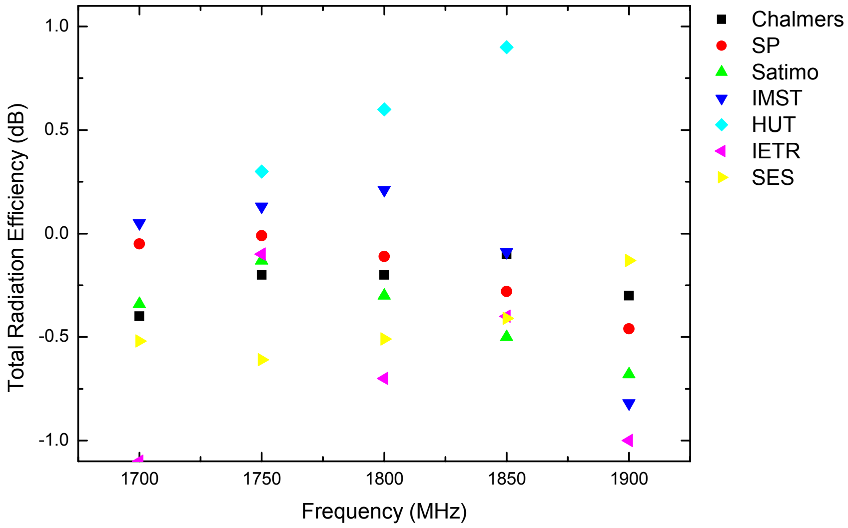

Fig. 6.4.1.1. Measured total radiation efficiency for the 1800 MHz dipole in free space.

		Frequency (MHz)				
		1700	1750	1800	1850	1900
	Mean (dB)	-0.38	-0.08	-0.13	-0.10	-0.55
Deviation from mean (dB)	CHALMERS	-0.02	-0.12	-0.07	0.00	0.25
	IMST	0.43	0.21	0.34	0.01	-0.27
	HUT	-	0.38	0.73	1.00	-
	EPFL					
	SATIMO	0.04	-0.05	-0.17	-0.40	-0.13
	UoB					
	SP	0.33	0.07	0.02	-0.18	0.09
	IETR	-0.72	-0.02	-0.57	-0.30	-0.45
	SES	-0.14	-0.53	-0.38	-0.31	0.42
	BenQ					

Table 6.4.1.1. Deviation from mean total radiation efficiency for the 1800 MHz dipole in free space.

6.4.2 20 mm distance between dipole and cylinder

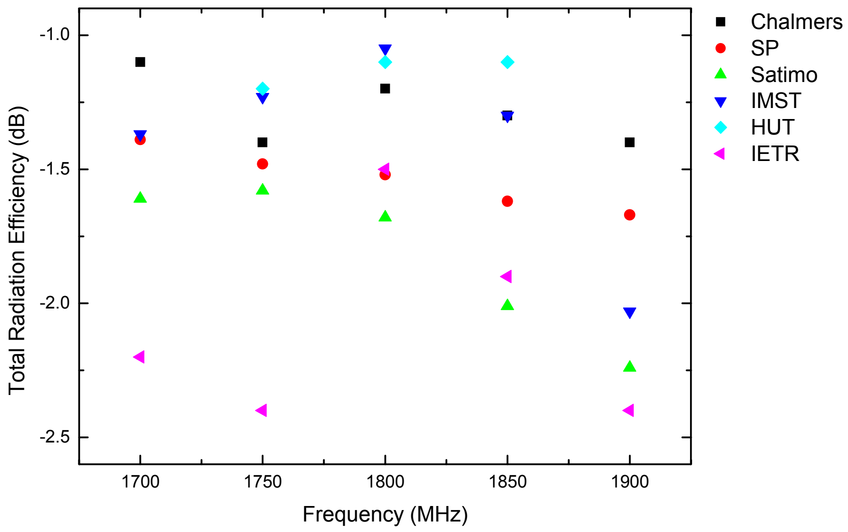

Fig. 6.4.2.1. Measured total radiation efficiency for the 1800 MHz dipole at a distance of 20 mm from the lossy cylinder.

		Frequency (MHz)				
		1700	1750	1800	1850	1900
	Mean (dB)	-1.52	-1.53	-1.34	-1.53	-1.93
Deviation from mean (dB)	CHALMERS	0.42	0.13	0.14	0.23	0.53
	IMST	0.15	0.30	0.29	0.23	-0.10
	HUT	-	0.33	0.24	0.43	-
	EPFL					
	SATIMO	-0.09	-0.05	-0.34	-0.48	-0.31
	UoB					
	SP	0.13	0.05	-0.18	-0.09	0.26
	IETR	-0.68	-0.87	-0.16	-0.37	-0.47
	SES					
	BenQ					

Table 6.4.2.1. Deviation from mean total radiation efficiency for the 1800 MHz dipole at a distance of 20 mm from the lossy cylinder.

6.4.3 10 mm distance between dipole and cylinder

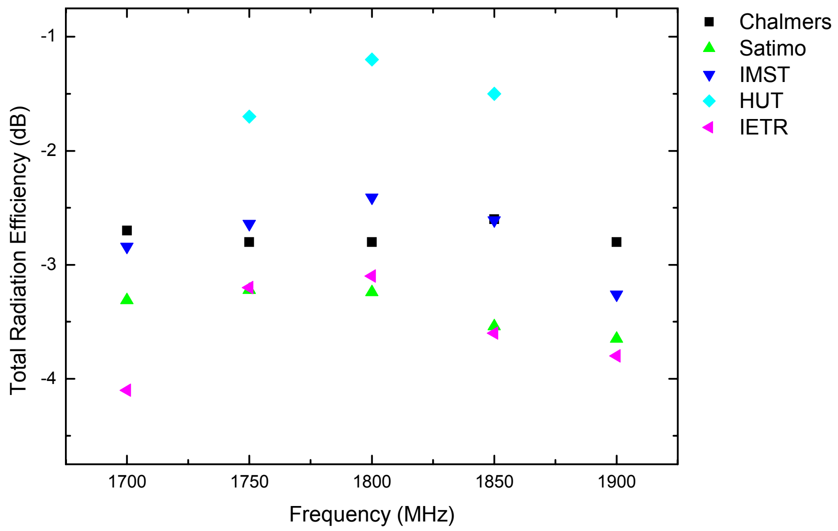

Fig. 6.4.3.1. Measured total radiation efficiency for the 1800 MHz dipole at a distance of 10 mm from the lossy cylinder.

		Frequency (MHz)				
		1700	1750	1800	1850	1900
	Mean (dB)	-3.20	-2.68	-2.48	-2.70	-3.36
Deviation from mean (dB)	CHALMERS	0.50	-0.12	-0.32	0.10	0.56
	IMST	0.36	0.04	0.07	0.09	0.10
	HUT	-	0.98	1.28	1.20	-
	EPFL					
	SATIMO	-0.11	-0.54	-0.76	-0.84	-0.29
	UoB					
	SP					
	IETR	-0.90	-0.52	-0.62	-0.90	-0.44
	SES					
	BenQ					

Table 6.4.3.1. Deviation from mean radiation efficiency for the 1800 MHz dipole at a distance of 10 mm from the lossy cylinder.

6.5 Radiation efficiency – 2400 MHz dipole

The radiation efficiency for the 2400 MHz dipole was measured by the participants as given in Table 6.5.1.

	Radiation Efficiency – Dipole & Cylinder		
	Free space	**20 mm**	**10 mm**
CHALMERS	X	X	X
IMST			
HUT	X	X	X
EPFL			
SATIMO	X	X	X
UoB			
SP	X	X	X
IETR	X	X	X
SES	X		
BenQ			

Table 6.5.1. Measured radiation efficiency for the 2400 MHz dipole.

6.5.1 Free space

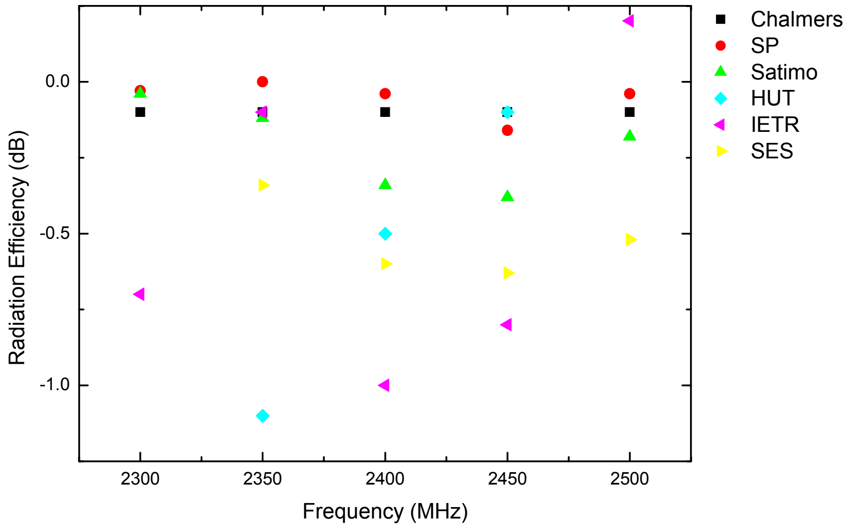

Fig. 6.5.1.1. Measured radiation efficiency for the 2400 MHz dipole in free space.

		Frequency (MHz)				
		2300	2350	2400	2450	2500
	Mean (dB)	-0.21	-0.28	-0.42	-0.35	-0.12
Deviation from mean (dB)	CHALMERS	0.11	0.18	0.32	0.25	0.02
	IMST					
	HUT	-	-0.82	-0.08	0.25	-
	EPFL					
	SATIMO	0.17	0.16	0.08	-0.03	-0.06
	UoB					
	SP	0.18	0.28	0.38	0.19	0.08
	IETR	-0.49	0.18	-0.58	-0.45	0.32
	SES	-	-0.06	-0.18	-0.28	-0.40
	BenQ					

Table 6.5.1.1. Deviation from mean radiation efficiency for the 2400 MHz dipole in free space.

6.5.2 20 mm distance between dipole and cylinder

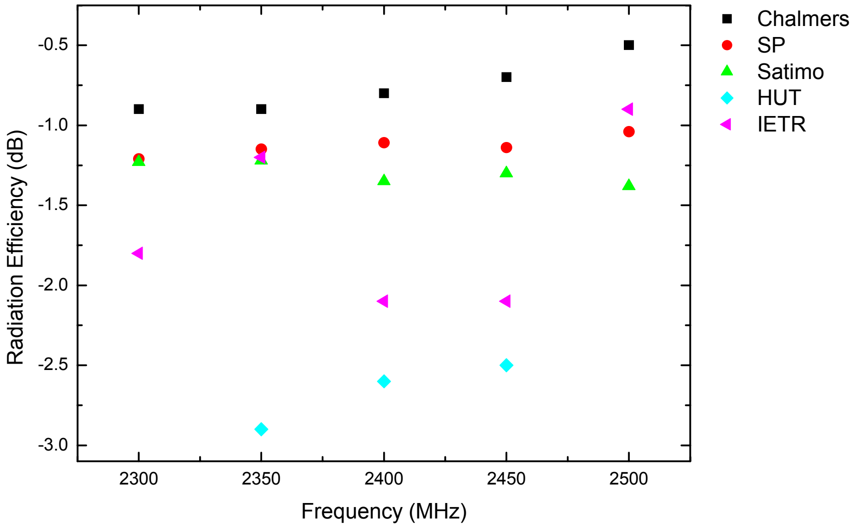

Fig. 6.5.2.1. Measured radiation efficiency for the 2400 MHz dipole at a distance of 20 mm from the lossy cylinder.

		Frequency (MHz)				
		2300	2350	2400	2450	2500
	Mean (dB)	-1.27	-1.42	-1.54	-1.50	-0.94
Deviation from mean (dB)	CHALMERS	0.37	0.52	0.74	0.80	0.44
	IMST					
	HUT	-	-1.48	-1.06	-1.00	-
	EPFL					
	SATIMO	0.04	0.20	0.19	0.20	-0.44
	UoB					
	SP	0.06	0.27	0.43	0.36	-0.10
	IETR	-0.53	0.22	-0.56	-0.60	0.04
	SES					
	BenQ					

Table 6.5.2.1. Deviation from mean radiation efficiency for the 2400 MHz dipole at a distance of 20 mm from the lossy cylinder.

6.5.3 10 mm distance between dipole and cylinder

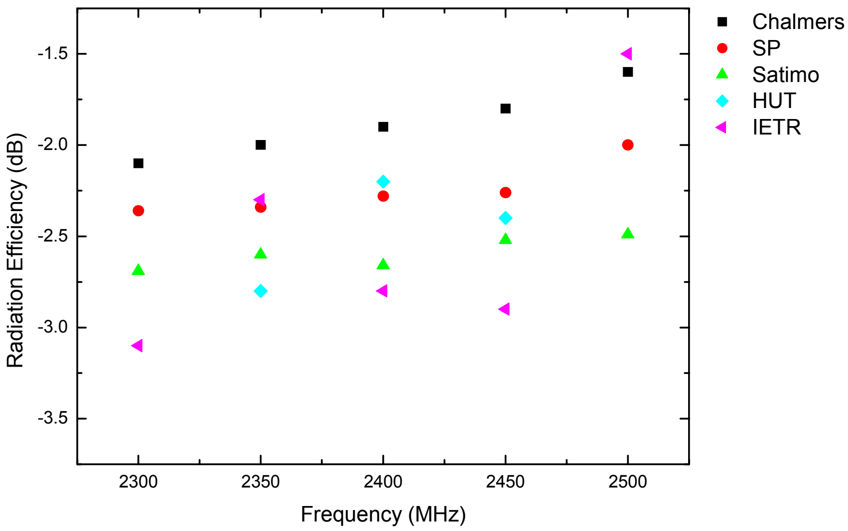

Fig. 6.5.3.1. Measured radiation efficiency for the 2400 MHz dipole at a distance of 10 mm from the lossy cylinder.

		Frequency (MHz)				
		2300	2350	2400	2450	2500
	Mean (dB)	-2.55	-2.40	-2.36	-2.36	-1.88
Deviation from mean (dB)	CHALMERS	0.45	0.40	0.46	0.56	0.28
	IMST					
	HUT	-	-0.40	0.16	-0.04	-
	EPFL					
	SATIMO	-0.14	-0.20	-0.30	-0.16	-0.61
	UoB					
	SP	0.19	0.06	0.08	0.10	-0.12
	IETR	-0.55	0.10	-0.44	-0.54	0.38
	SES					
	BenQ					

Table 6.5.3.1. Deviation from mean radiation efficiency for the 2400 MHz dipole at a distance of 10 mm from the lossy cylinder.

6.6 Total radiation efficiency – 2400 MHz dipole

The total radiation efficiency for the 2400 MHz dipole was measured by the participants as given in Table 6.6.1.

	Total Radiation Efficiency – Dipole & Cylinder		
	Free space	**20 mm**	**10 mm**
CHALMERS	X	X	X
IMST		X	X
HUT	X	X	X
EPFL			
SATIMO	X	X	X
UoB			
SP	X	X	X
IETR	X	X	X
SES	X		
BenQ			

Table 6.6.1. Measured total radiation efficiency for the 2400 MHz dipole.

6.6.1 Free space

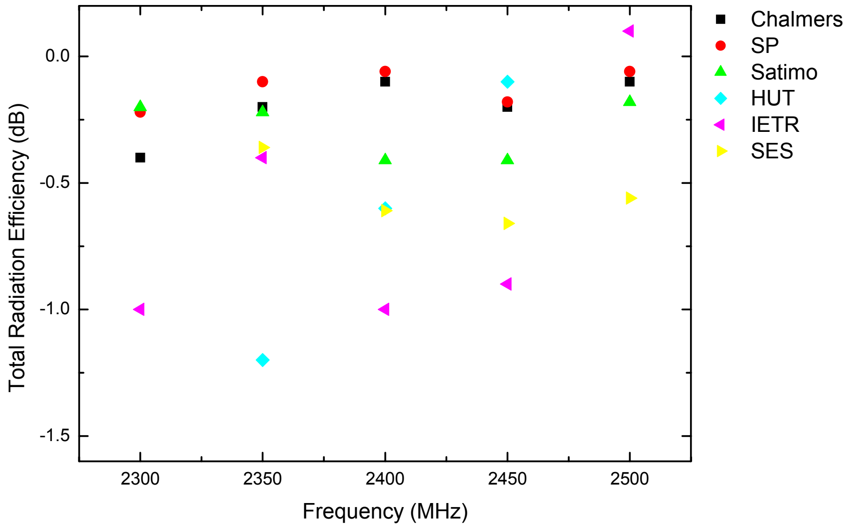

Fig. 6.6.1.1. Measured total radiation efficiency for the 2400 MHz dipole in free space.

		Frequency (MHz)				
		2300	2350	2400	2450	2500
	Mean (dB)	-0.44	-0.40	-0.45	-0.40	-0.15
Deviation from mean (dB)	CHALMERS	0.04	0.20	0.35	0.20	0.05
	IMST					
	HUT	-	-0.80	-0.15	0.30	-
	EPFL					
	SATIMO	0.24	0.18	0.04	-0.01	-0.03
	UoB					
	SP	0.22	0.30	0.39	0.22	0.09
	IETR	-0.56	0.00	-0.55	-0.50	0.25
	SES	-	0.04	-0.16	-0.26	-0.41
	BenQ					

Table 6.6.1.1. Deviation from mean total radiation efficiency for the 2400 MHz dipole in free space.

6.6.2 20 mm distance between dipole and cylinder

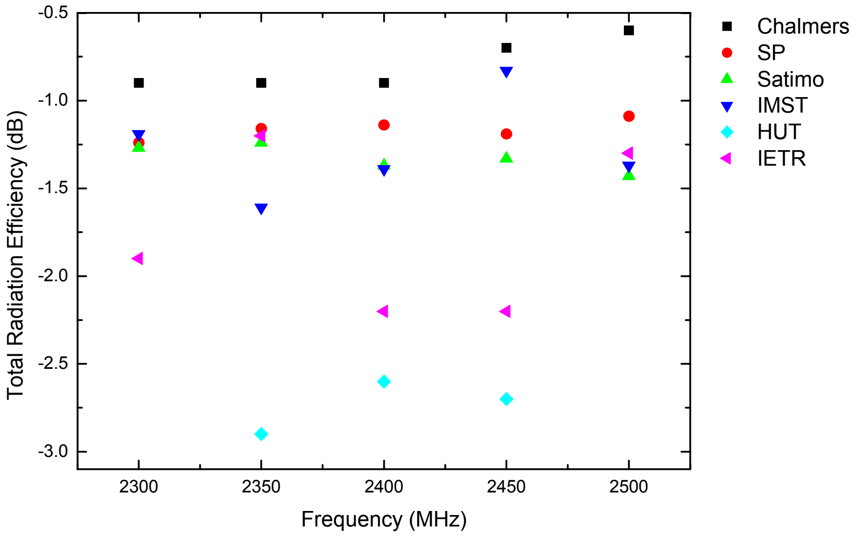

Fig. 6.6.2.1. Measured total radiation efficiency for the 2400 MHz dipole at a distance of 20 mm from the lossy cylinder.

		Frequency (MHz)				
		2300	2350	2400	2450	2500
	Mean (dB)	-1.29	-1.46	-1.56	-1.43	-1.15
Deviation from mean (dB)	CHALMERS	0.39	0.56	0.66	0.73	0.55
	IMST	0.10	-0.15	0.17	0.60	-0.22
	HUT	-	-1.44	-1.04	-1.27	-
	EPFL					
	SATIMO	0.02	0.22	0.19	0.10	-0.28
	UoB					
	SP	0.05	0.30	0.42	0.24	0.06
	IETR	-0.61	0.26	-0.64	-0.77	-0.15
	SES					
	BenQ					

Table 6.6.2.1. Deviation from mean total radiation efficiency for the 2400 MHz dipole at a distance of 20 mm from the lossy cylinder.

