RESULTS AND EXPERIENCES FROM TWO YEARS OF BENCHMARKING OF MEASUREMENT FACILITIES FOR SMALL ANTENNAS AND TERMINALS WITHIN ACE

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ABSTRACT

This paper presents the test cases defined in ACE (European Antenna Centre of Excellence) for benchmarking of facilities for measuring small mobile terminals and antennas, as well as results and experiences of the round robin test. The emphasis is put on measurements in the most popular communication frequency bands. Several test cases for passive antennas as well as for active devices were defined and collected in a test kit that was sent to different test facilities around Europe in a round robin test. The measured parameters include radiation efficiency, total radiated power, diversity gain and receiver sensitivity. The test cases include different locations of the test devices relative to a lossy cylinder that has dielectric characteristics resembling that of a human head.

1. INTRODUCTION

Benchmarking of facilities for measuring small mobile terminals and antennas is a work package included in the small terminals and smart antennas activity within ACE – Antenna Centre of Excellence [1]. Among the main objectives of the work package are the definition of representative test cases for the benchmarking of terminal antennas and the comparison of results from measurements performed at different antenna test facilities around Europe.

Usually, antennas are characterized by their radiation patterns. This is appropriate when the lobes are narrow and there is line of sight between the two sides. However, when considering terminal antennas, such as those used in mobile phones and PDA devices, the environment varies with time and is very complex with several scatterers. This means that the environment can only be described statistically and therefore a better way to describe antennas used in such conditions is to use the total radiation efficiency. This includes contributions from losses in the antenna itself, losses in the near-in environment of the antenna and impedance mismatch. When the impedance mismatch is not included, we call the remaining factor the radiation efficiency. The total radiation efficiency is a correct measure of the quality of antennas that are designed for use in a so called uniform multi-path environment, where there is no line of sight to the base station and reflected and scattered waves come in with equal probability from all directions in space. Total radiation efficiency for terminal antennas can be measured using many different methods, e.g. by measuring the 3D radiation pattern and integrating, using a reverberation chamber [2] or a Wheeler cap [3]. Since participants in the round robin use different test methods, the test devices are constructed so that they can be used in different set-ups and at the same time be configurable so that several test cases can be defined using the same device. Of course, it is also an advantage if the test devices are simple enough to allow numerical simulations with good accuracy for enabling additional comparisons. The dipole antenna test fixture that was constructed and manufactured fulfils these requirements. It can be used for both efficiency and diversity gain measurements.

The active devices included in the test kit are intended for measuring total radiated power (TRP) and total isotropic receiving sensitivity (TIS). The TRP test cases include a GSM phone with special software allowing it to radiate at a constant power level, and a specially developed 1.785 GHz device radiating a continuous signal without modulation. The sensitivity test case is a standard GSM phone, and requires the use of a mobile communication test unit for the measurements. TRP and TIS measurements for the GSM phones can be done with the phone in a free space position as well as in a talk position close to a head phantom. TRP for the 1.785 GHz device is only measured for free space conditions. An overview of the different possible test cases and the test kit can be seen in Fig. 1 and 2, respectively.

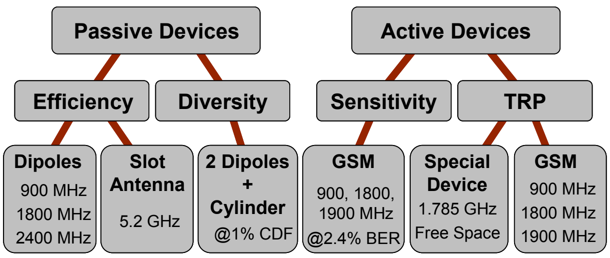

Figure 1. Test cases.

Proc. 'EuCAP 2006', Nice, France
6–10 November 2006 (ESA SP-626, October 2006)

Figure 2. Test kit including suitcase used for shipping.

