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Whole-body SAR measurements of millimeter wave base station in a reverberation chamber

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Summary

This work presents a method for measuring whole-body specific absorption rate (WBSAR) of millimeter wave base stations in a reverberation chamber (RC). By first measuring the power radiated from the equipment under test (EUT) and then measuring the radiated power when a phantom is placed directly in front of the EUT, the power absorbed in the phantom can be obtained and hence WBSAR. When calibrated, the resulting absorbed power is given by direct illumination of the phantom only. The measurement method was tested at 28 GHz using a horn antenna and an Ericsson massive MIMO base station. The results show good agreement to numerical computations using CST and allows for fast measurements. The method can be used for electromagnetic field exposure assessment of compliance with ICNIRP 2020 guidelines which extends the validity of WBSAR above 10 GHz.

1. Introduction

To be placed on the market, radio equipment must comply with internationally recognized radio frequency electromagnetic field exposure (EMF) limits such as the ones specified by ICNIRP [1]. ICNIRP provides basic restrictions related to physical quantities inside the body. Whole-body specific absorption rate (WBSAR) is one of the basic restrictions, valid up to 300 GHz and defined as

$$\text{WBSAR} = \frac{P_{Abs}}{m} \tag{1}$$

where P_{Abs} is the power absorbed in the body and m is the whole-body mass. While previously limited to frequencies lower than 10 GHz, in the 2020 guidelines ICNIRP extended the validity of WBSAR up to 300 GHz. Hence, there is currently a need for methods for measurements of WBSAR at millimeter wave frequencies [1]. In this work, a method is proposed to measure WBSAR by means of a reverberation chamber (RC). A two-step approach is used to identify the contribution to WBSAR caused by direct illumination of the exposed body, i.e., the required quantity to assess EMF compliance.

2. Measuring the radiated power of a source in a RC

The radiated power for the equipment under test (EUT), $P_{Tx|\text{EUT}}$, is simply determined by measurements of the power at the receiving antenna, $P_{Rx|\text{EUT}}$, and by knowledge of the transfer function

$$G = \frac{\langle P_{Rx|\text{Ref}} \rangle}{\langle P_{Tx|\text{Ref}} \rangle} = \frac{\langle P_{Rx|\text{EUT}} \rangle}{\langle P_{Tx|\text{EUT}} \rangle} \tag{2}$$

where $P_{Rx|\text{Ref}}$ and $P_{Tx|\text{Ref}}$ represent the received power at the receiving antenna and transmit power from the reference antenna, respectively, and $\langle \quad \rangle$ is the mean value in time. G is obtained as part of the RC calibration process and can be reused if the chamber contents remain the same [2].

3. Measuring the absorbed power in a phantom using a RC

The method proposed in this work is built upon an extension of the radiated measurements described in Section 2. The radiated power in the chamber is measured for the EUT when placed in proximity of a phantom, $P_{Tx|l}$. As described in [3], the method considers different combinations of three key parameters: the transmitting antenna (reference or EUT), the exclusion or inclusion of the phantom, and the illumination of the phantom, leading to four measurement steps. The procedure allows for the assessment of absorbed power in a phantom P_{Abs} due to direct illumination excluding the contribution from multipath reflections simply as:

$$P_{Tx|\text{EUT}} - P_{Tx|l} = P_{Abs} \tag{3}$$

4. Measurement

Measurements were performed in a Bluetest RTS85HP chamber at a center frequency of 28 GHz with a LB-SJ-180400 horn antenna and the Ericsson base station (BS) AIR 1281. Both EUTs were set to transmit a 5G signal with a carrier bandwidth of

100 MHz. The mmW-BLAP-V1 phantom from Speag was used as a proxy for the human body. The setup with the AIR1281 as the EUT can be seen in Figure 1. The transfer function measurement was averaged over 600 samples, with a span of 1 GHz each, which took 15 minutes. The radiated power measurements were averaged over 1000 samples at a bandwidth of 100 MHz which took 1.5 minutes. The transfer function measurements can be reused for the same EUT so additional measurements are only 1.5 minutes long. The selected separation distance R between the phantom and the EUT, as seen in Figure 1, was 1 cm to 80 cm for the horn and 1 cm to 70 cm for the Ericsson BS.