6.6.3 10 mm distance between dipole and cylinder

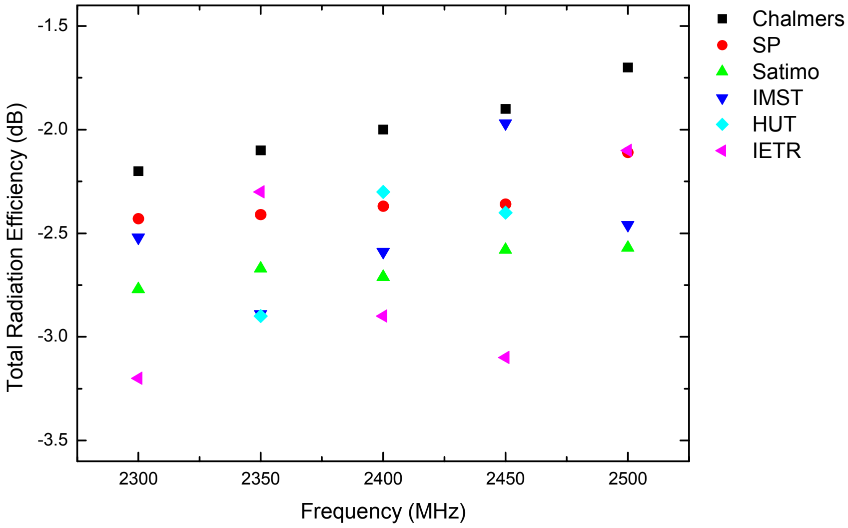

Fig. 6.6.3.1. Measured total radiation efficiency for the 2400 MHz dipole at a distance of 10 mm from the lossy cylinder.

		Frequency (MHz)				
		2300	2350	2400	2450	2500
	Mean (dB)	-2.61	-2.53	-2.47	-2.37	-2.18
Deviation from mean (dB)	CHALMERS	0.41	0.43	0.47	0.47	0.48
	IMST	0.09	-0.36	-0.12	0.40	-0.28
	HUT	-	-0.37	0.17	-0.03	-
	EPFL					
	SATIMO	-0.16	-0.14	-0.24	-0.21	-0.39
	UoB					
	SP	0.18	0.12	0.10	0.01	0.07
	IETR	-0.59	0.23	-0.43	-0.73	0.08
	SES					
	BenQ					

Table 6.6.3.1. Deviation from mean total radiation efficiency for the 2400 MHz dipole at a distance of 10 mm from the lossy cylinder.

6.7 Radiation efficiency – 5.2 GHz slot antenna

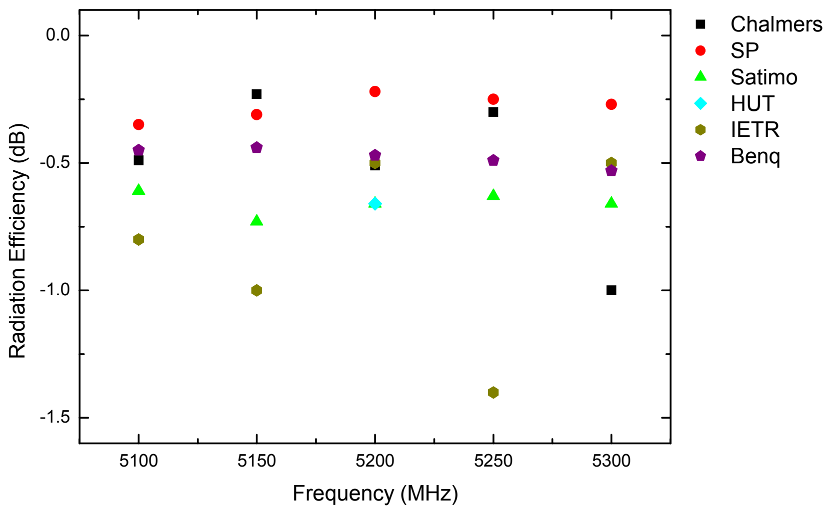

Fig. 6.7.1. Measured radiation efficiency for the 5.2 GHz slot antenna in free space.

		Frequency (MHz)				
		5100	5150	5200	5250	5300
	Mean (dB)	-0.54	-0.53	-0.50	-0.59	-0.59
Deviation from mean (dB)	CHALMERS	0.05	0.30	-0.01	0.29	-0.41
	IMST					
	HUT	-	-	-0.16	-	-
	EPFL					
	SATIMO	-0.07	-0.20	-0.16	-0.04	-0.07
	UoB					
	SP	0.19	0.22	0.28	0.34	0.32
	IETR	-0.26	-0.47	0.00	-0.81	0.09
	SES					
	BenQ	0.09	0.09	0.03	0.10	0.06

Table 6.7.1. Deviation from mean radiation efficiency for the 5.2 GHz slot antenna in free space.

Note 1: Chalmers measurements done in December 2005.

6.8 Total radiation efficiency – 5.2 GHz slot antenna

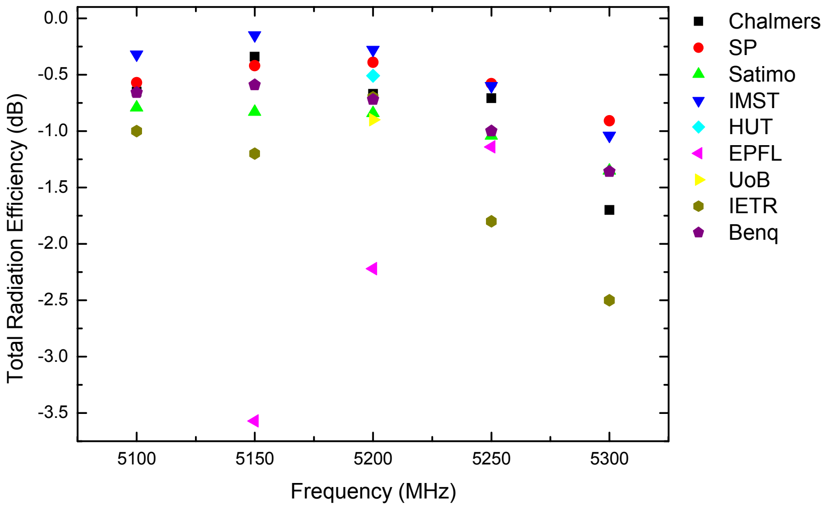

Fig. 6.8.1. Measured total radiation efficiency for the 5.2 GHz slot antenna in free space.

		Frequency (MHz)				
		5100	5150	5200	5250	5300
	Mean (dB)	-0.66	-0.90	-0.77	-0.96	-1.45
Deviation from mean (dB)	CHALMERS	0.01	0.56	0.10	0.25	-0.25
	IMST	0.34	0.75	0.49	0.36	0.41
	HUT	-	-	0.26	-	-
	EPFL	-	-2.67	-1.45	-0.18	-
	SATIMO	-0.13	0.07	-0.07	-0.08	0.10
	UoB	-	-	-0.13	-	-
	SP	0.09	0.48	0.38	0.38	0.54
	IETR	-0.34	-0.30	0.07	-0.84	-1.05
	SES					
	BenQ	0.00	0.31	0.05	-0.04	0.09

Table 6.8.1. Deviation from mean total radiation efficiency for the 5.2 GHz slot antenna in free space.

Note 1: Chalmers measurements done in December 2005.

6.9 Peak gain – 5.2 GHz slot antenna

	Peak gain (dBi)
CHALMERS	-
IMST	5.7
HUT	4.8
EPFL	4.8
SATIMO	4.15
UoB	6.4
SP	-
IETR	-
SES	-
BenQ	-

Table 6.9.1. Measured peak gain for the 5.2 GHz slot antenna in free space.

6.10 Diversity gain – Two dipoles close to lossy cylinder

	Effective gain (dB)	**Actual gain (dB)**	**Apparent gain (dB)**
CHALMERS	3.50	7.45	8.73
IMST	-	-	-
HUT	-	-	-
EPFL	-	-	-
SATIMO	-	-	-
UoB	-	-	-
SP	-	-	-
IETR	6.8	7.7	9.9
SES	-	-	-
BenQ	-	-	-

Table 6.10.1. Measured diversity gain for two 900 MHz dipoles close to lossy cylinder.

6.11 Total radiated power – GSM phone 900 MHz band

6.11.1 Free space

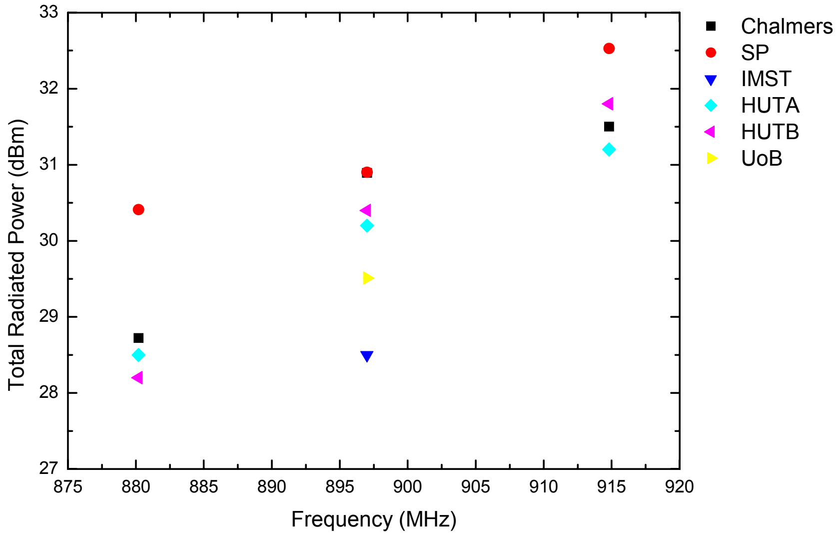

Fig. 6.11.1.1. Measured total radiated power for the special GSM phone in free space – 900 MHz band.

Note 1: HUTA and HUTB denote measurements by HUT using two different reference antennas, respectively.

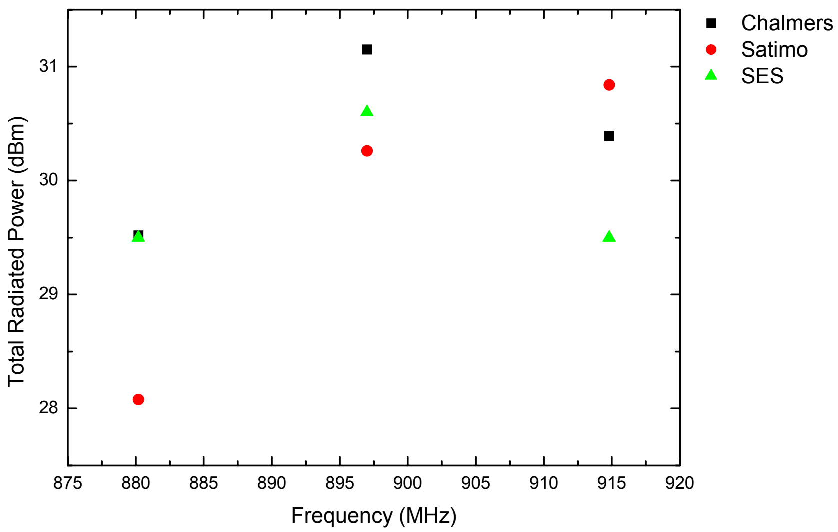

*Fig. 6.11.1.2. Measured total radiated power for the standard GSM phone (*IMEI 35441600-275764-9*) in free space – 900 MHz band.*

6.11.2 Close to head phantom

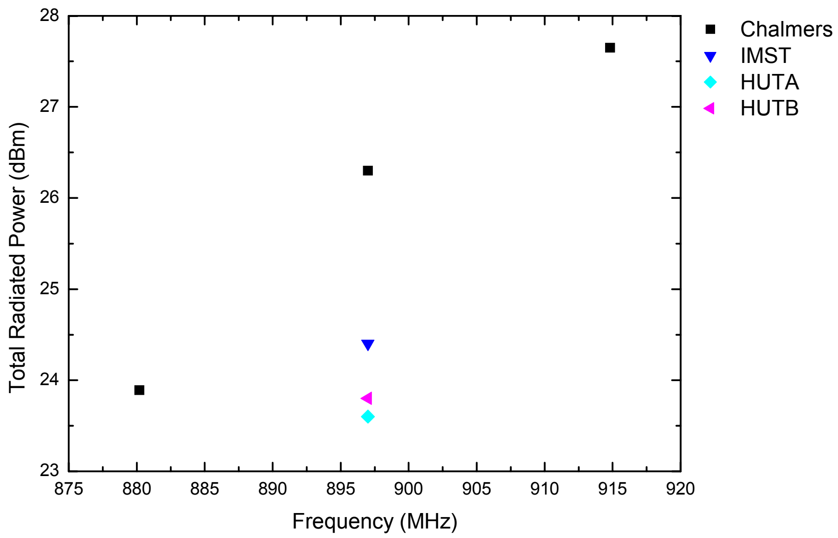

Fig. 6.11.2.1. Measured total radiated power for the special GSM phone close to head phantom – 900 MHz band.

Note 1: Chalmers used a SPEAG generic head phantom V3.5.
Note 2: IMST used a SPEAG SAM V4.5 anthropomorphic head phantom.
Note 3: HUT used a non-standard liquid-filled full head phantom.
Note 4: HUTA and HUTB denote measurements by HUT using two different reference antennas, respectively.

6.12 Total radiated power – GSM phone 1800 MHz band

6.12.1 Free space

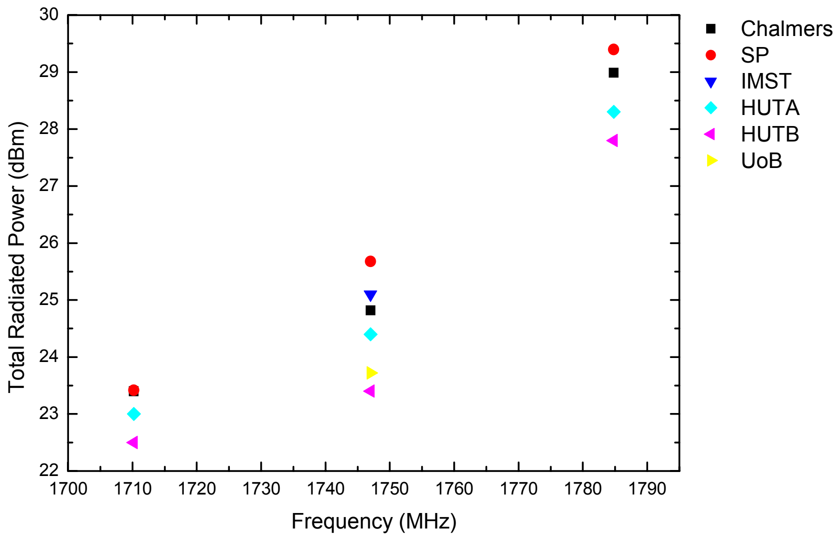

Fig. 6.12.1.1. Measured total radiated power for the special GSM phone in free space – 1800 MHz band.

Note 1: HUTA and HUTB denote measurements by HUT using two different reference antennas, respectively.

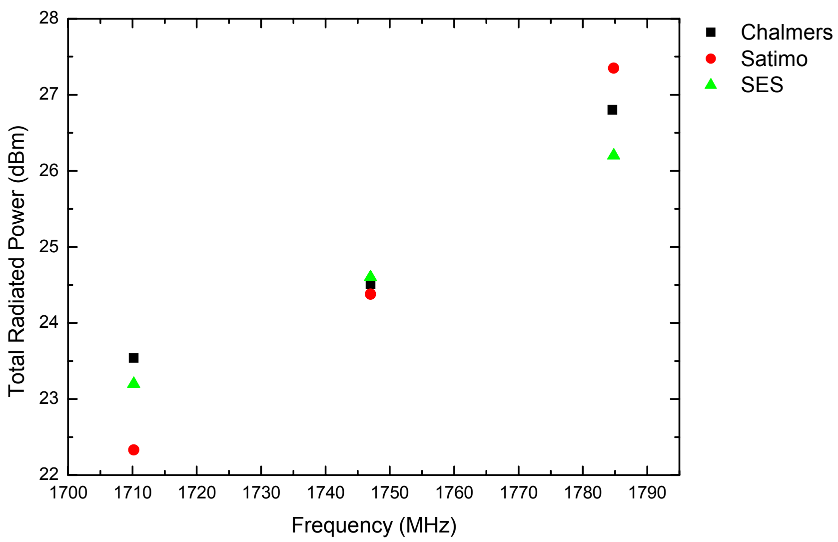

*Fig. 6.12.1.2. Measured total radiated power for the standard GSM phone (*IMEI 35441600-275764-9*) in free space – 1800 MHz band.*

Note 1: Chalmers measured on channel 884 instead of 885 (200 kHz difference).

6.12.2 Close to head phantom

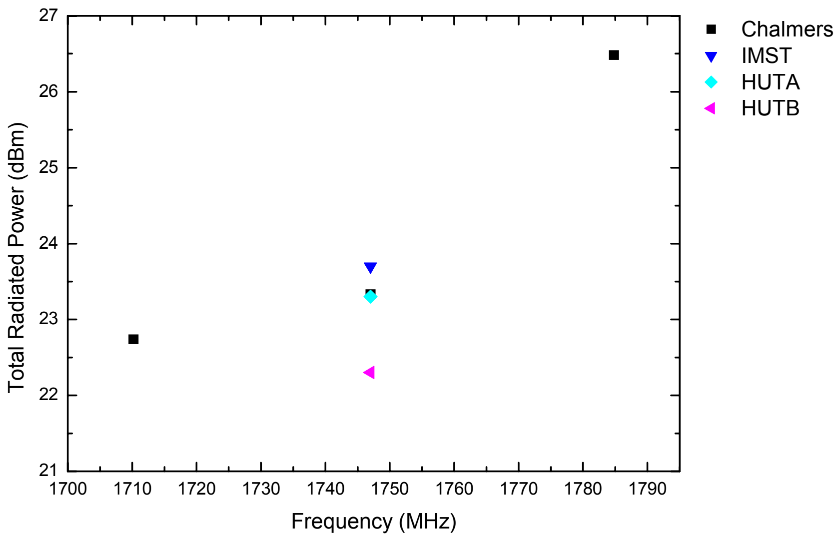

Fig. 6.12.2.1. Measured total radiated power for the special GSM phone close to head phantom – 1800 MHz band.

Note 1: Chalmers used a SPEAG generic head phantom V3.5.
Note 2: IMST used a SPEAG SAM V4.5 anthropomorphic head phantom.
Note 3: HUT used a non-standard liquid-filled full head phantom.
Note 4: HUTA and HUTB denote measurements by HUT using two different reference antennas, respectively.

6.13 Total radiated power – GSM phone 1900 MHz band

6.13.1 Free space

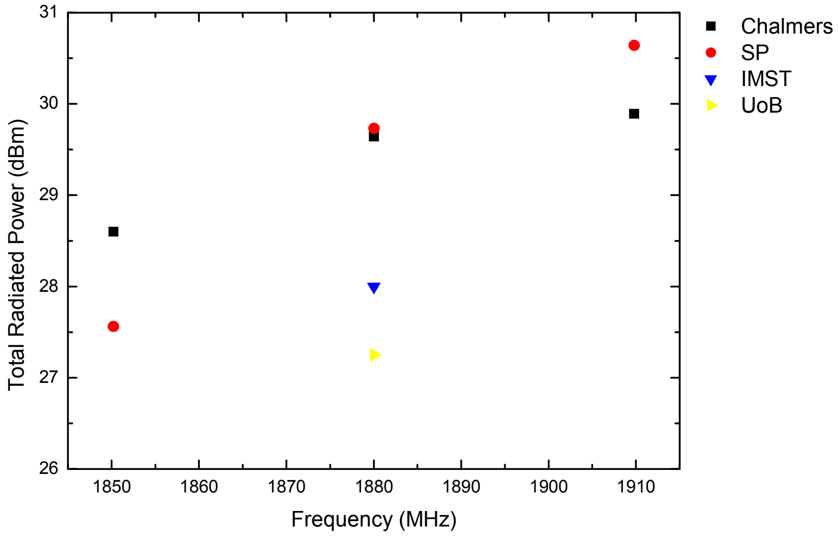

Fig. 6.13.1.1. Measured total radiated power for the special GSM phone in free space – 1900 MHz band.

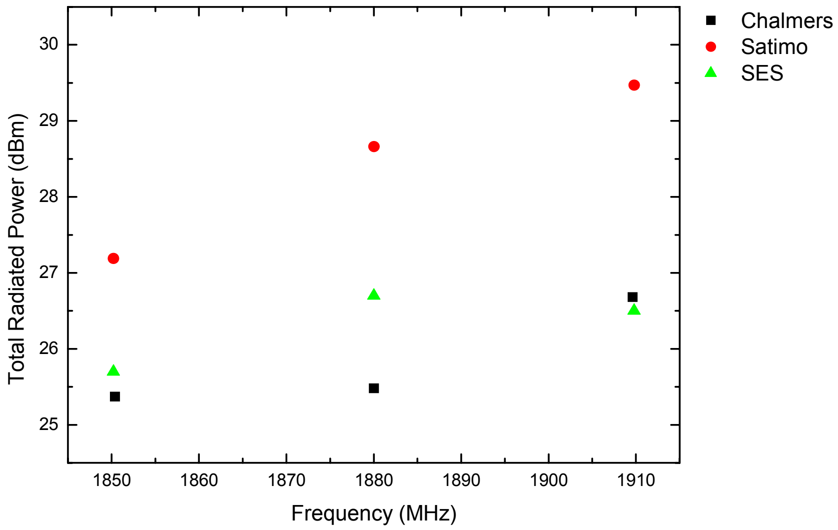

*Fig. 6.13.1.2. Measured total radiated power for the standard GSM phone (*IMEI 35441600-275764-9*) in free space – 1900 MHz band.*

Note 1: Chalmers measured on channel 513 instead of 512 and 809 instead of 810, respectively (200 kHz difference in both cases).