2. TEST CASES

In order to define simple and repeatable test cases for the round robin, passive antennas consisting of dipoles for 900, 1800 and 2400 MHz bands and a slot antenna for the 5.2 GHz band are used. The dipoles are equipped with standard shielded quarter-wavelength baluns. In order to account for losses in objects close to the terminal antenna, resembling e.g. the head of a mobile phone user, the test fixture consist of a lossy cylinder and an adjustable antenna mount, Fig. 3. The distance between the antenna and the lossy cylinder can be adjusted which means that the radiation efficiency can be varied. The distance can accurately be read on a scale on the antenna mount so that repeatability is guaranteed. All antennas are measured for free space conditions as well as at different distances from the lossy cylinder using the fixture in Fig. 3. In order to measure diversity gain the same fixture can be used but now with two dipoles mounted as shown in Fig. 3.

Figure 3. Test fixture for passive antennas.

As active devices a triple band GSM phone and a small active device for the 1.785 GHz band are used. The GSM phone is a standard triple band phone equipped with special software making it radiate at full power. The channel can be set by using the key pad which means that the phone is usable even without a base station emulator. It is therefore possible to measure it at test facilities that do not have such emulators. The phone has an external antenna connector so that the output power delivered directly from the transmit amplifier can be checked both before and after the radiated power measurements. This is done in order to ensure that changes in battery power do not affect measured results and to ensure that nothing has happened to the phone during the course of the round robin. For both the phone and the small active device the total radiated power is measured both for free space conditions, and when the phone is located in a talk position close to a head phantom. The head phantom is actually not included in the test kit; the idea is to see the effects of different type of head phantoms that might be used at the participating laboratories.

The same type of triple band GSM phone can be also used for the receiver sensitivity measurements. For this case the phone is a standard phone with the original software, and it is therefore necessary to use a base station emulator. These measurements can also be done both for free space conditions and for a talk position with the phone close to a head phantom.

3. ROUND ROBIN

In order to collect data from different test facilities around Europe the passive as well as active test cases described in the previous section have been sent to ten different test facilities in a round robin test. In order to guarantee comparable results only one test kit has been sent around, see Fig. 2. This means e.g. that the same sealed lossy cylinder with its liquid and the same active devices are measured at all participating facilities.

Given the passive and active device configurations described in the previous sections, it is possible to define many different test cases. However, it should be noted that not all test facilities have the technical capabilities to measure all possible test cases. Also, it might be too time consuming to measure all cases due to the limited time available for each test facility. Of these reasons test matrices with priority levels were defined from which the participants could select which test cases to measure. The round robin was organised in such a way that the participants would not know which organisations had already performed their measurements, in order to guarantee that no one had access to results beforehand. The ten participants used different measurement methods including 3D radiation pattern integration in fully anechoic chambers, spherical near field methods [4]-[5], a random positioner system, and reverberation chambers [2], [6]-[7].

The measurements were conducted in two periods between December 2004 and June 2005 and September 2005 and December 2005, respectively. 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 are therefore comparable.

A time period of two weeks for the measurements was allocated for each of the participants and at least one week in-between was reserved for shipping of the devices. This schedule turned out to work well in the first measurement period but we experienced some problems in keeping the schedule in the second period. This was mainly due to problems with customs and that some of the devices were damaged during shipping. E.g. was it unfortunately necessary to remove the active device for the 1.785 GHz band from the benchmarking since it was destroyed at the beginning of the second period.

4. RESULTS

Since the number of test cases included in the benchmarking are quite many only a few examples can be presented here. As a first example, Fig. 4-5 show the total radiation efficiency for the 1800 MHz dipole in free space and when it is located at a distance of 20 mm from the lossy cylinder, respectively. In Table 1 the difference from the mean value for the free space condition is shown. From Fig. 4-5 and Table 1 it can be observed that the maximum difference between measured values is less the 1.5 dB and the maximum deviation from the mean value is 1.0 dB.

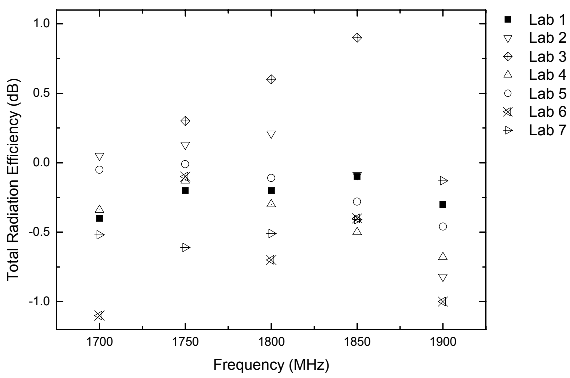

Figure 4. Measured total radiation efficiency for the 1800 MHz dipole in free space.