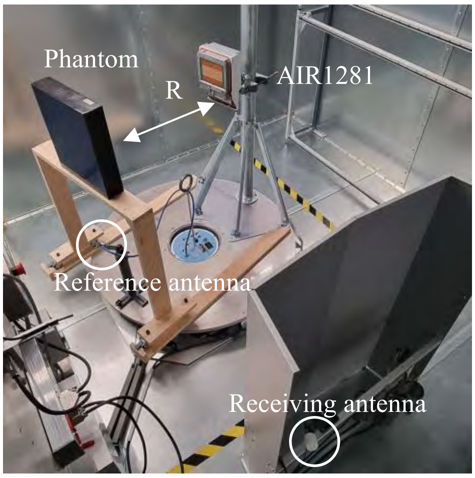

Figure 1 Measurement setup inside the RC with AIR1281

5. Simulation

Simulations were performed in CST using the integral solver for the horn and using a hybrid approach for the AIR 1281. The phantom was modelled as a coated perfect electric conductor (PEC) so that the surface properties of the phantom would be the same as for the mmW-BLAP-V1 phantom. The antenna array of the Ericsson BS contained small details which required a hybrid approach. The antenna array was simulated in free-space using the time domain solver to generate a field source. This was then inserted in the integral domain solver to compute the fields when in the presence of the phantom. While the antenna array was simulated in detail, the body of the AIR 1281 was simply modelled as a PEC boundary corresponding to the size of the base station.

6. Results

To compare the measurements to simulations the P_{Abs} was normalized by the $P_{Tx|\mathrm{EUT}}$ to give the ratio

$$R_{Abs} = \frac{P_{Abs}}{P_{Tx|\mathrm{EUT}}} \tag{4}$$

Figure 2 presents a comparison between simulated and measured values of R_{Abs} for the horn antenna and the AIR1281. The agreement is excellent, and the difference is less than 0.7 dB for the horn antenna and 0.2 dB for the Ericsson BS.

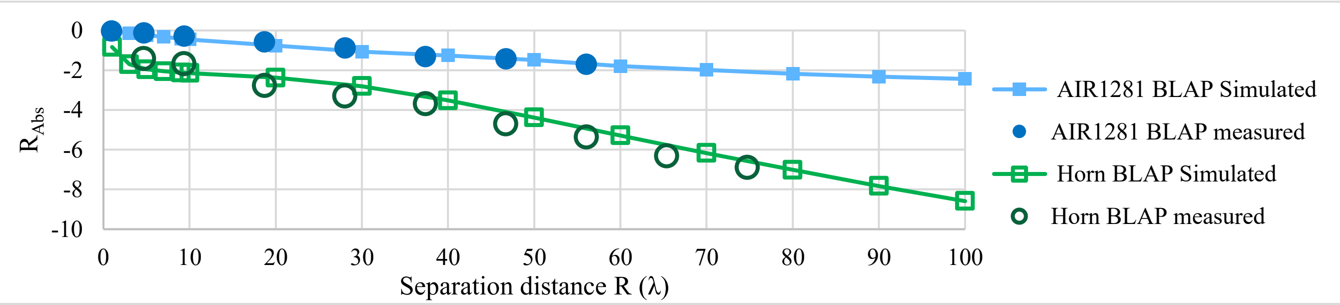

Figure 2 R_{Abs} comparison between the measured and simulated values for the horn antenna and the Ericsson BS AIR1281.

7. Conclusion

Using a RC to measure P_{Abs} and hence WBSAR from base stations has been shown to be accurate and fast. By measuring the radiated power of the EUT and the EUT combined with the phantom, P_{Abs} can be obtained. The difference between the measured R_{Abs} to the simulated was less than 0.7 dB and 0.2 dB for the horn and the Ericsson BS, respectively. The RC calibration takes about 35 minutes, but additional measurements only take 1.5 minutes as the transfer function measurements can be reused. The method shows potential to be considered as a standard approach to assess WBSAR for BS operating at millimeter wave frequencies.

8. References

[1] "Guidelines for limiting exposure to electromagnetic fields (100 kHz to 300 GHz)," eng, *Health physics*, vol. 118, no. 5, pp. 483–524, 2020, ISSN: 0017-9078.

[2] M. Andersson, A. Wolfgang, C. Orlenius, and J. Carlsson, "Measuring Performance of 3GPP LTE Terminals and Small Base Stations in Reverberation Chambers" in *Long Term Evolution: 3GPP LTE radio and cellular technology, en, ser. Internet and communications* B. Furht and S. Ahson, Eds. Boca Raton, FL: CRC Press/Taylor & Francis, 2009, ISBN: 978-1-4200-7210- 5.

[3] J. Eilers Bischoff, 'Whole-body SAR measurements of 5G mmW base stations in a reverberation chamber', Dissertation, 2022