6.13.2 Close to head phantom

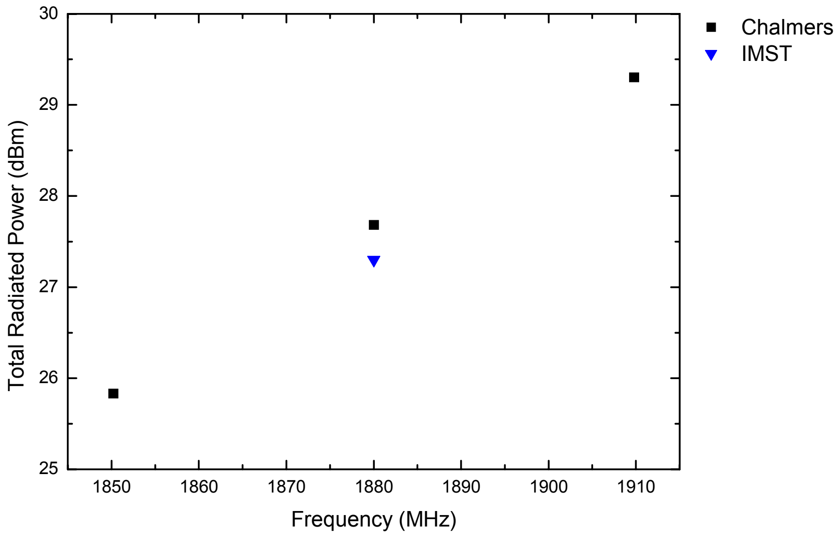

Fig. 6.13.2.1. Measured total radiated power for the special GSM phone close to head phantom – 1900 MHz band.

Note 1: Chalmers used a SPEAG generic head phantom V3.5.
Note 2: IMST used a SPEAG SAM V4.5 anthropomorphic head phantom.

6.14 Special 1.785 GHz device

6.14.1 Total radiated power

	TRP (dBm)
CHALMERS	-0.3
IMST	-
HUT	-0.1
EPFL	-1.4
SATIMO	-1.4
UoB	-
SP	-
IETR	-
SES	-
BenQ	-

Table 6.14.1.1. Measured total radiated power for the special 1.785 GHz device.

6.14.2 Total radiation efficiency

	Efficiency (dB)
CHALMERS	-
IMST	-
HUT	-0.2
EPFL	-0.7
SATIMO	-0.8
UoB	-
SP	-
IETR	-
SES	-
BenQ	-

Table 6.14.2.1. Measured total radiation efficiency for the special 1.785 GHz device.

6.15 Total isotropic sensitivity – GSM phone 900 MHz band

6.15.1 Free space

	Sensitivity (dBm)
CHALMERS	-
IMST	-104.42
HUT	-
EPFL	-
SATIMO	-
UoB	-
SP	-
IETR	-
SES	-104.1
BenQ	-

Table 6.15.1.1. Measured total isotropic sensitivity for the standard GSM phone – 900 MHz band.

6.15.2 Close to head phantom

	Sensitivity (dBm)
CHALMERS	-
IMST	-96.96
HUT	-
EPFL	-
SATIMO	-
UoB	-
SP	-
IETR	-
SES	-
BenQ	-

Table 6.15.1.1. Measured total isotropic sensitivity for the standard GSM phone – 900 MHz band.

Note 1: IMST used a SPEAG SAM V4.5 anthropomorphic head phantom.

6.16 Total isotropic sensitivity – GSM phone 1800 MHz band

6.16.1 Free space

	Sensitivity (dBm)
CHALMERS	-
IMST	-104.06
HUT	-
EPFL	-
SATIMO	-
UoB	-
SP	-
IETR	-
SES	-102.2
BenQ	-

Table 6.15.1.1. Measured total isotropic sensitivity for the standard GSM phone – 1800 MHz band.

6.16.2 Close to head phantom

	Sensitivity (dBm)
CHALMERS	-
IMST	-103.31
HUT	-
EPFL	-
SATIMO	-
UoB	-
SP	-
IETR	-
SES	-
BenQ	-

Table 6.15.1.1. Measured total isotropic sensitivity for the standard GSM phone – 1800 MHz band.

Note 1: IMST measured in position cheek left instead of the intended cheek right.
Note 2: IMST used a SPEAG SAM V4.5 anthropomorphic head phantom.

6.17 Total isotropic sensitivity – GSM phone 1900 MHz band

6.17.1 Free space

	Sensitivity (dBm)
CHALMERS	-
IMST	-103.63
HUT	-
EPFL	-
SATIMO	-
UoB	-
SP	-
IETR	-
SES	-
BenQ	-

Table 6.15.1.1. Measured total isotropic sensitivity for the standard GSM phone – 900 MHz band.

6.17.2 Close to head phantom

	Sensitivity (dBm)
CHALMERS	-
IMST	-102.52
HUT	-
EPFL	-
SATIMO	-
UoB	-
SP	-
IETR	-
SES	-
BenQ	-

Table 6.15.1.1. Measured total isotropic sensitivity for the standard GSM phone – 900 MHz band.

Note 1: IMST measured in position cheek left instead of the intended cheek right.
Note 2: IMST used a SPEAG SAM V4.5 anthropomorphic head phantom.

7 Control measurements

In order to check that nothing had happened to the test devices during the benchmarking periods Chalmers performed measurements of relevant test cases before as well as after each round robin period. The results from these measurements are presented in this chapter.

The control measurements show that the differences between the measurements performed in December 2004, June 2005 and December 2005 are for all cases less than the claimed uncertainties given in Table 5.1.1. From this the conclusion is that all test devices were intact and worked as they should after the completed round robin periods and results from the different participants are therefore comparable.

7.1 900 MHz dipole

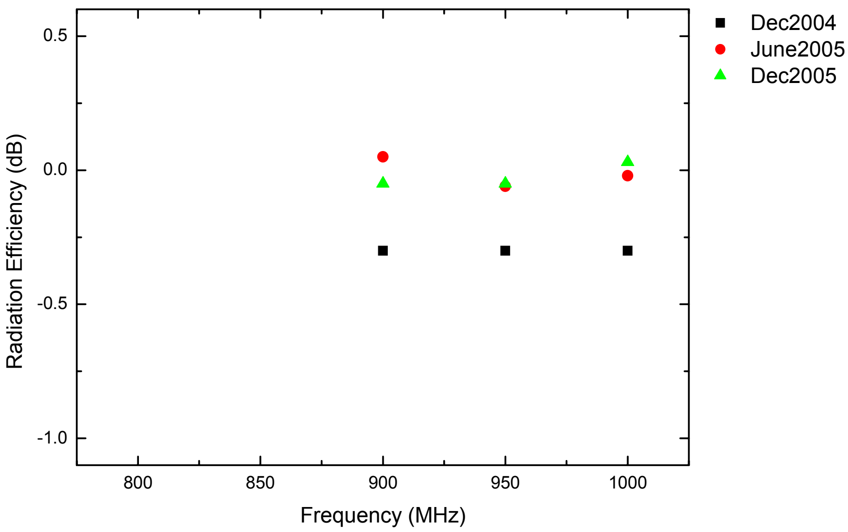

Fig. 7.1.1. Measured radiation efficiency for the 900 MHz dipole in free space. Measurements by Chalmers in December 2004, June 2005 and December 2005.

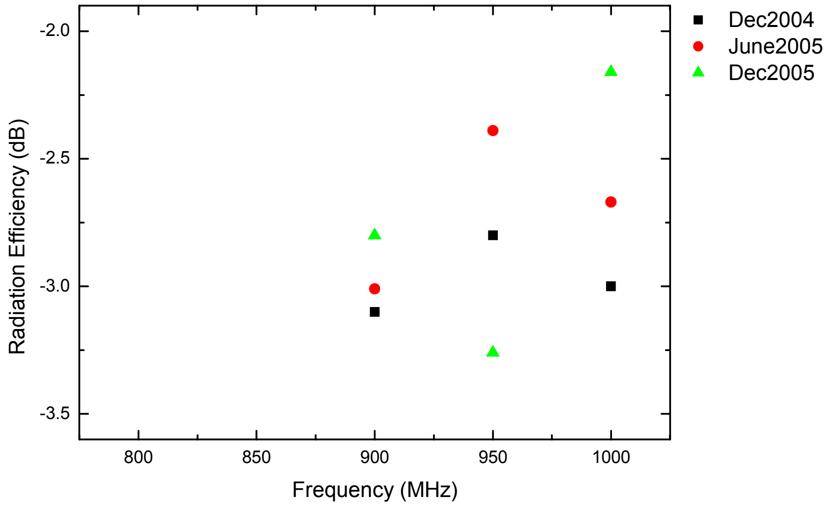

Fig. 7.1.2. Measured radiation efficiency for the 900 MHz dipole at a distance of 20 mm from the lossy cylinder. Measurements by Chalmers in December 2004, June 2005 and December 2005.

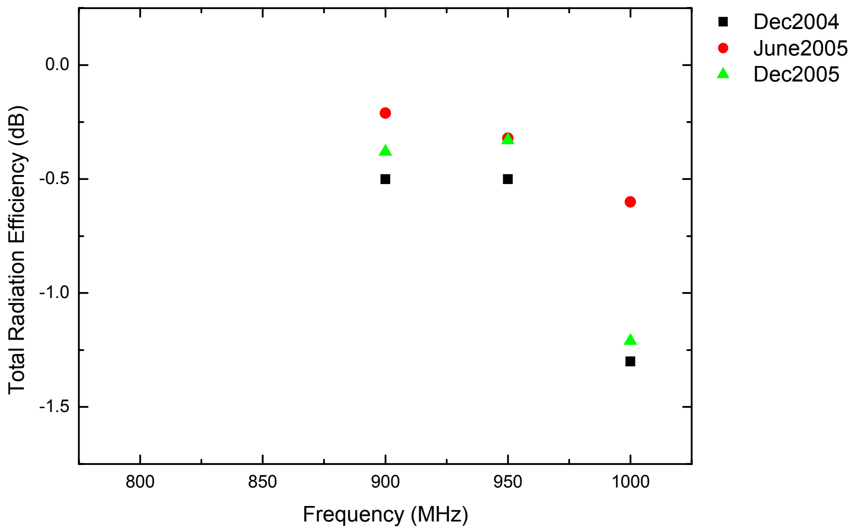

Fig. 7.1.3. Measured total radiation efficiency for the 900 MHz dipole in free space. Measurements by Chalmers in December 2004, June 2005 and December 2005.

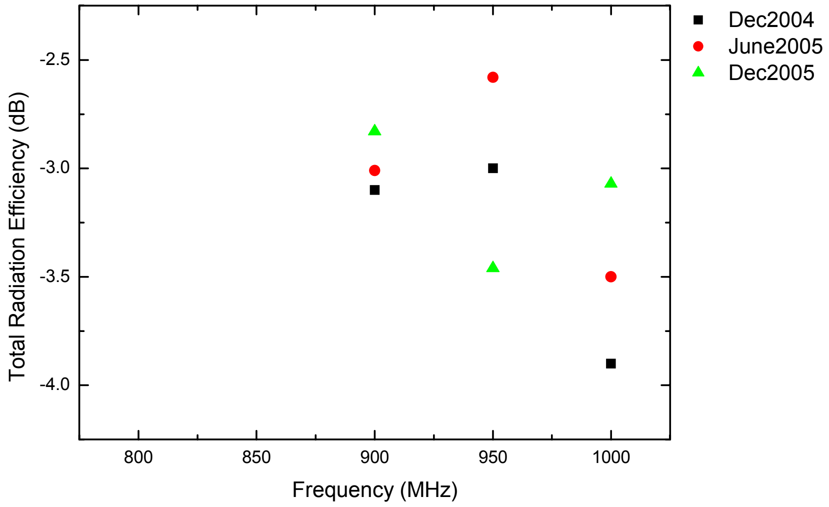

Fig. 7.1.4. Measured total radiation efficiency for the 900 MHz dipole at a distance of 20 mm from the lossy cylinder. Measurements by Chalmers in December 2004, June 2005 and December 2005.

7.2 1800 MHz dipole

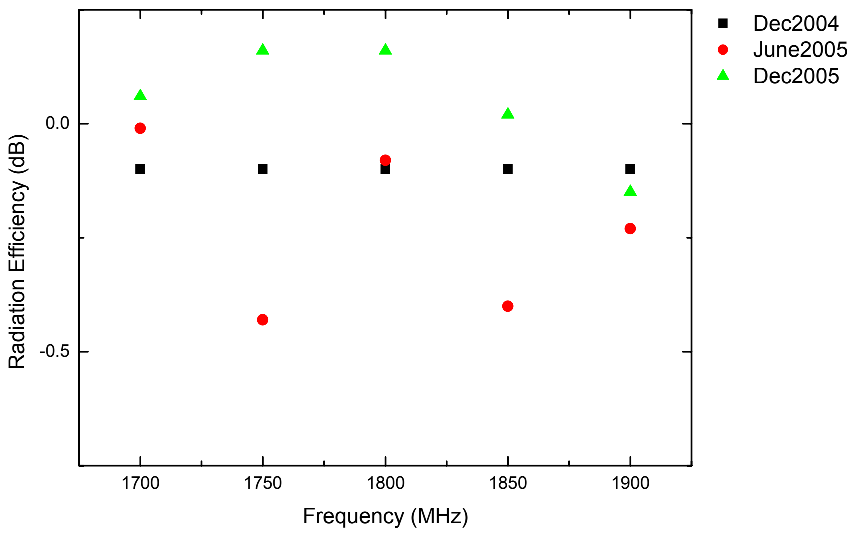

Fig. 7.2.1. Measured radiation efficiency for the 1800 MHz dipole in free space. Measurements by Chalmers in December 2004, June 2005 and December 2005.

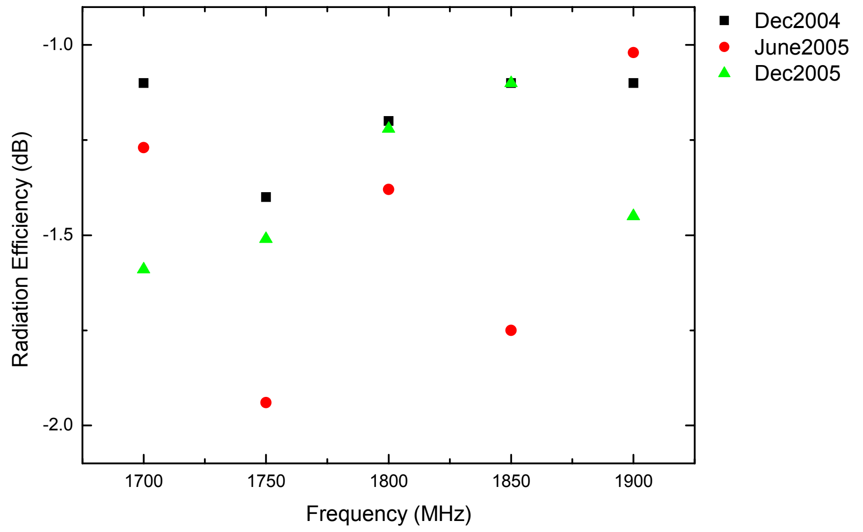

Fig. 7.2.2. Measured radiation efficiency for the 1800 MHz dipole at a distance of 20 mm from the lossy cylinder. Measurements by Chalmers in December 2004, June 2005 and December 2005.

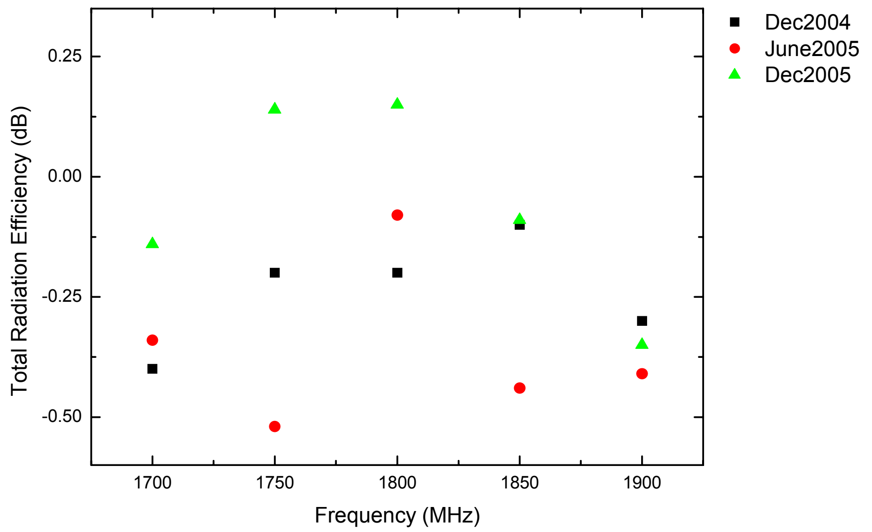

Fig. 7.2.3. Measured total radiation efficiency for the 1800 MHz dipole in free space. Measurements by Chalmers in December 2004, June 2005 and December 2005.

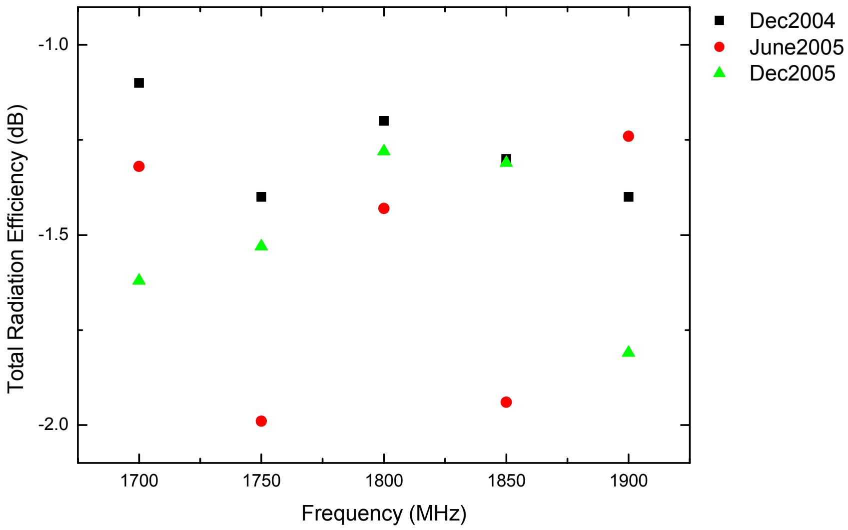

Fig. 7.2.4. Measured total radiation efficiency for the 1800 MHz dipole at a distance of 20 mm from the lossy cylinder. Measurements by Chalmers in December 2004, June 2005 and December 2005.

7.3 2400 MHz dipole

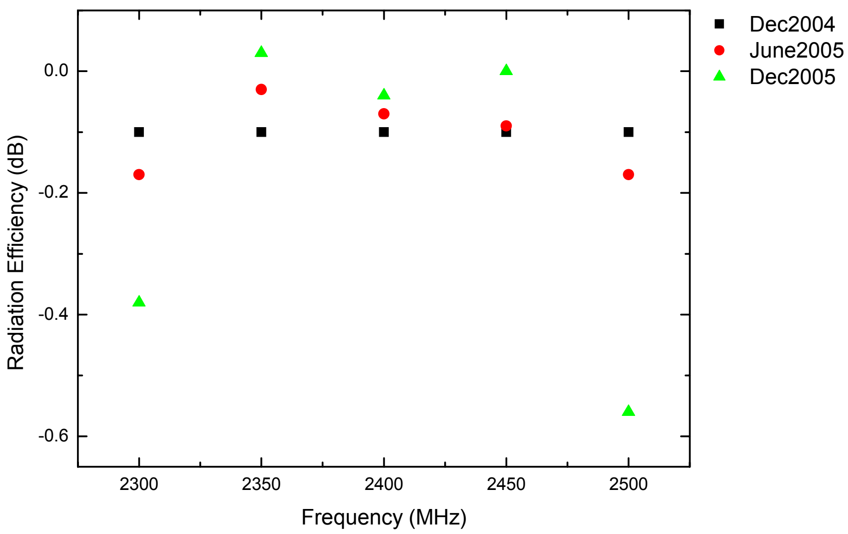

Fig. 7.3.1. Measured radiation efficiency for the 2400 MHz dipole in free space. Measurements by Chalmers in December 2004, June 2005 and December 2005.