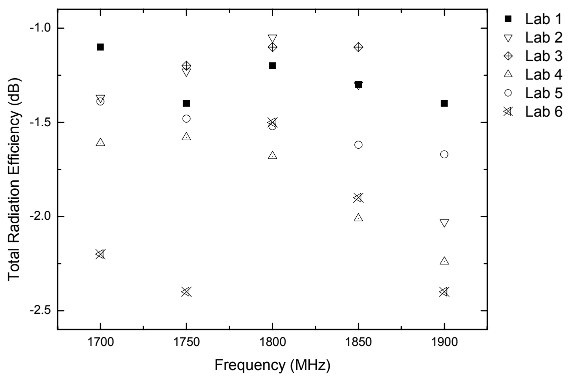

Figure 5. Measured total radiation efficiency for the 1800 MHz dipole when it is located at a distance of 20 mm from the lossy cylinder.

		Frequency (MHz)				
		1700	1750	1800	1850	1900
	Mean (dB)	-0.38	-0.08	-0.13	-0.10	-0.55
Deviation from mean (dB)	Lab 1	-0.02	-0.12	-0.07	0.00	0.25
	Lab 2	0.43	0.21	0.34	0.01	-0.27
	Lab 3	-	0.38	0.73	1.00	-
	Lab 4	0.04	-0.05	-0.17	-0.40	-0.13
	Lab 5	0.33	0.07	0.02	-0.18	0.09
	Lab 6	-0.72	-0.02	-0.57	-0.30	-0.45
	Lab 7	-0.14	-0.53	-0.38	-0.31	0.42

Table 1. Deviation from mean total radiation efficiency for the 1800 MHz dipole in free space.

The measured total radiation efficiency for the 5.2 GHz slot antenna is shown in Fig. 6, and the difference from the mean value is given in Table 2. The slot antenna was only measured for free space conditions. It can be observed that the spread in the measured values is larger for the slot antenna than it is for the dipole.

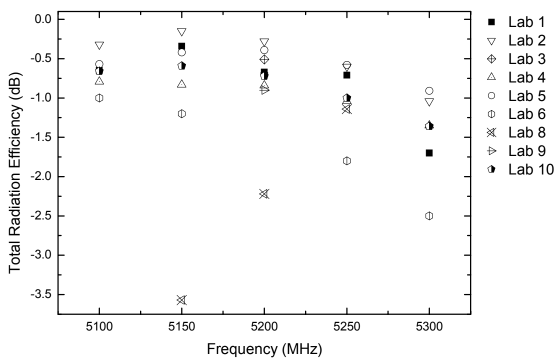

Figure 6. Measured total radiation efficiency for the 5.2 GHz slot antenna in free space.

		Frequency (MHz)				
		5100	5150	5200	5250	5300
	Mean (dB)	-0.66	-0.90	-0.77	-0.96	-1.45
Deviation from mean (dB)	Lab 1	0.01	0.56	0.10	0.25	-0.25
	Lab 2	0.34	0.75	0.49	0.36	0.41
	Lab 3	-	-	0.26	-	-
	Lab 4	-0.13	0.07	-0.07	-0.08	0.10
	Lab 5	0.09	0.48	0.38	0.38	0.54
	Lab 6	-0.34	-0.30	0.07	-0.84	-1.05
	Lab 8	-	-2.67	-1.45	-0.18	-
	Lab 9	-	-	-0.13	-	-
	Lab 10	0.00	0.31	0.05	-0.04	0.09

Table 2. Deviation from mean total radiation efficiency for the 5.2 GHz slot antenna in free space.

Total radiated power was measured for a triple band GSM phone equipped with special software making it radiate at full power. Measurements were performed for free space conditions and also with the phone in a talk position close to a head phantom. The three participants using head phantoms used different types of phantoms; SPEAG generic head phantom V3.5, SPEAG SAM V4.5 anthropomorphic head model and a non-standard liquid full head phantom. For all cases the measurements were performed with the phone in a cheek right position according to the SAR measurement standard EN 50361. The results are shown in Fig. 7-10. From the results it can be seen that the loss in the head phantom is much higher in the 900 MHz band than it is in the higher frequency band. This agrees well with experience from other investigations. It can also be noted that the loss in the different head phantoms is very similar.