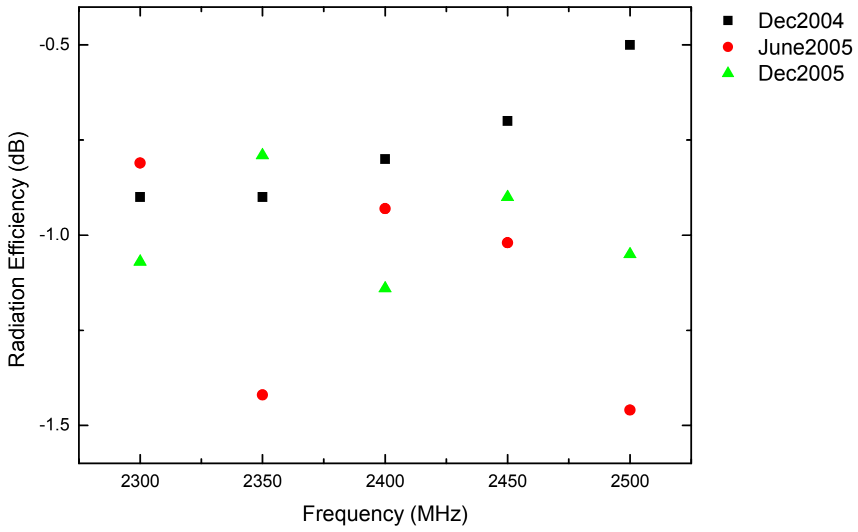

Fig. 7.3.2. Measured radiation efficiency for the 2400 MHz dipole at a distance of 20 mm from the lossy cylinder. Measurements by Chalmers in December 2004, June 2005 and December 2005.

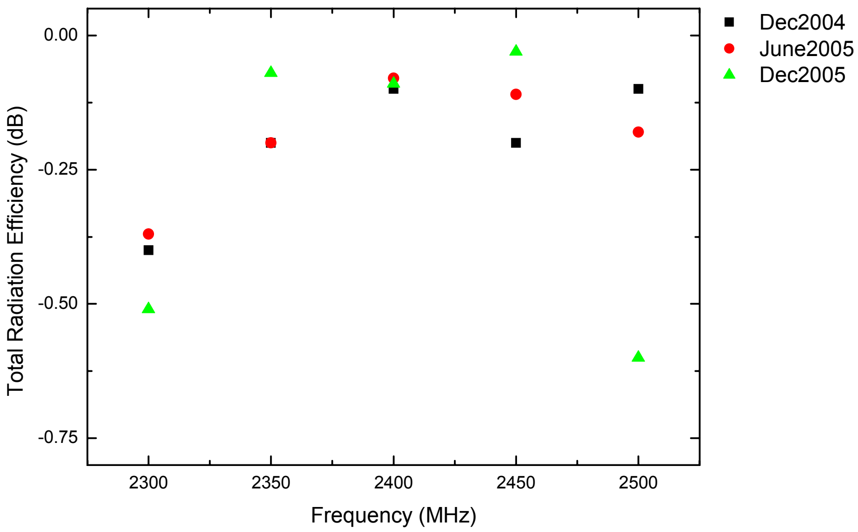

Fig. 7.3.3. Measured total radiation efficiency for the 2400 MHz dipole in free space. Measurements by Chalmers in December 2004, June 2005 and December 2005.

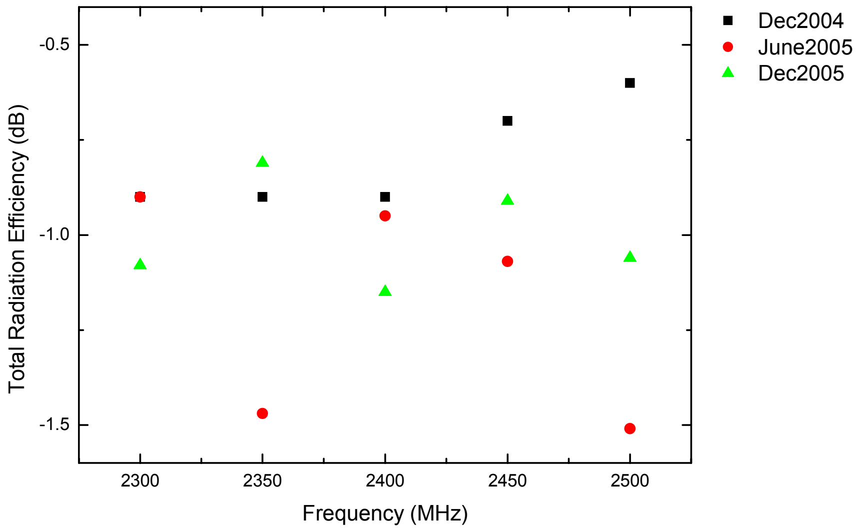

Fig. 7.3.4. Measured total radiation efficiency for the 2400 MHz dipole at a distance of 20 mm from the lossy cylinder. Measurements by Chalmers in December 2004, June 2005 and December 2005.

7.4 5.2 GHz slot antenna

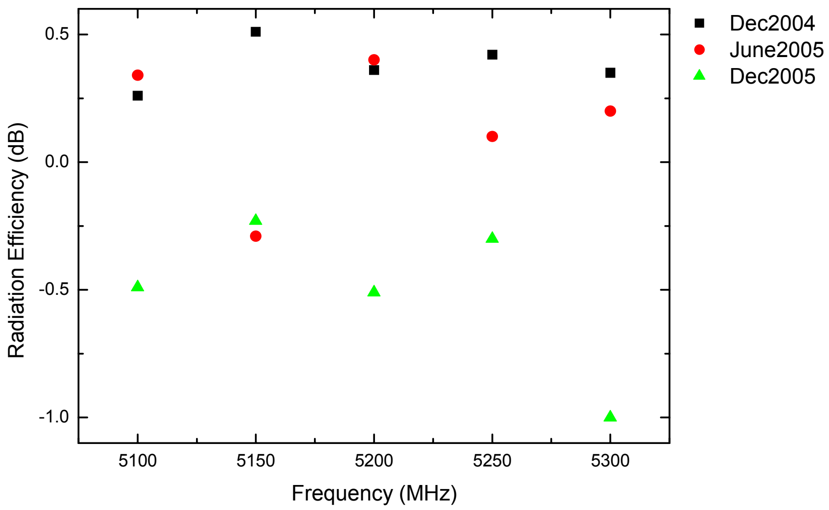

Fig. 7.4.1. Measured radiation efficiency for the 5.2 GHz slot antenna in free space. Measurements by Chalmers in December 2004, June 2005 and December 2005.

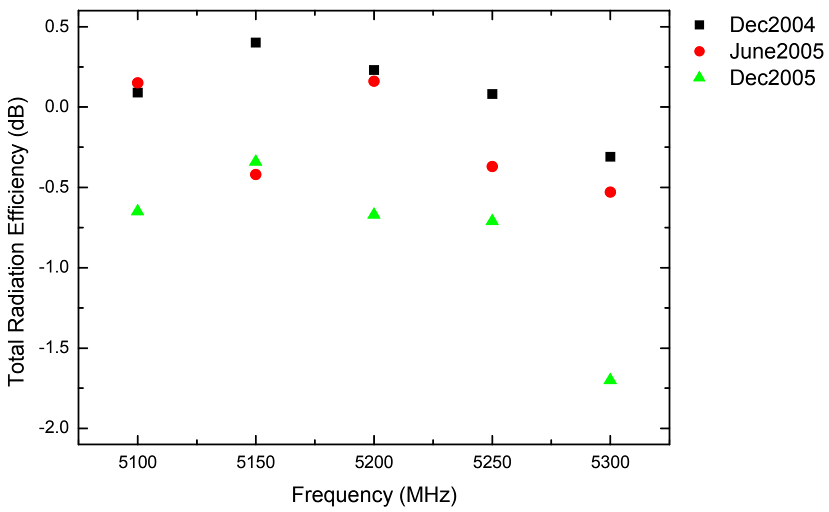

Fig. 7.4.2. Measured total radiation efficiency for the 5.2 GHz slot antenna in free space. Measurements by Chalmers in December 2004, June 2005 and December 2005.

Note 1: For the measurements on the slot antenna in December 2005 another reference antenna was used.

7.5 Total radiated power – GSM phone 900 MHz band

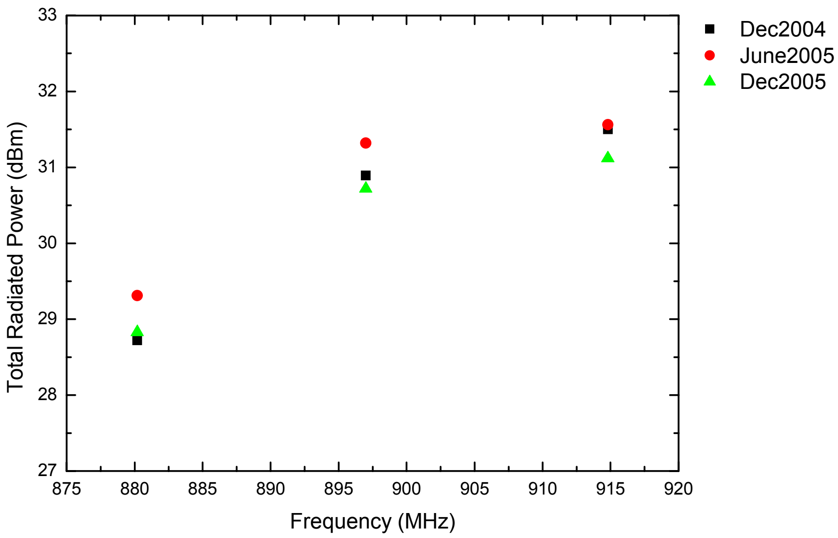

Fig. 7.5.1. Measured total radiated power for the special GSM phone in free space – 900 MHz band. Measurements by Chalmers in December 2004, June 2005 and December 2005.

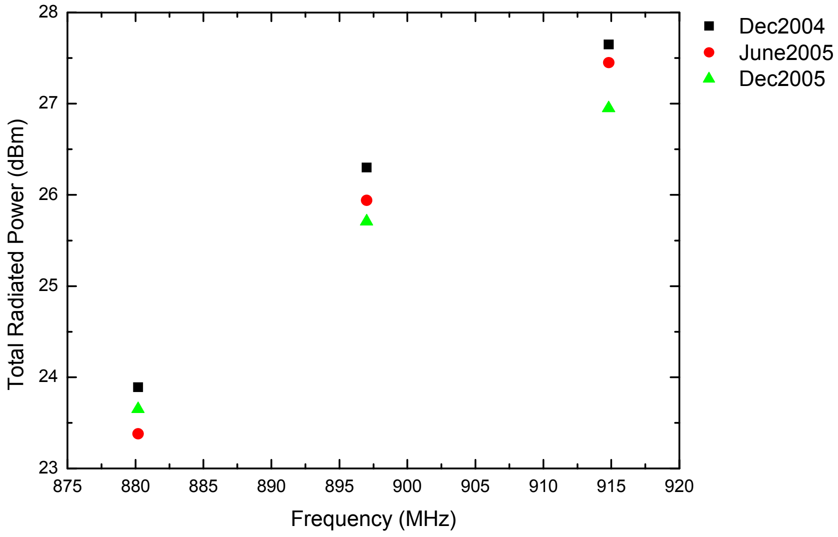

Fig. 7.5.2. *Measured total radiated power for the special GSM phone close to head phantom – 900 MHz band. Measurements by Chalmers in December 2004, June 2005 and December 2005.*

7.6 Total radiated power – GSM phone 1800 MHz band

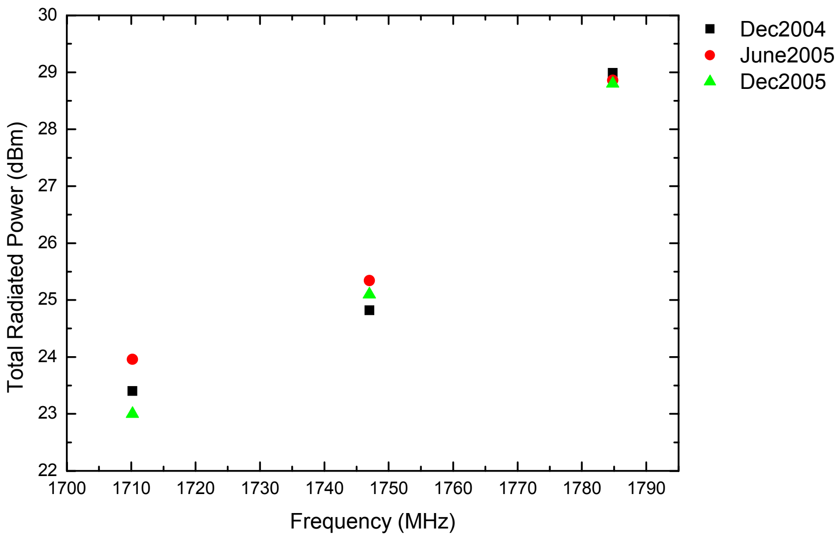

Fig. 7.6.1. *Measured total radiated power for the special GSM phone in free space – 1800 MHz band. Measurements by Chalmers in December 2004, June 2005 and December 2005.*

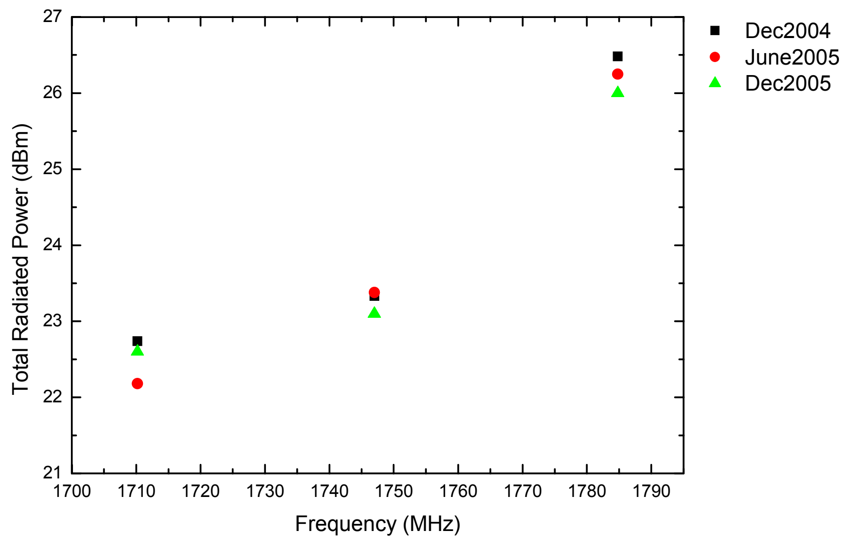

Fig. 7.6.2. Measured total radiated power for the special GSM phone close to head phantom – 1800 MHz band. Measurements by Chalmers in December 2004, June 2005 and December 2005.

7.7 Total radiated power – GSM phone 1900 MHz band

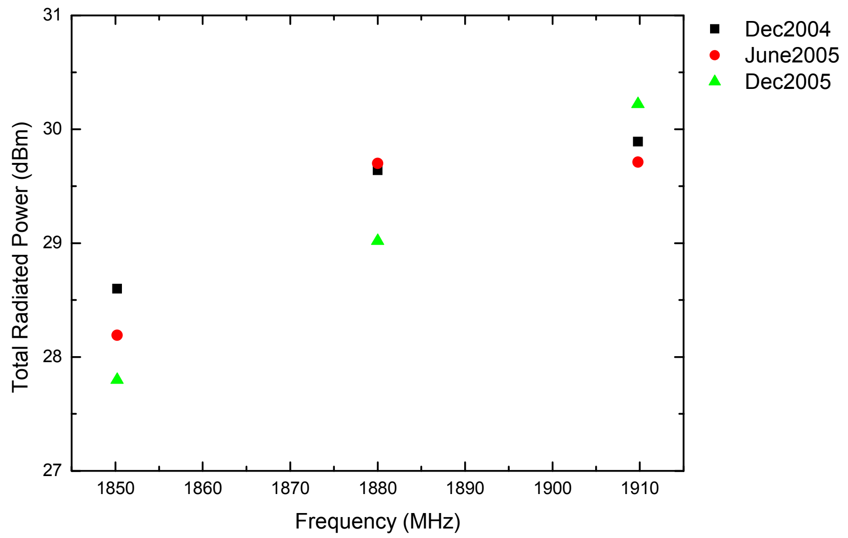

Fig. 7.7.1. Measured total radiated power for the special GSM phone in free space – 1900 MHz band. Measurements by Chalmers in December 2004, June 2005 and December 2005.

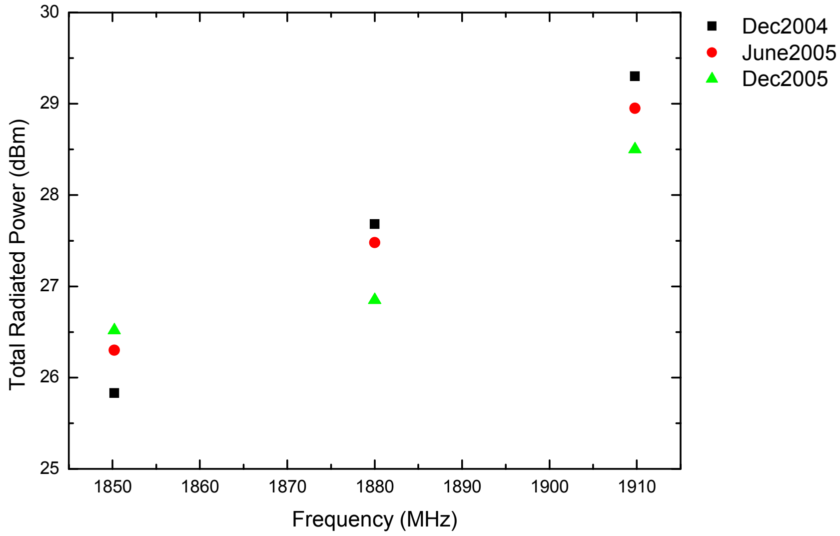

Fig. 7.7.2. Measured total radiated power for the special GSM phone close to head phantom – 1900 MHz band. Measurements by Chalmers in December 2004, June 2005 and December 2005.

7.8 Total radiated power – Special 1.785 GHz device

	TRP (dBm)
December 2004	-0.3
June 2005	-0.4

Table 7.8.1. Measured total radiated power for the special 1.785 GHz device. Measurements by Chalmers in December 2004 and June 2005, respectively.

Note 1: The special 1.785 GHz active device was damaged during the second period of the round robin and was taken out from the remaining part of the benchmarking.

8 Summary and conclusions

This measurement campaign within ACE has been the first benchmarking of measurement facilities performed at a European level, to assess the adequacy of the different setups to assess the performance of small terminal antennas. Similar activities are also taking place at a national level [14], [15], with collaboration of some ACE participants. This will help standardise measurement procedures, and enhance their accuracy. Due to the great success of the measurement campaign, and the interest of other institutions, both within ACE and external, the benchmarking will continue in the next coming ACE. The preliminary results and conclusions have been presented in different events [16], [17], [18], [19].

In order to check that the performance of the test devices did not change during the course of the round robin control measurements were performed by one of the participants at three occasions, at the beginning, in the middle and at the end of the benchmarking campaign. Results from these measurements showed that all test devices were stable and performed as they should. Measured results from the different participants presented in this report are therefore comparable.

Results from measurements of radiation efficiency and total radiation efficiency for the passive antennas included in the benchmarking show that the deviation from mean value is less than 1.5 dB except for the 5.2 GHz slot antenna. For this case the maximum deviation from mean value is 2.67 dB but if one particular participant is disregarded the maximum deviation from mean value is 1.5 dB for all cases. Only two participants measured diversity gain for two dipoles placed close to the lossy cylinder.

The maximum difference in measured total radiated power from GSM phones was 3.18 dB. No significant difference between the GSM bands, 900, 1800 and 1900 MHz, can be observed. Only two participants measured total isotropic sensitivity and only one of them both cases of the phone in free space and in a position close to a head phantom. Unfortunately, the special 1.785 GHz active device was damaged during the second benchmarking period so it had to be taken out from the rest of the round robin. The maximum difference in total radiated power between the four participants that had the chance to measure on it is 1.3 dB.

9 References

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[16] J. Carlsson, "Benchmarking of Small Terminal Antennas Measurement Facilities", Proceedings of the JINA Conference, Nice (France), 2004.

[17] J. Carlsson, P. S. Kildal, "Round Robin Test of Active and Passive Small Terminal Antennas", Proceedings of the LAPC 2005 conference, Loughborough (UK), April 4 – 6, 2005.

[18] J. Carlsson, "Benchmarking of Facilities for Small Terminal Antenna Measurements", Proceedings of the AP-S, Washington DC (USA), 2005.

[19] J. Carlsson, "Benchmarking of Facilities for Measuring Small Mobile Terminals and their Antennas: Results of a Round Robin Test in ACE", Proceedings of the ICEcom2005 Conference, Dubrovnik (Croatia), 2005.

Annex I

BENCHMARKING TEST KIT CONTENTS LIST

1. Bluetest dipole set containing four dipoles
   a. 900 MHz dipole, id. 8.9
   b. 900 MHz dipole, id. 10.9
   c. 1800 MHz dipole, id. 8.18
   d. 2400 MHz dipole, id. 8.24

2. Satimo dipole set containing four dipoles
   a. 900 MHz dipole, id. 900-16
   b. 1800 MHz dipole, id. 1800-13
   c. 1900 MHz dipole, id. 1900-14
   d. 2450 MHz dipole, id. 2450-13

3. Special GSM phone for TRP measurements (IMEI 35441600-275762-3)

4. Normal GSM phone for sensitivity measurements (IMEI 35441600-275764-9)

5. Two battery chargers for the GSM phones

6. 1.785 GHZ active device for TRP and efficiency measurements

7. 5.2 GHz slot antenna

8. Sealed plastic cylinder containing lossy liquid

9. Two plastic spacers for diversity measurement setup

10. Two CD-ROMs containing documentations

Annex II

HANDLING INSTRUCTIONS FOR BENCHMARKING DEVICES

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Background

This document contains operation instructions for the test equipment defined in the work package WP 2.2-2 "Benchmarking of Measurement Facilities". The work package is a part of the "Small Terminal and Smart Antennas" activity within the ACE, the FP6 Network of Excellence dedicated to antennas [1]. The instructions in this document should be followed when performing the benchmarking tests described in "Description of Benchmarking Tests with Tables for Results", [2].

Contents

1 Contact information

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2 Overview

All test equipment for the round robin test is placed in a suitcase, Fig. 1. The suitcase is equipped with absorbing material so that it should be possible to send it as a normal package without any special arrangements.

Fig. 1. The suitcase containing all test equipment.

The different devices included in the test set have the following identification numbers:

- 900 MHz dipole, 8.9
- 900 MHz dipole, 10.9
- 1800 MHz dipole, 8.18
- 2400 MHz dipole, 8.24
- Special GSM phone for total radiated power measurements, 35441600-275762-3 (IMEI)
- Normal GSM phone for sensitivity measurements, 35441600-275764-9 (IMEI)

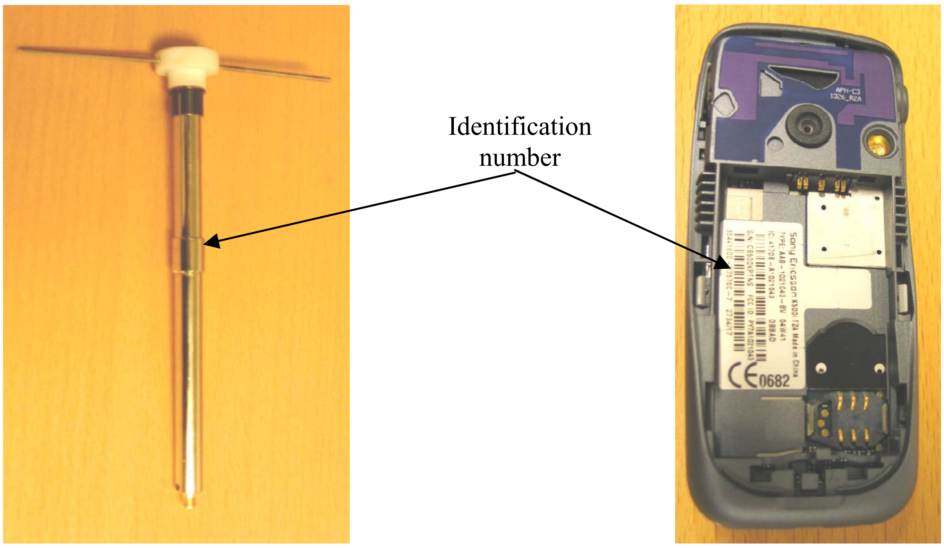


Fig. 2. Placement of identification numbers.

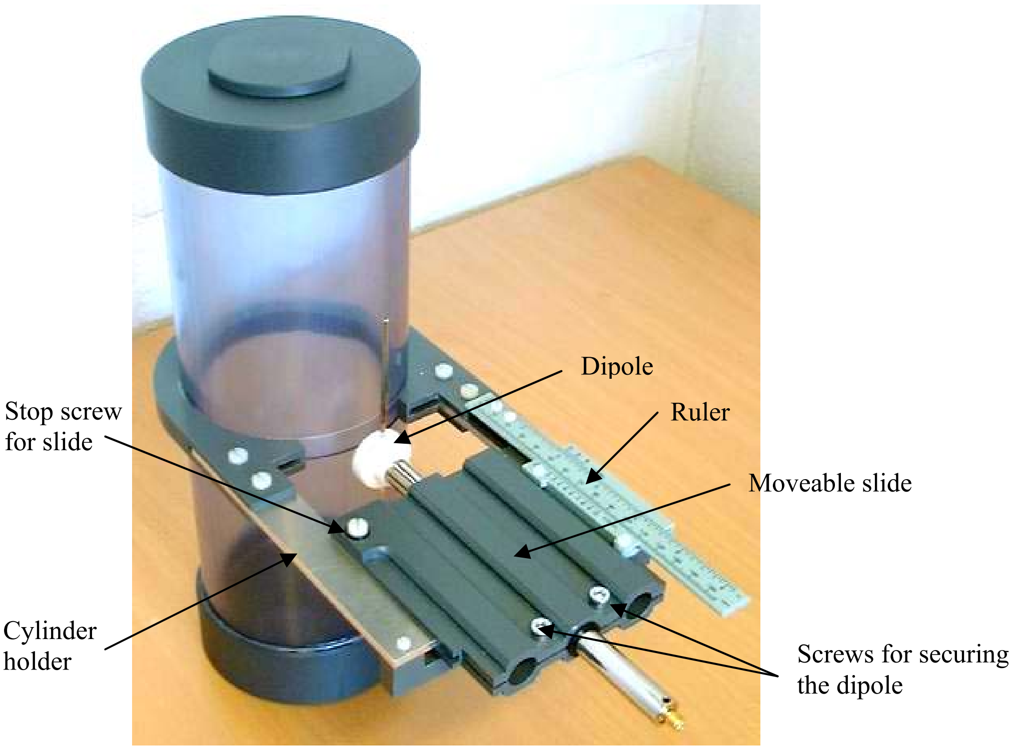


Fig. 3. Single dipole mounted close to cylinder.

3 Single dipole close to lossy cylinder – Efficiency setup

In order to configure the test setup for a single dipole close to the cylinder the following steps should be taken.

Step 1: Dismount the slide from the cylinder by first loosening the stop screw (see Fig. 3) and then push it out from the cylinder holder. Make sure that the plastic spacer close to the dipole arms is at place, Fig. 4. Note that the 2400 MHz dipole should not have a plastic spacer close to the dipole arms (there is not room for any).

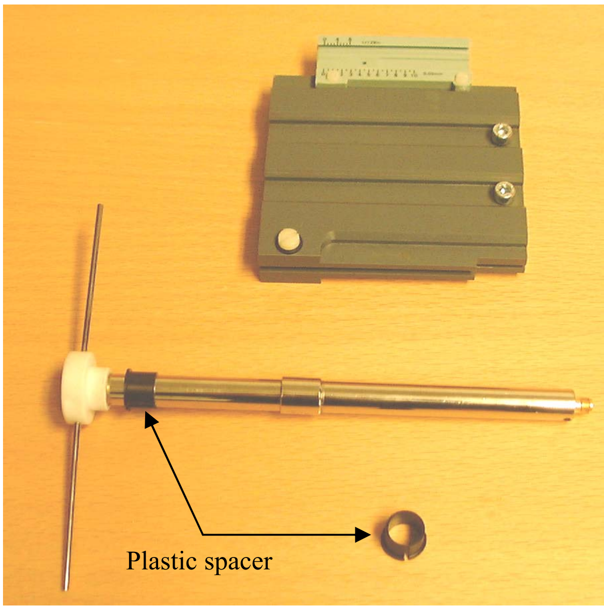


Fig. 4. Dipole and slide dismounted from cylinder.

Step 2: Insert the dipole in the centre hole of the slide. Note that the dipole should be pushed into place from the side of the slide which is closest to the white plastic stop screw. Place the second plastic spacer on the dipole and push both of them into place into the slide, Fig. 5-6. Do not tighten the dipole yet.

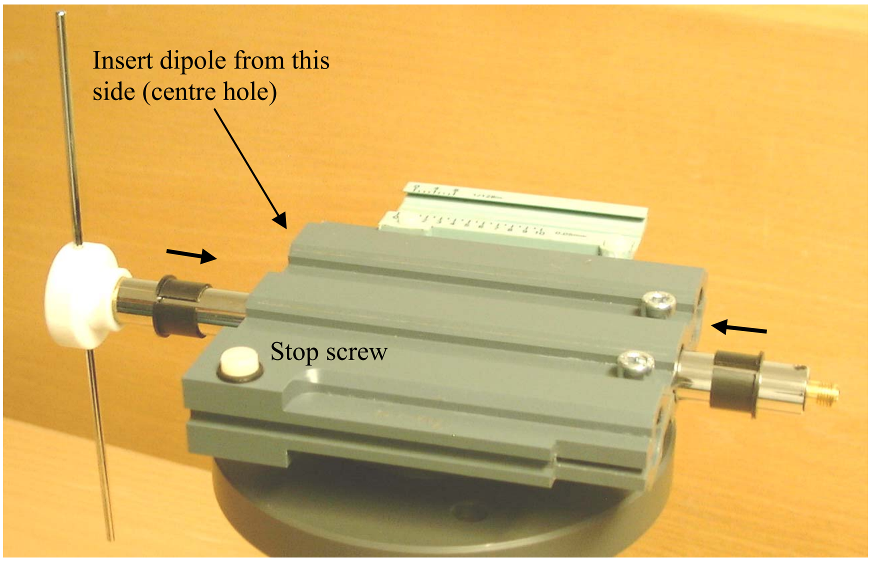


Fig. 5. Dipole mounted in slide, not completed yet.

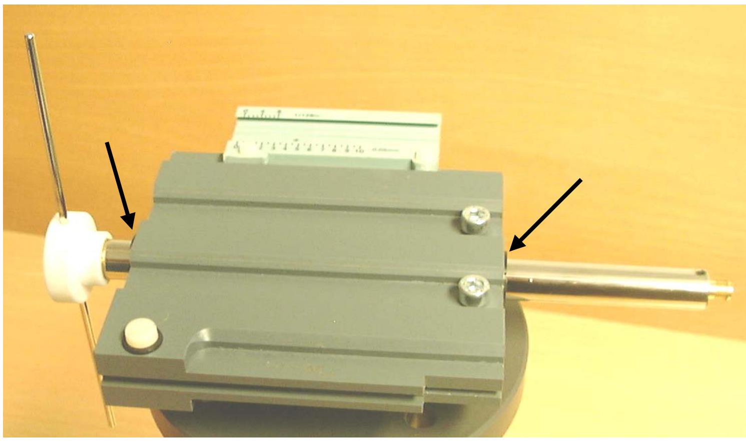


Fig. 6. Dipole mounted in slide, plastic spacers in place.

Step 3: Mount the slide in the cylinder holder and place the dipole spacer on the top of the dipole, Fig. 7.

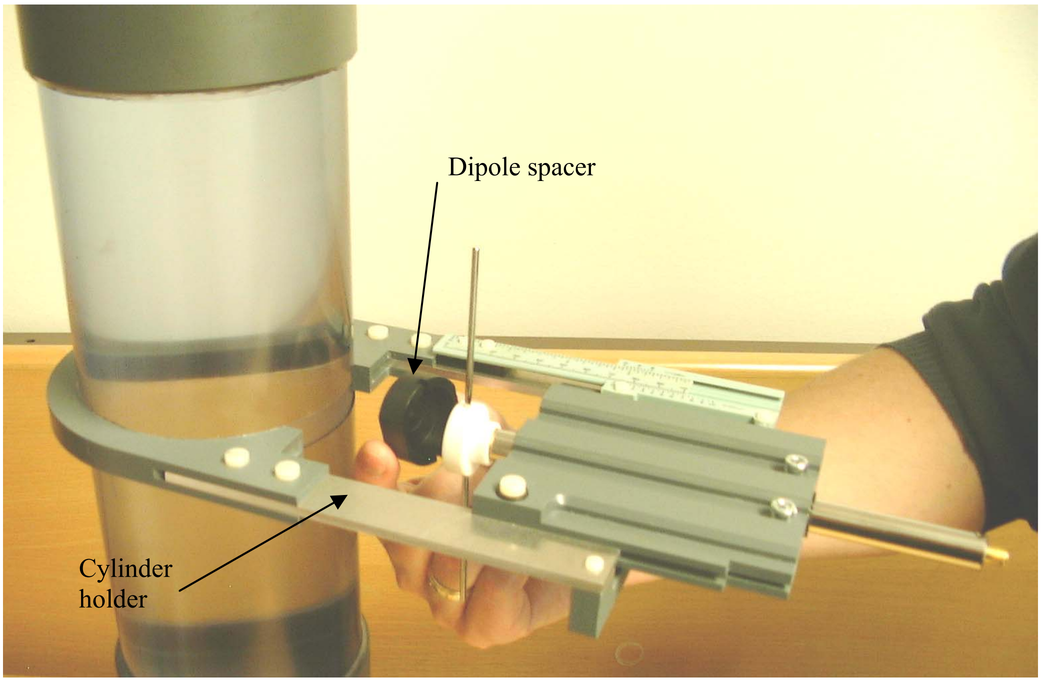


Fig. 7. Slide mounted in cylinder holder.

Step 4: Push the dipole towards the cylinder so that the dipole spacer is pressed against the cylinder, Fig. 8-9. Press the slide as far as it goes, i.e. the dipole is moved with respect to the slide.

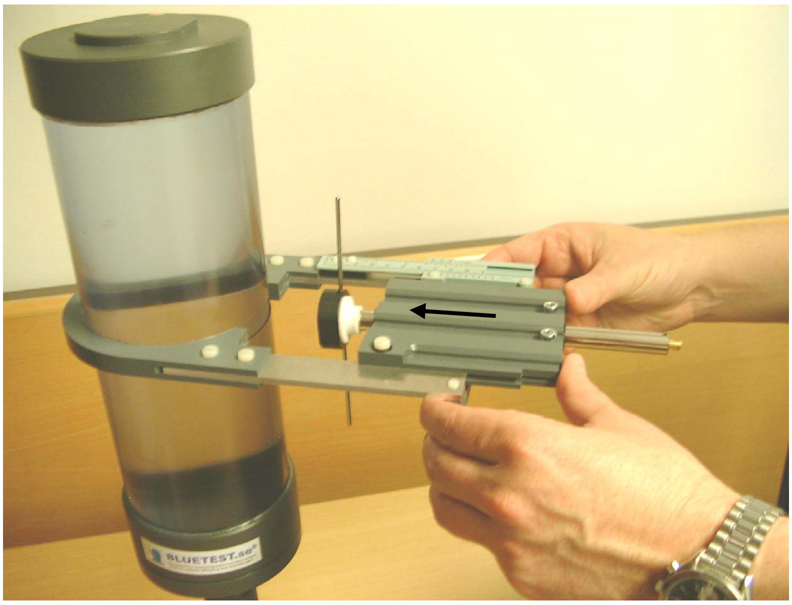


Fig. 8. Push the dipole towards the cylinder.

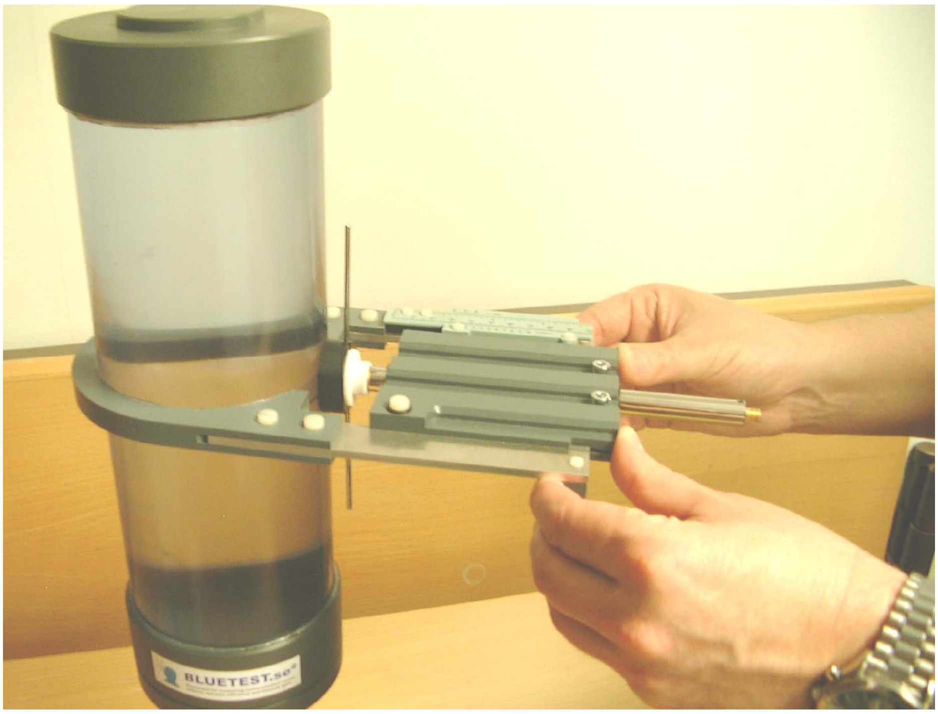


Fig. 9. Dipole spacer pressed against the cylinder. This corresponds to a distance of 10 mm between the dipole and the cylinder.

Step 5: Make sure that the dipole is vertically aligned along the cylinder axis and then secure the dipole by tighten the look screws, Fig. 10. Make a note of the position on the ruler. When the dipole spacer is pressed against the cylinder the distance between the dipole and the cylinder is 10 mm.

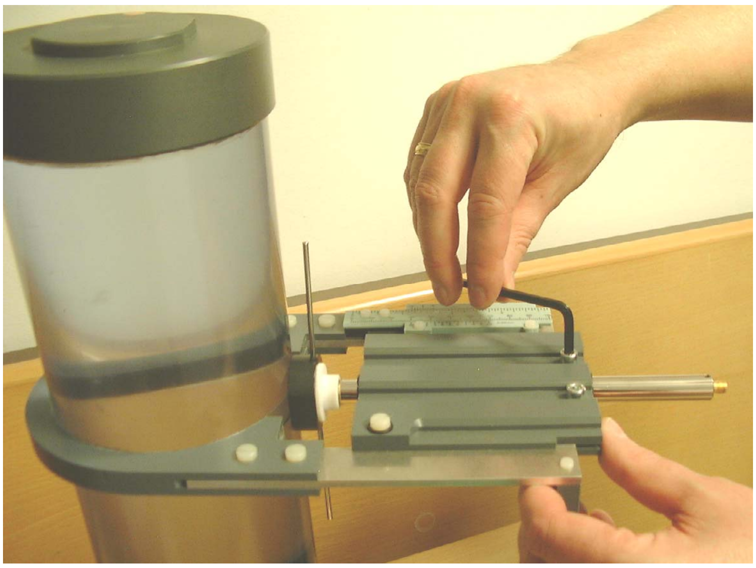


Fig. 10. Make sure that the dipole is aligned vertically and secure the dipole by tighten the look screws. Note the position by reading the ruler.

Step 6: Push the slide away from the cylinder again and remove the dipole spacer, Fig. 11.