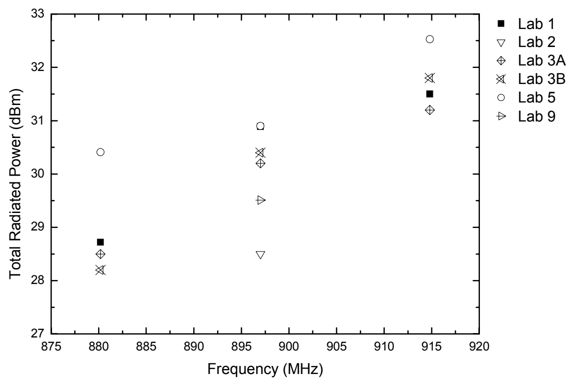

Figure 7. Measured total radiated power in the 900 MHz band for the special GSM phone in free space.

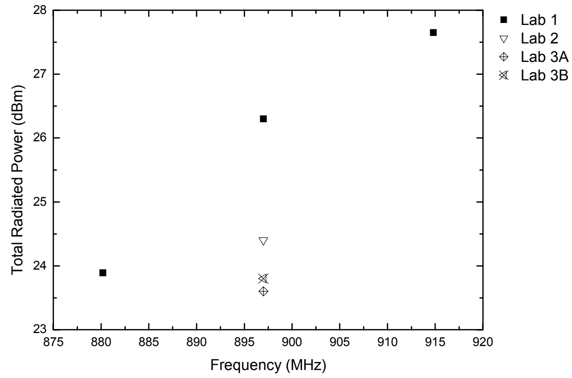

Figure 8. Measured total radiated power in the 900 MHz band for the special GSM phone when it is in a talk position close to a head phantom.

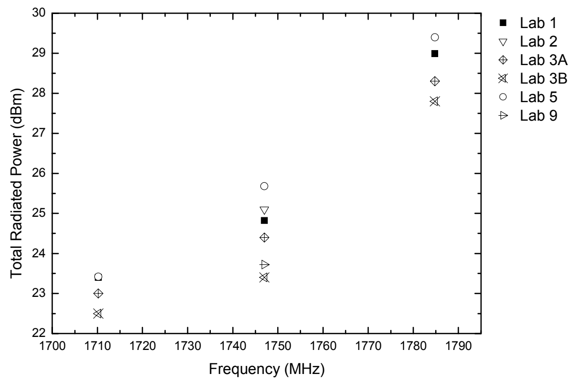

Figure 9. Measured total radiated power in the 1800 MHz band for the special GSM phone in free space.

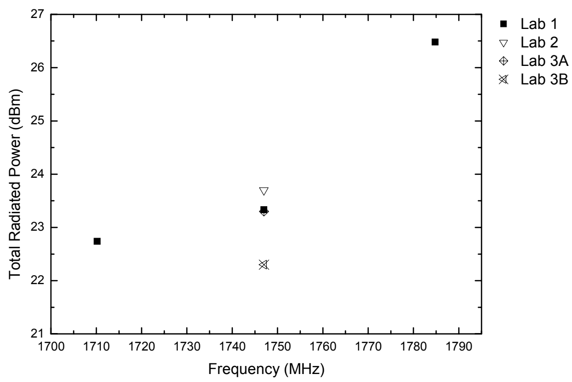

Figure 10. Measured total radiated power in the 1800 MHz band for the special GSM phone when it is in a talk position close to a head phantom.

5. CONCLUSION

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 results from one particular participant are disregarded the maximum deviation from mean value is 1.5 dB for all cases. 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 diversity gain for two dipoles placed close to the lossy cylinder and also total isotropic sensitivity was measured by two participants 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.

Overall, the benchmarking was successful so it will be continued in ACE-2 that recently has been started. In the new benchmarking the same devices will be used but new cases will also be added. One example is a 3G-phone that will be used for TRP as well as TIS measurements.

6. REFERENCES

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