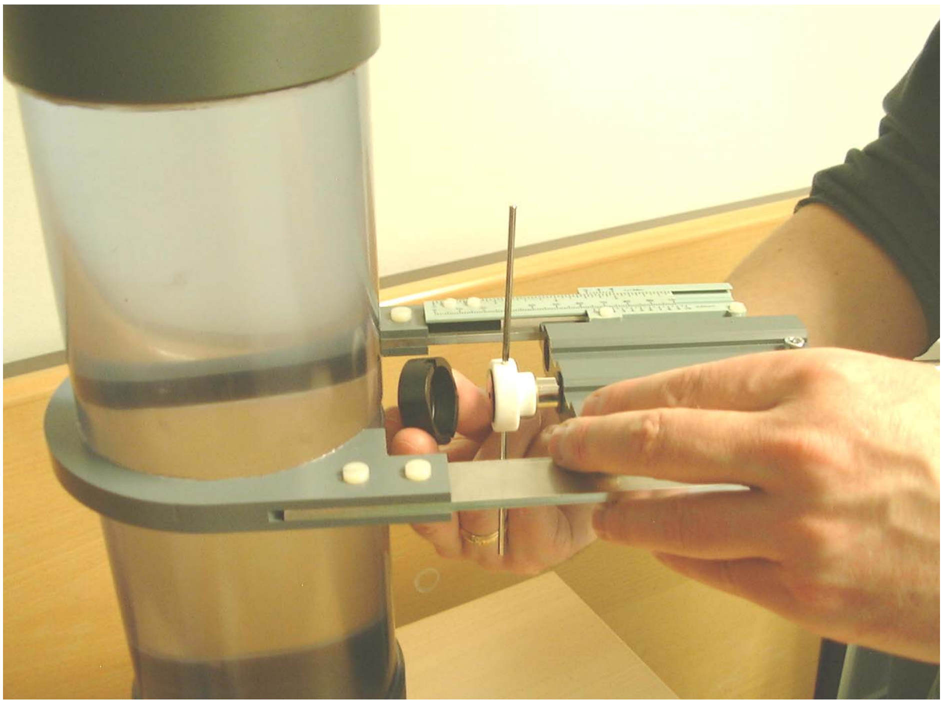


Fig. 11. Slide back again and remove the dipole spacer.

Step 7: Position the dipole at the desired distance from the cylinder by reading the ruler. Secure the slide by tighten the look screw, Fig. 12.

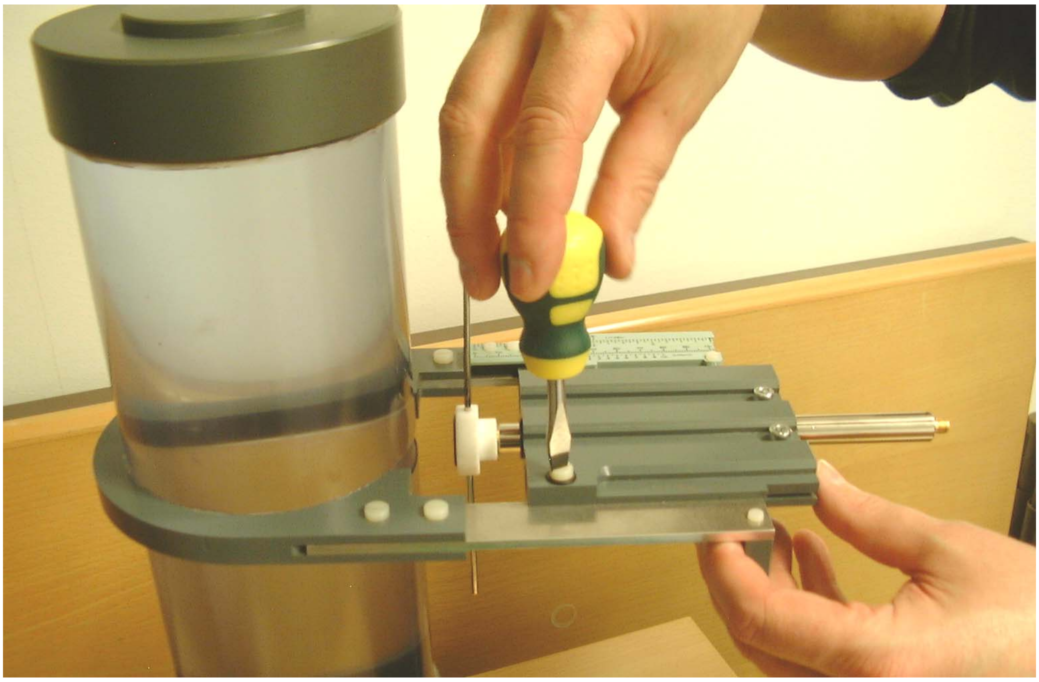


Fig. 12. Position the dipole at the desired distance from the cylinder and secure the slide.

Fig. 13. The single dipole close to lossy cylinder efficiency measurement setup.

4 Two dipoles close to lossy cylinder – Diversity setup

In order to configure the test setup for two dipoles close to the cylinder for diversity measurements the following steps should be taken.

Step 1: Mount the two 900 MHz dipoles in the slide as described in chapter 3, see Fig. 14. Note that the dipole with identification number 8.9 should be placed in the centre. Do not tighten the dipoles yet.

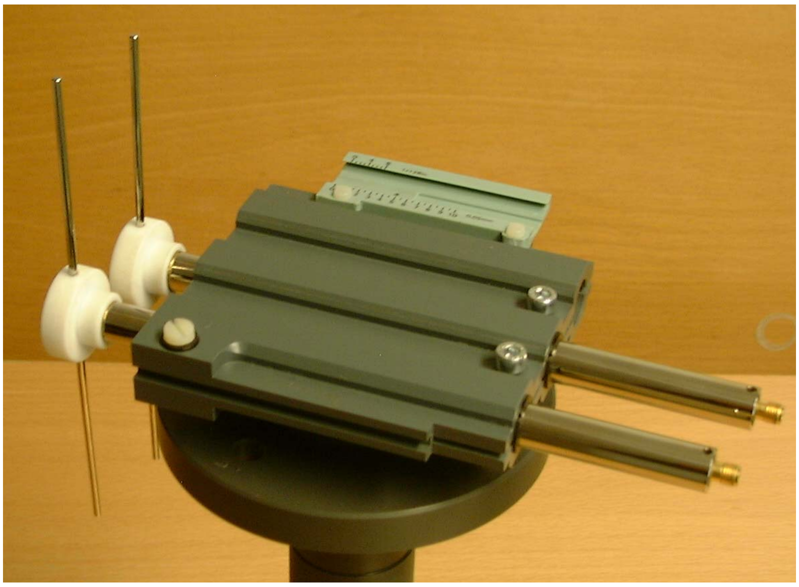


Fig. 14. Two dipoles for diversity measurements placed in the slide.

Step 2: Mount the spacers for diversity setup on the cylinder, Fig. 15. Use rubber bands for holding the spacers.

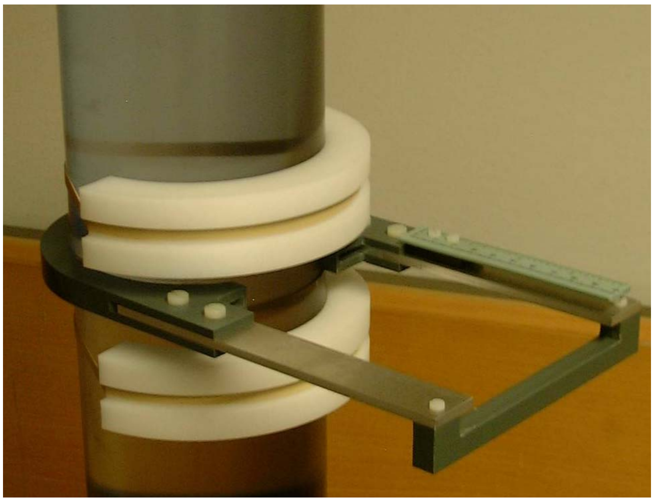


Fig. 15. Spacers for diversity setup mounted on the cylinder.

Step 3: Mount the slide in the cylinder holder and push the dipoles towards the cylinder so that the dipole arms are pressed against the spacers, Fig. 16-17. Make sure that both dipoles are touching the spacers.

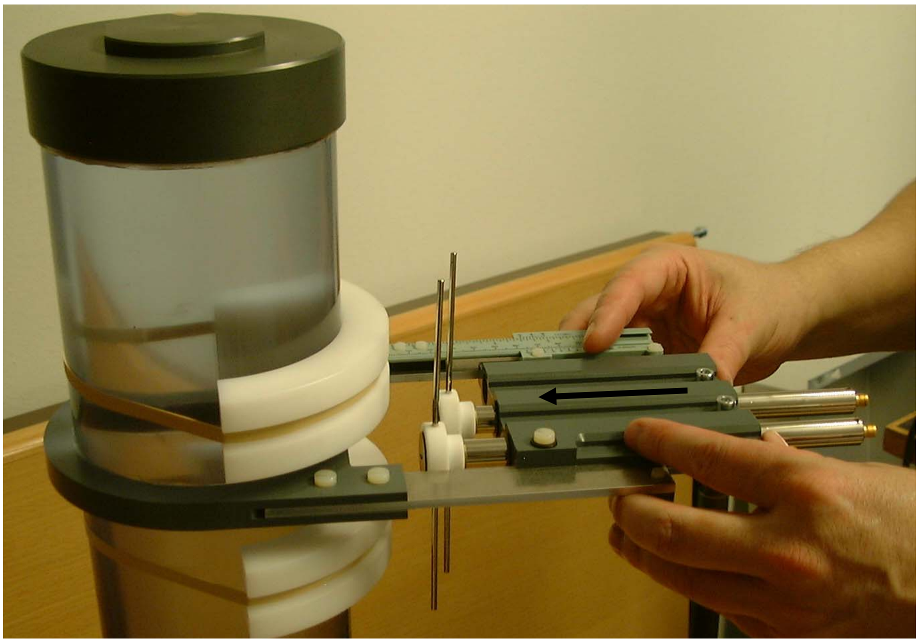


Fig. 16. Push the dipoles towards the cylinder.

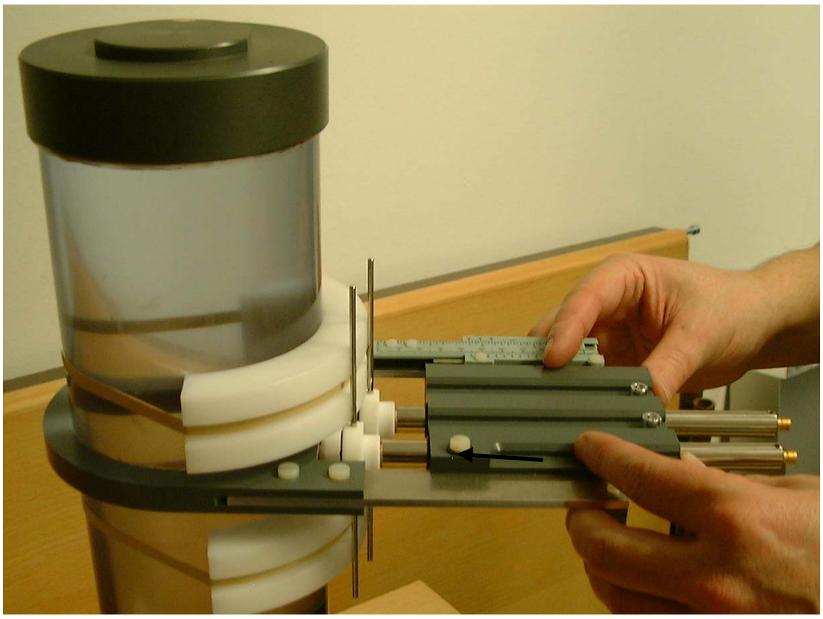


Fig. 17. Dipole arms pressed against the spacers on the cylinder. This corresponds to the correct distance between the dipoles and the cylinder.

Step 4: Make sure that both dipoles are vertically aligned along the cylinder axis and then secure the dipoles by tighten the look screws, Fig. 18. Secure the slide by tighten the look screw, Fig. 19.

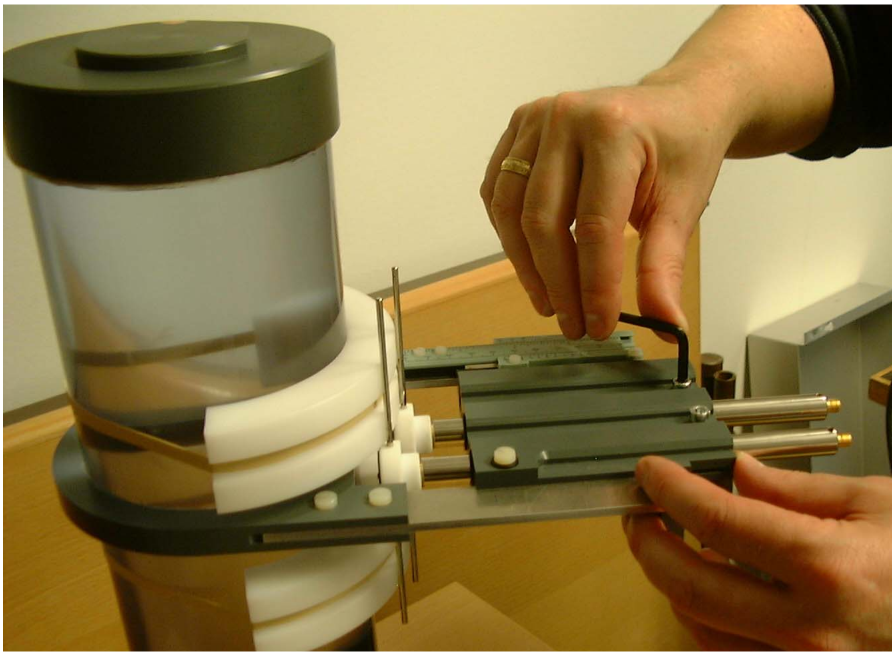


Fig. 18. Make sure that the dipoles are aligned vertically and secure the dipoles by tighten the look screws.

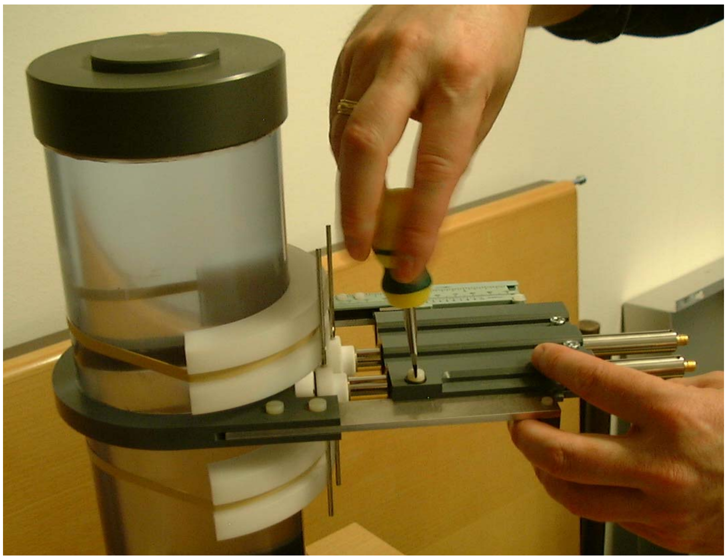


Fig. 19. Secure the slide.

Step 5: Carefully dismount the spacers again, Fig. 20-21.

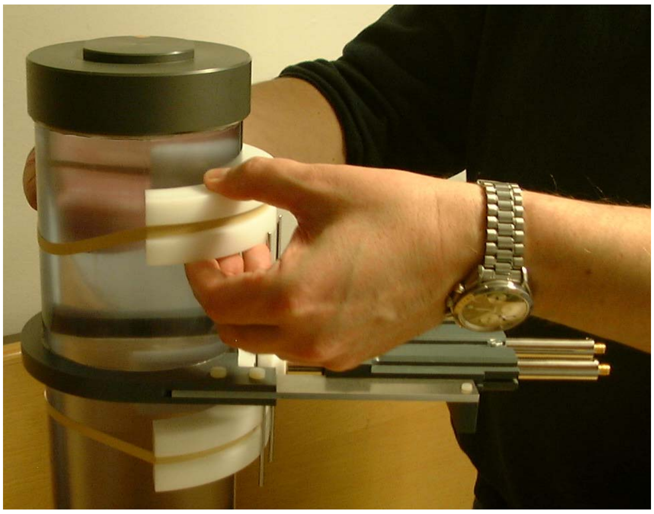


Fig. 20. Dismount the spacers.

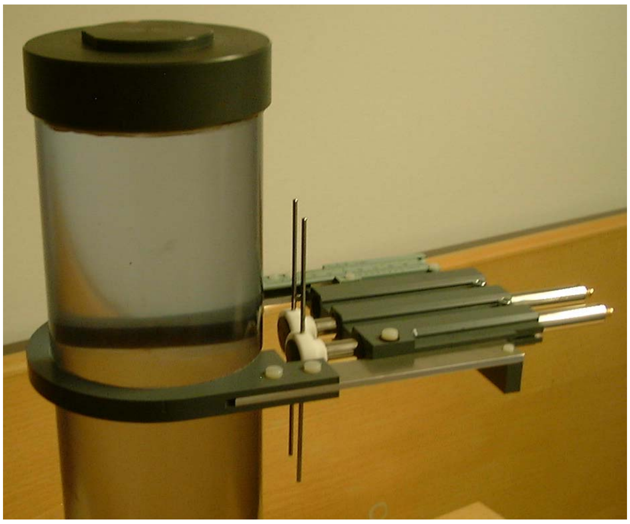


Fig. 21. The diversity setup.

5 Operation of special GSM phone for TRP measurements

Important

All personnel involved in handling these phones commit not to use the phones for any other purpose than radiation testing as described by the ACE program. Phones including SW are the property of Sony Ericsson and should be returned after the completed round robin test.

Note

The phones will transmit at full power once the test mode is enabled and in order not to interfere with networks the tests should be conducted in shielded environments.

IMEI number 35441600-275762-3

Instruction

Push ON at the top of the phone, display remains black

Push 4 to illuminate the keyboard

Push 5 to start the transmit test mode

Push 9 to transmit at channel 975 (full power)

Push 9 to change to channel 35

Push 9 to change to channel 124

Continue to push 9 to sequentially enter channels 512, 696, 885, 512, 661, 810 (128,190, 251), off

Push on at top of phone to switch off

975= 880.2 MHz, 35=897 MHz, 124=914.8 MHz, 512=1710.2 MHz, 696=1747 MHz, 885=1784.8 MHz, 512=1850.2 MHz, 661=1880 MHz, 810=1909.8 MHz

6 Operation of 1.785 GHz device for TRP measurements

6.1 General description

The device for TRP and efficiency measurement consists of a modified standard box (Telemeter ZG2-2-GN) measuring ~59x34x16 mm. On the long side of the box, a massive brass PIFA antenna is mounted, see Fig. 22.

The box contains a Murata VCO (MQE921-1840) covering the 1720-1980 MHz band, two LR1 1.5V alkaline batteries, a voltage stabilization IC, an ON/OFF switch, a potentiometer for the VCO tuning, and a voltage test point.

The PIFA antenna is easily removable and can be replaced by an SMA connector in order to measure the VCO power at every desired frequency.

As this device is an accurate piece of equipment, it should be handled with care, following the instructions of this document.

Fig. 22. The complete device with accessories in its box.

6.2 Replacing the batteries

Two LR1 1.5V alkaline batteries are used. They have a capacity of 700 mAh, and should normally last dozens of hours. As the VCO power output is very sensitive to voltage variations, a voltage stabilization IC has been added, which delivers an extremely stable voltage of 2.698V ±0.002V to the VCO. If the battery voltage becomes insufficient, the IC will no more be able to stabilize the voltage at the required value. The voltage should be checked at the beginning and at the end of each measurement, and the batteries replaced immediately if the voltage is outside the value indicated above. As a voltage check pin is available at the side opposite to the PIFA, this can be checked very easily with a DVM without opening the case.

Always replace both batteries with identical types. Pay attention to the polarity when inserting the batteries: there is no protection against wrong polarity! Reversing the polarity could destroy the voltage stabilizer IC and/or the VCO! Once the batteries have been changed, carefully close the cover and tighten (not too much) the screws. A shorter screw is used close to the PIFA pin.

To replace the batteries the following steps should be taken.

Step 1: Open the cover, using an appropriate screwdriver to avoid damaging the screws. Note that the screw which is close to the pin of the PIFA is shorter than the others! See Fig. 23.

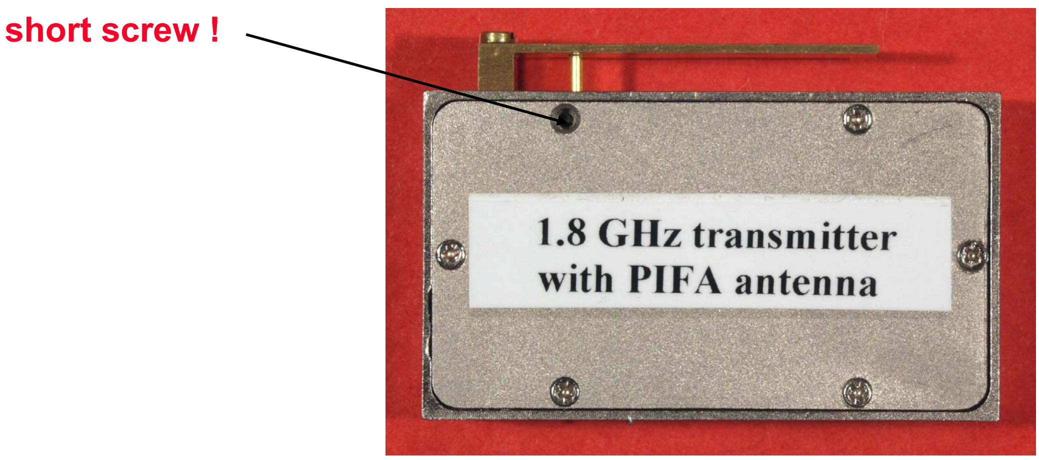


Fig. 23. Opening the cover.

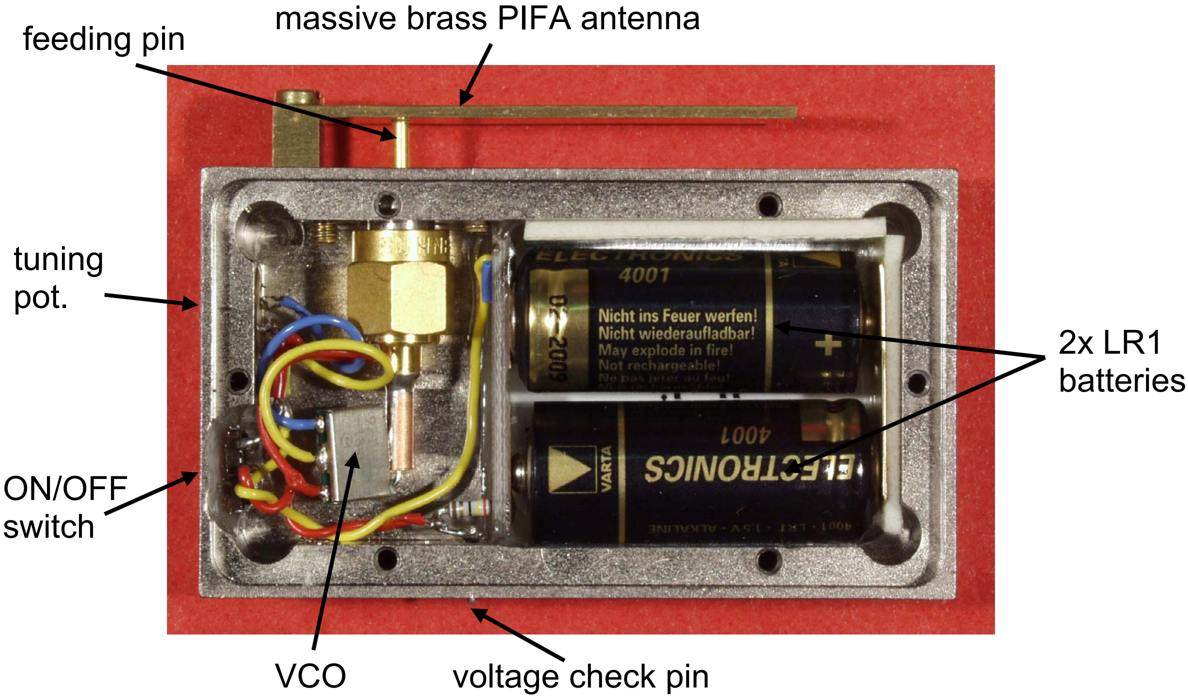


Fig. 24. Cover removed.

Step 2: Replace both batteries with identical types. Pay attention to the polarity when inserting the batteries: there is no protection against wrong polarity!

6.3 Replacing the PIFA with the SMA connector

In order to measure the VCO power output at the desired frequencies, the PIFA has to be removed and replaced with the SMA connector. In order to do this the following steps should be taken.

Step 1: Remove the two M2 screws fastening the PIFA, Fig. 25.

Fig. 25. M2 screws fastening the PIFA.

Step 2: Extract the PIFA with its connecting pin, which is soldered to the PIFA, Fig. 26.

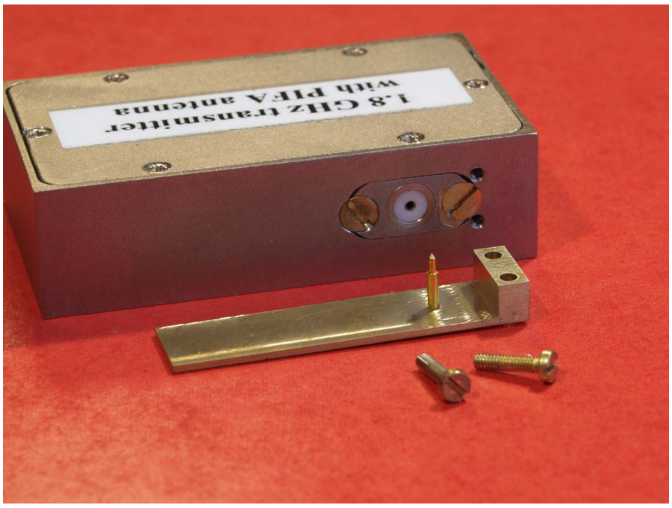


Fig. 26. PIFA dismounted.

Step 3: Remove the two screws fastening the connector to the box, Fig. 27.

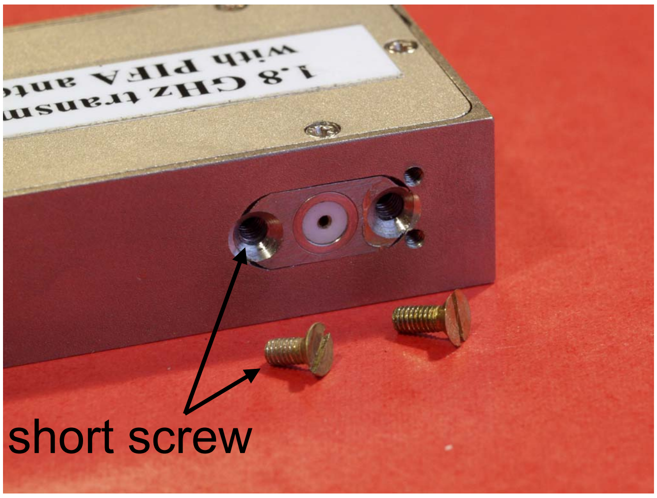


Fig. 27. Screws fastening the connector to the box.

Step 4: Insert the SMA connector in place, and fasten it with the two M2.5 screws , Fig. 28.

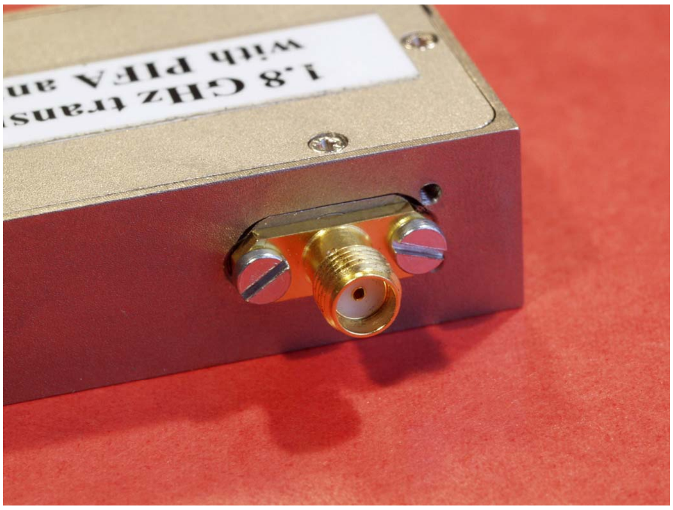


Fig. 28. SMA connector mounted.

To re-install the PIFA, proceed in the inverse order, taking care to the screws fastening the connector to the box: they have different length (see Fig. 27).

Secure the screws firmly, but not too much, they are small and delicate!

6.4 Tuning potentiometer and ON/OFF switch

In order to tune the frequency of the VCO use the tuning potentiometer shown in Fig. 29.

The battery voltage can be checked at the voltage check pin, Fig. 30, when the ON/OFF switch (shown in Fig. 29) is in OFF. When the switch is in ON position the voltage at the voltage check pin is that of the stabilized VCO voltage.

The stabilized VCO voltage should be 2.698V ±0.002V.

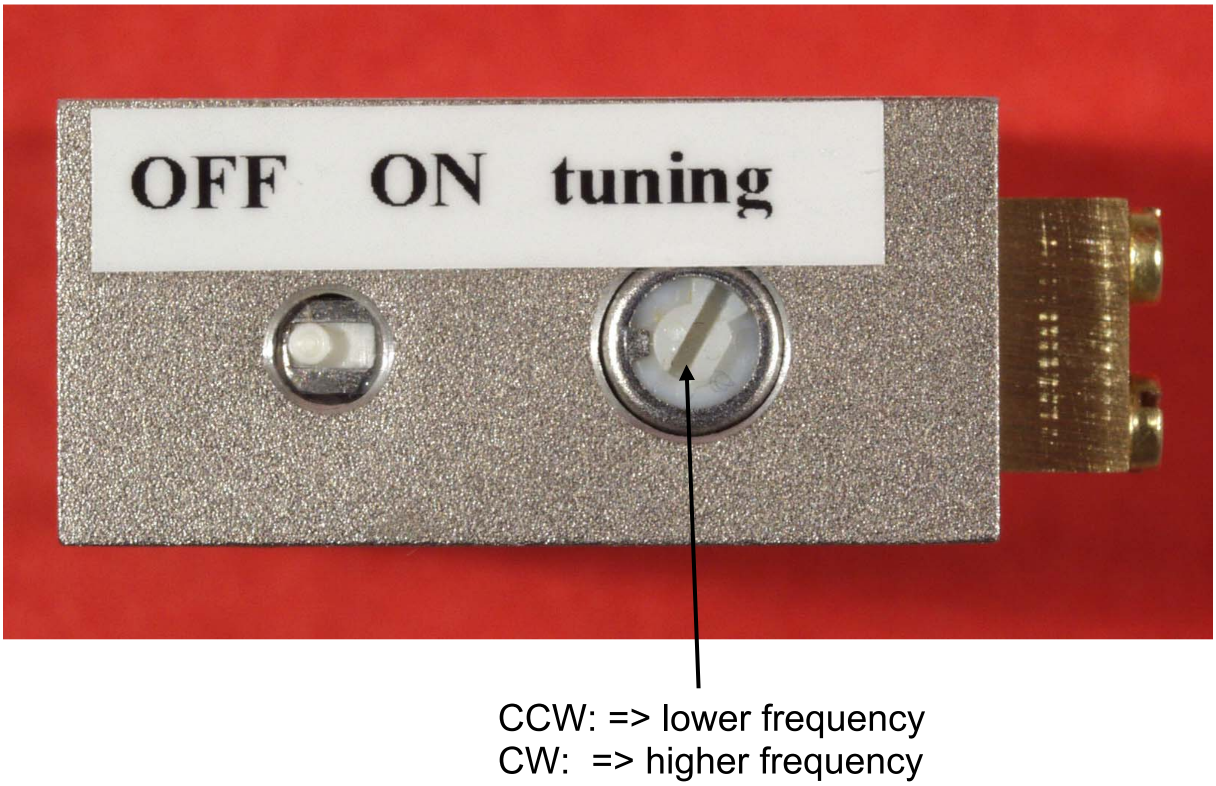
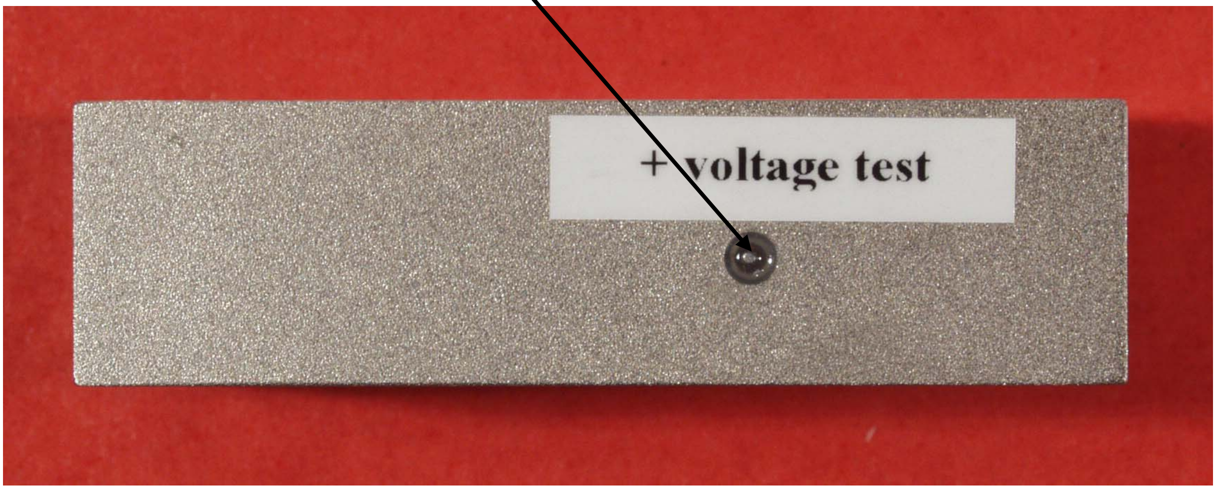


Fig. 29. Tuning potentiometer and ON/OFF switch.

the voltage can be tested at any time without opening the box.
Switch OFF: battery voltage, switch ON: VCO voltage (stabilized)



Note: the stabilized VCO voltage should be 2.698V ±0.002V

Fig. 30. Voltage test pin.

6.5 VCO power measurement

Once the PIFA has been removed and replaced with the SMA connector, the VCO output power can be measured at the desired frequencies.

First, the VCO voltage has to be checked with an accurate DVM; it should be 2.698V ±0.002V. If it is lower, the batteries have to be replaced.

Use an accurately calibrated power meter, check the zero before each measurement, and verify the calibration at the end of the measurements. To simultaneously measure the frequency, connect a microwave probe (a coaxial cable with the shielding removed at one end) to a spectrum analyzer with counter capability, or to a sensitive frequency counter, and place the open end of the coaxial cable close to the voltage test pin: there is enough leakage at this pin to allow measurement of the signal frequency. Turning the potentiometer with a screwdriver, the frequency can be adjusted between approximately 1720 and 1980 MHz.

7 References

[1] ACE – Antenna Centre of Excellence (http://www.ist-ace.org/).
[2] ACE WP 2.2-2 document, "Description of Benchmarking Tests with Tables for Results".

Annex III

DESCRIPTION OF BENCHMARKING TESTS WITH TABLES FOR RESULTS

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Background

This document describes measurement cases that have been defined within the ACE, the FP6 Network of Excellence dedicated to antennas [1]. The measurement cases have been defined within the work package "Benchmarking of Measurement Facilities" which is a part of the "Small Terminal and Smart Antennas" activity. The main objectives are the definition of test cases for the characterisation of terminal antennas and the comparison of results from measurements performed at different antenna test facilities around Europe.

Since the time slot for each participating laboratory is limited and some of the measurement cases might be quite time consuming, colour codes are used for marking the priority. A dark grey colour defines the highest priority; these measurements should be done by all who have the capability of measuring the particular parameter. Light grey and white colours define the next two priority levels; these measurements should be done if the allocated time allows for it. Please note that it is important that as many test cases as possible are measured in order to guarantee a sufficient number of cases for a good comparison.

Contents

1 Contact information

The results reported in this document have been measured by the following organisation:

Name of organisation: ………………………………………………………………

Address: ……………………………………………………………………………….

Country: ……………………………………………………………………………….

Contact person at the above organisation is:

First name: ……………………………………………………………………………

Family name: …………………………………………………………………………

E-mail address: ……………………………………………………………………….

Measured results should be reported by filling out this document, either in electronic format or in paper format, and then the document should be sent to:

Jan Carlsson, ELx
SP Swedish National Testing and Research Institute
Box 857
SE-501 15 Borås
Sweden
E-mail address: jan.carlsson@sp.se

2 Efficiency measurements

Efficiency measurements should be done for three dipoles and one slot antenna. The dipoles should be measured in free space and close to a lossy cylinder, respectively. The slot antenna should only be measured in free space.

The test setup consists of a dipole and a cylinder which is filled with a lossy liquid, see Fig. 1. The distance between the dipole and the cylinder can be varied so that the radiation efficiency can be adjusted. Three dipoles for different frequency ranges are used. Measurement cases with the dipole in free space and at two distances from the cylinder are defined, thus a total of nine configurations. For instructions on how to handle the dipoles and the cylinder see the document "Handling Instructions for Benchmarking Devices", [2]. For the 5.2 GHz band a slot antenna is used instead of a dipole. The slot antenna should only be measured in free space, i.e. the cylinder is not used when measuring this antenna. However, for the slot antenna both efficiency and the peak gain should be measured.

Parameters to measure are *radiation efficiency* and *total radiation efficiency.* Here we define the *radiation efficiency* as the ratio of the radiated power to the net power delivered to the antenna. The *total radiation efficiency* is defined as the ratio of the radiated power to the maximum available power from a 50 ohm source. Thus, this includes losses in the antenna itself, losses in the near-in environment of the antenna, and impedance mismatch. The definitions are given by:

$$\begin{cases} Radiation\ Efficiency = \dfrac{P_{rad}}{P_{in}} \\ Total\ Radiation\ Efficiency = \dfrac{P_{rad}}{P_{\max}} = \left(1-\left|S_{11}\right|^2\right)\dfrac{P_{rad}}{P_{in}} \end{cases}$$

Fig. 1. Passive device test setup – Single dipole for efficiency measurements.

2.1 Single dipole close to cylinder – 900 MHz band

Laboratory ………………………………………………………………………………………
Description of measurement method and setup (preferable also pictures)…………………..
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Ambient temperature (°C).………………..………………………………………………..
Relative humidity (%)………………..………………………………………………………
Claimed total expanded uncertainty, 2σ (dB)…………………………………………………
Approx. meas. time per frequency (s)…………………………………………………………

Note: The dipole with the identification number 8.9 should be used for these measurements.

	Dipole in free space				
	800 MHz	850 MHz	900 MHz	950 MHz	1000 MHz
Radiation Efficiency (dB)					
Total Radiation Efficiency (dB)					

	Distance between dipole and cylinder 20 mm				
	800 MHz	850 MHz	900 MHz	950 MHz	1000 MHz
Radiation Efficiency (dB)					
Total Radiation Efficiency (dB)					

	Distance between dipole and cylinder 10 mm				
	800 MHz	850 MHz	900 MHz	950 MHz	1000 MHz
Radiation Efficiency (dB)					
Total Radiation Efficiency (dB)					

Highest priority	2nd highest priority	Lowest priority

2.2 Single dipole close to cylinder – 1800 MHz band

Laboratory ………………………………………………………………………………………
Description of measurement method and setup (preferable also pictures)….………………..
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……………….………………………………………………………………………………..
Ambient temperature (°C).……………..………………………………………………..
Relative humidity (%)……………….…………………………………………………………
Claimed total expanded uncertainty, 2σ (dB)………………………………………………
Approx. meas. time per frequency (s)……………………………………………………

Note: The dipole with the identification number 8.18 should be used for these measurements.

	Dipole in free space				
	1700 MHz	1750 MHz	1800 MHz	1850 MHz	1900 MHz
Radiation Efficiency (dB)					
Total Radiation Efficiency (dB)					

	Distance between dipole and cylinder 20 mm				
	1700 MHz	1750 MHz	1800 MHz	1850 MHz	1900 MHz
Radiation Efficiency (dB)					
Total Radiation Efficiency (dB)					

	Distance between dipole and cylinder 10 mm				
	1700 MHz	1750 MHz	1800 MHz	1850 MHz	1900 MHz
Radiation Efficiency (dB)					
Total Radiation Efficiency (dB)					

Highest priority	2nd highest priority	Lowest priority

2.3 Single dipole close to cylinder – 2400 MHz band

Laboratory ……………………………………………………………………………………
Description of measurement method and setup (preferable also pictures)….………………..
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Ambient temperature (°C).……………..………………………………………………..
Relative humidity (%)……………….……………………………………………………
Claimed total expanded uncertainty, 2σ (dB)………………………………………………
Approx. meas. time per frequency (s)……………………………………………………

Note: The dipole with the identification number 8.24 should be used for these measurements.

	Dipole in free space				
	2300 MHz	2350 MHz	2400 MHz	2450 MHz	2500 MHz
Radiation Efficiency (dB)					
Total Radiation Efficiency (dB)					

	Distance between dipole and cylinder 20 mm				
	2300 MHz	2350 MHz	2400 MHz	2450 MHz	2500 MHz
Radiation Efficiency (dB)					
Total Radiation Efficiency (dB)					

	Distance between dipole and cylinder 10 mm				
	2300 MHz	2350 MHz	2400 MHz	2450 MHz	2500 MHz
Radiation Efficiency (dB)					
Total Radiation Efficiency (dB)					

Highest priority	2nd highest priority	Lowest priority

2.4 Slot antenna in free space – 5200 MHz band

Laboratory ………………………………………………………………………………
Description of measurement method and setup (preferable also pictures)………………………..
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…………………………………………………………………………………………..
Ambient temperature (°C)………………………………………………………………..
Relative humidity (%)……………………………………………………………………
Claimed total expanded uncertainty, 2σ (dB)………………………………………………
Approx. meas. time per frequency (s)…………………………………………………………

	Slot antenna in free space				
	5100 MHz	5150 MHz	5200 MHz	5250 MHz	5300 MHz
Radiation Efficiency (dB)					
Total Radiation Efficiency (dB)					

	Slot antenna in free space
	5200 MHz
[1]*Peak Gain* (dBi)	

[1]Power gain in the direction of maximum radiation relative a lossless isotropic source. Power gain is defined as 4π times the radiation intensity to the net power accepted by the antenna from a connected source.

Highest priority	2nd highest priority	Lowest priority

3 Diversity gain measurements

The diversity gain measurements should be done for one configuration at one frequency only.

The test setup consists of two dipoles for the 900 MHz band and a cylinder which is filled with a lossy liquid, see Fig. 2. Since diversity measurements normally are quite time consuming we have restricted the measurements to only one case. Thus, the dipoles are mounted at only one distance from the cylinder and from each other, respectively. Details for the mounting of the dipoles can be found in the document "Handling Instructions for Benchmarking Devices", [2].

Parameters to measure are *effective, actual* and *apparent diversity gains* at 900 MHz and at a cumulative probability level (CDF) of 1 % when selection combining is used. The environment is assumed to be isotropic, i.e. equal probability for all angles of arrival.

By *effective diversity gain* we mean the gain relative to what is obtained by using a separate single antenna with 0 dB radiation efficiency, i.e. compared to an ideal reference in free space. *Actual diversity gain* is defined as the gain relative to a single dipole placed close to the cylinder and *apparent diversity gain* is defined as relative the strongest branch. These definitions can be found in references [3] – [5] and are also shown in Fig. 3.

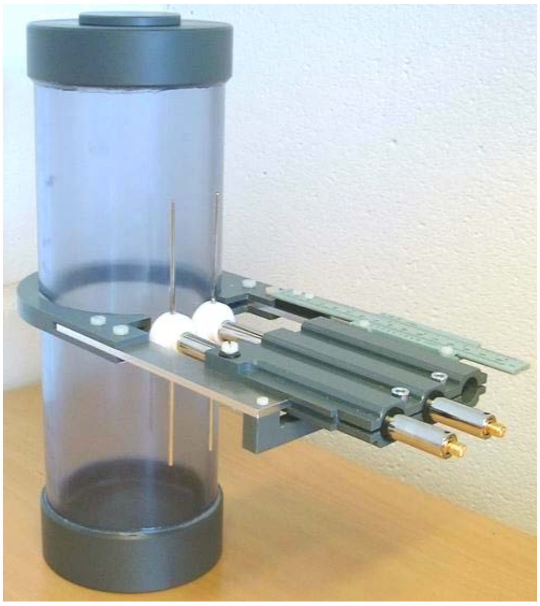

Fig. 2. Passive device test setup – Two dipoles for diversity measurements.

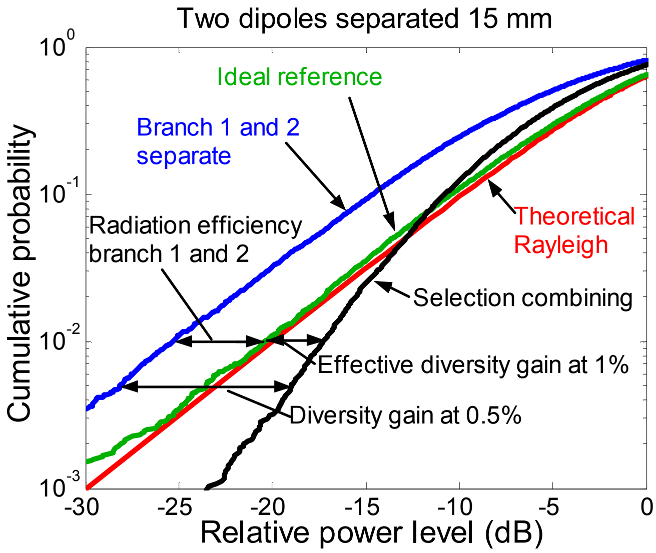

Fig. 3. Diversity gain of an example dual dipole diversity antenna. The apparent and effective diversity gains are marked as 1% and 0.5% cumulative probability levels, respectively. The diversity algorithm is selection combining

3.1 Two dipoles close to cylinder – 900 MHz band

Laboratory ……………………………………………………………………………………
Description of measurement method and setup (preferable also pictures)…………………..
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…………………………………………………………………………………………..
…………………………………………………………………………………………..
Ambient temperature (°C)…………………………………………………………………..
Relative humidity (%)………………………………………………………………………
Claimed total expanded uncertainty, 2σ (dB)…………………………………………………
Approx. meas. time per frequency (s)………………………………………………………

Note: The dipole with the identification number 8.9 should be mounted in the centre. This dipole should also be used as the reference for effective and actual diversity gain measurements.

	Diversity gain @ 1% CDF, selection combining Two dipoles separated 30 mm and at a distance of 20 mm from cylinder		
	[1] Effective Diversity Gain (dB)	[2] Actual Diversity Gain (dB)	[3] Apparent Diversity Gain (dB)
900 MHz			

[1] Relative one of the dipoles when it is placed in free space
[2] Relative the centre mounted dipole when the other is absent
[3] Relative the strongest branch (both dipoles mounted)

4 Total radiated power measurements

Total radiated power should be measured for a special triple band GSM phone and a small active device radiating at 1.785 GHz. Measurements should be done for free space conditions and for the GSM phone also for a talk position close to a head phantom. The head phantom and the talk position "cheek right" that should be used are according to what is described in [6]. The idea behind the use of the head phantom is to get a measure of the variations between different laboratories due to the use of different phantoms and the positioning of the phone by different operators.

Operation instructions for the active devices can be found in the document "Handling Instructions for Benchmarking Devices", [2].

The total radiated power (TRP) is a measure of the power the device actually radiates, when non-idealities such as mismatch and losses in the antenna are taken into account. The TRP is defined as the integral of the power transmitted in different directions over the entire radiation sphere, [7]. For the GSM phone the power level should be determined as the average of the samples over the 147 useful bits, i.e. the useful part, of the GSM pulse, Fig. 6 and reference [8].

Fig. 4. Special phone for total radiated power measurements. Front and backside, respectively.

Fig. 5. Active device radiating at 1.785 GHz used for total radiated power measurements.

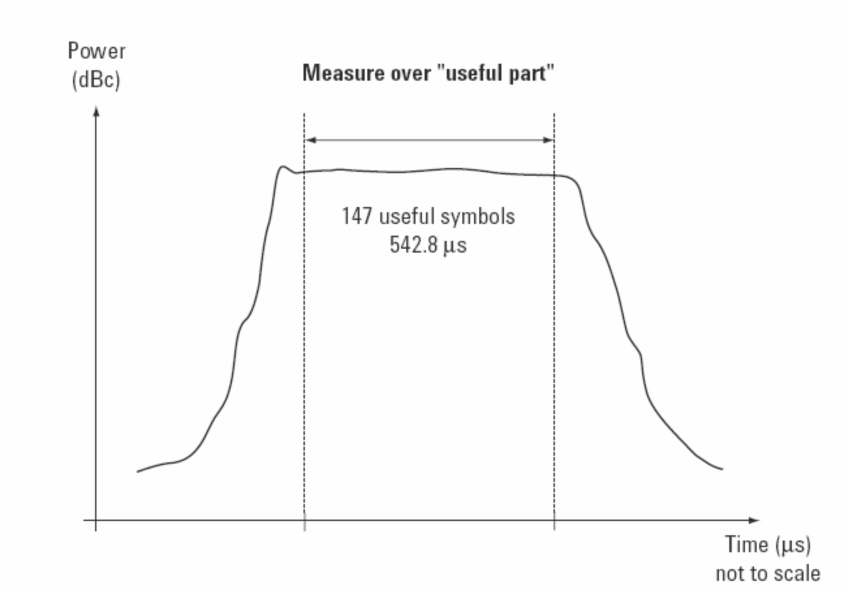

Fig. 6. GSM pulse.

4.1 Special triple band GSM phone – 900 MHz band

Laboratory ………………………………………………………………………………………
Description of measurement method and setup (preferable also pictures)…………………..
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Type of head phantom …...………………..……………………………………………………..
Ambient temperature (°C)……………...…………………………………………………..
Relative humidity (%)…………………………………………………………………………
Claimed total expanded uncertainty, 2σ (dB)………………………………………………
Approx. meas. time per frequency (s)…………………………………………………………

Note: The special phone that should be used has IMEI number 35441600-275762-3.

	Special triple band GSM phone Free space position		
	Ch 975 880.2 MHz	Ch 35 897 MHz	Ch 124 914.8 MHz
[1] *Connector power before TRP* (dBm)			
Total Radiated Power (dBm)			
[2] *Connector power after TRP* (dBm)			

	Special triple band GSM phone Talk position – Cheek right[3]		
	Ch 975 880.2 MHz	Ch 35 897 MHz	Ch 124 914.8 MHz
[1] *Connector power before TRP* (dBm)			
Total Radiated Power (dBm)			
[2] *Connector power after TRP* (dBm)			

[1,2] Power should be measured at the connector before and after the total radiated power measurements in order to have control of the battery status.
[3] Head phantom and position according to EN 50361

Highest priority	2nd highest priority	Lowest priority

4.2 Special triple band GSM phone – 1800 MHz band

Laboratory ………………………………………………………………………………………
Description of measurement method and setup (preferable also pictures)….………………..
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……………….………………………………………………………………………………..
Type of head phantom …...……………..……………………………………………………..
Ambient temperature (°C)……………..………………………………………………………..
Relative humidity (%)………………..………………………………………………………
Claimed total expanded uncertainty, 2σ (dB)………………………………………………
Approx. meas. time per frequency (s)…………………………………………………………

Note: The special phone that should be used has IMEI number 35441600-275762-3.

	Special triple band GSM phone Free space position		
	Ch 512 1710.2 MHz	Ch 696 1747 MHz	Ch 885 1784.8 MHz
[1] *Connector power before TRP* (dBm)			
Total Radiated Power (dBm)			
[2] *Connector power after TRP* (dBm)			

	Special triple band GSM phone Talk position – Cheek right[3]		
	Ch 512 1710.2 MHz	Ch 696 1747 MHz	Ch 885 1784.8 MHz
[1] *Connector power before TRP* (dBm)			
Total Radiated Power (dBm)			
[2] *Connector power after TRP* (dBm)			

[1,2] Power should be measured at the connector before and after the total radiated power measurements in order to have control of the battery status.
[3] Head phantom and position according to EN 50361

Highest priority	2nd highest priority	Lowest priority

4.3 Special triple band GSM phone – 1900 MHz band

Laboratory ……………………………………………………………………………………
Description of measurement method and setup (preferable also pictures)……………………..
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…………………………………………………………………………………………………..
Type of head phantom ….……………..…………………………………………………..
Ambient temperature (°C)……………..…………………………………………………..
Relative humidity (%)……………….………………………………………………………
Claimed total expanded uncertainty, 2σ (dB)………………………………………………
Approx. meas. time per frequency (s)……………………………………………………

Note: The special phone that should be used has IMEI number 35441600-275762-3.

	Special triple band GSM phone Free space position		
	Ch 512 1850.2 MHz	Ch 661 1880 MHz	Ch 810 1909.8 MHz
[1] *Connector power before TRP* (dBm)			
Total Radiated Power (dBm)			
[2] *Connector power after TRP* (dBm)			

	Special triple band GSM phone Talk position – Cheek right[3]		
	Ch 512 1850.2 MHz	Ch 661 1880 MHz	Ch 810 1909.8 MHz
[1] *Connector power before TRP* (dBm)			
Total Radiated Power (dBm)			
[2] *Connector power after TRP* (dBm)			

[1,2] Power should be measured at the connector before and after the total radiated power measurements in order to have control of the battery status.
[3] Head phantom and position according to EN 50361

Highest priority	2nd highest priority	Lowest priority

4.4 Special 1.785 GHz device

Laboratory ………………………………………………………………………………………
Description of measurement method and setup (preferable also pictures)…..………………..
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Ambient temperature (°C)………………..………………………………………………..
Relative humidity (%)……………….……………………………………………………
Claimed total expanded uncertainty, 2σ (dB)…………………………………………………
Approx. meas. time per frequency (s)………………………………………………………

	Special 1.785 GHz device in free space
	1.785 GHz
Total Radiated Power (dBm)	
[1]*Total Radiation Efficiency* (dB)	

[1]The antenna on the active device can be removed

Highest priority	2nd highest priority	Lowest priority

5 Sensitivity measurements

Sensitivity measurements should be done for a standard triple band GSM phone in free space and in a talk position close to a head phantom. The head phantom and the talk position "cheek right" that should be used are according to what is described in [6]. The idea behind the use of the head phantom is to get a measure of the variations between different laboratories due to the use of different phantoms and the positioning of the phone by different operators.

Since the phone that should be used for these measurements is a standard GSM phone a base station simulator is needed.

The sensitivity level that should be measured is defined as the total isotropic sensitivity at a BER of 2.4 % (± 0.1 %), see [7] and [9]. Since the measurement is time consuming only one channel in each frequency band should be measured. If there is not enough time for all three bands the 900 MHz band is of highest priority.

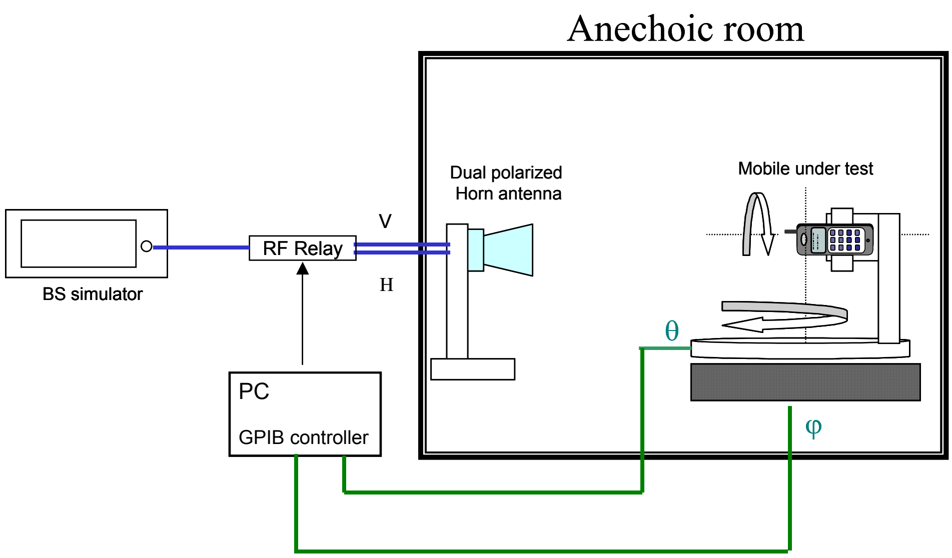

Fig. 7. Typical measurement setup for sensitivity measurements, from [7].

5.1 GSM phone – 900 MHz band

Laboratory ……………………………………………………………………………………
Description of measurement method and setup (preferable also pictures)….………………..
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Type of head phantom …...………………..……………………………………………………..
Ambient temperature (°C)……………….……………………………………………………..
Relative humidity (%)…………………………………………………………………………
Claimed total expanded uncertainty, 2σ (dB)………………………………………………
Approx. meas. time per frequency (s)…………………………………………………………

Note: The GSM phone that should be used has IMEI number 35441600-275764-9.

	Total isotropic sensitivity @ 2.4 % (±0.1 %) BER **Free space position**
	Power Level (dBm)
900 MHz band, Ch 35	

	Total isotropic sensitivity @ 2.4 % (±0.1 %) BER **Talk position – Cheek right[1]**
	Power Level (dBm)
900 MHz band, Ch 35	

[1] Head phantom and position according to EN 50361

Highest priority	2nd highest priority	Lowest priority

5.2 GSM phone – 1800 MHz band

Laboratory ……………………………………………………………………………………
Description of measurement method and setup (preferable also pictures)….…………………..
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……………….………………………………………………………………………………..
Type of head phantom …...………………..…………………………………………………..
Ambient temperature (°C)………………..……………………………………………………..
Relative humidity (%)…………………….………………………………………………………
Claimed total expanded uncertainty, 2σ (dB)………………………………………………
Approx. meas. time per frequency (s)……………………………………………………………

Note: The GSM phone that should be used has IMEI number 35441600-275764-9.

	Total isotropic sensitivity @ 2.4 % (±0.1 %) BER Free space position
	Power Level (dBm)
1800 MHz band, Ch 696	

	Total isotropic sensitivity @ 2.4 % (±0.1 %) BER Talk position – Cheek right[1]
	Power Level (dBm)
1800 MHz band, Ch 696	

[1] Head phantom and position according to EN 50361

Highest priority	2nd highest priority	Lowest priority

5.3 GSM phone – 1900 MHz band

Laboratory ……………………………………………………………………………………
Description of measurement method and setup (preferable also pictures)………………….
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……………………………………………………………………………………………..
Type of head phantom ……………………………………………………………………..
Ambient temperature (°C)………………………………………………………………..
Relative humidity (%)………………………………………………………………………
Claimed total expanded uncertainty, 2σ (dB)……………………………………………
Approx. meas. time per frequency (s)……………………………………………………

Note: The GSM phone that should be used has IMEI number 35441600-275764-9.

	Total isotropic sensitivity @ 2.4 % (±0.1 %) BER Free space position
	Power Level (dBm)
1900 MHz band, Ch 661	

	Total isotropic sensitivity @ 2.4 % (±0.1 %) BER Talk position – Cheek right[1]
	Power Level (dBm)
1900 MHz band, Ch 661	

[1] Head phantom and position according to EN 50361

Highest priority	2nd highest priority	Lowest priority

6 References

[1] ACE – Antenna Centre of Excellence (http://www.ist-ace.org/).
[2] ACE WP 2.2-2 document, "Handling Instructions for Benchmarking Devices".
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[5] P-S. Kildal, K. Rosengren, J. Byun, J. Lee, "Definition of effective diversity gain and how to measure it in a reverberation chamber", Microwave and Optical Technology Letters, Vol. 34, No 1, pp. 56-59, July 5, 2002.
[6] European Standard EN 50361, Basic standard for the measurement of Specific Absorption Rate related to human exposure to electromagnetic fields from mobile phones (300 MHz – 3 GHz), CENELEC European Committee for Electrotechnical Satandardization, rue de Stassart 35, B – 1050 Brussels, July 2001.
[7] COST 273 SWG2.2 Pre-standard, "Measurements of Radio Performances for UMTS Terminals in Speech Mode", 28th of Oct. 2004.
[8] 3GPP TS 51.010-1 v. 5.10.0 release 5.
[9] M. B. Knudsen, "Antenna Systems for Handsets", PhD Thesis, Aalborg University, Nov. 2001.