

## Statistics of Measured Body Loss for Mobile Phones

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*Published in:*  
IEEE Transactions on Antennas and Propagation

*DOI (link to publication from Publisher):*  
[10.1109/8.947029](https://doi.org/10.1109/8.947029)

*Publication date:*  
2001

*Document Version*  
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*  
Nielsen, J. Ø., Pedersen, G. F., Olesen, K., & Kovacs, I. Z. (2001). Statistics of Measured Body Loss for Mobile Phones. *IEEE Transactions on Antennas and Propagation*, 49(9), 1351-1353. <https://doi.org/10.1109/8.947029>

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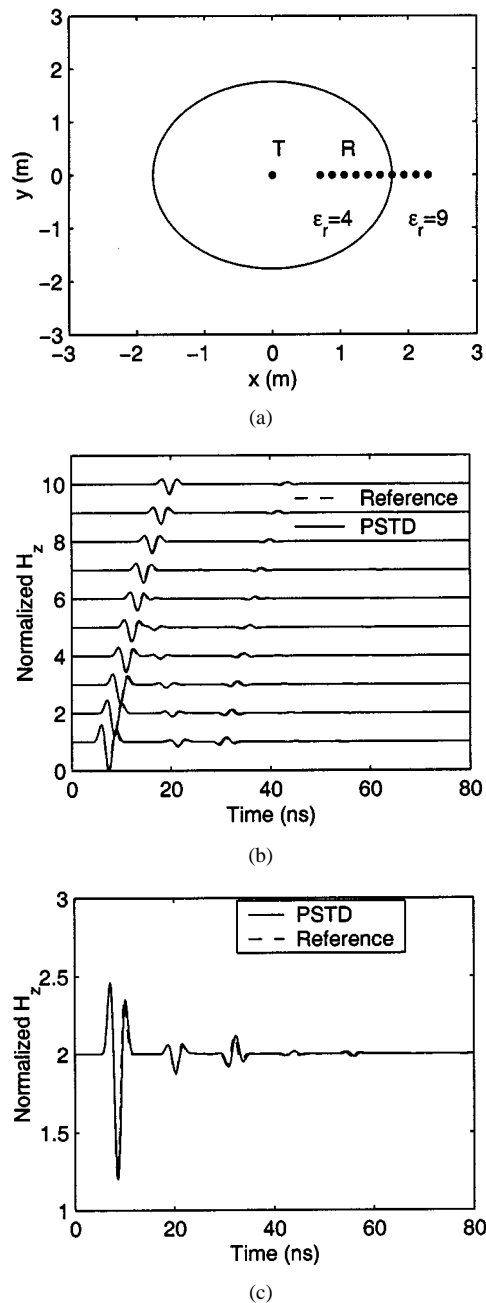


Fig. 2. PSTD results for a smoothed magnetic point source in a dielectric sphere. (a) Geometry. (b) The array waveforms. (c) The second waveform.

can save substantial amount of computer memory and computation time because of its high accuracy in spatial derivatives achieved by the FFT algorithm. Moreover, the additional advantages of PSTD in cylindrical coordinates include the removal of the singularity at the axis and a substantial reduced number of required time steps compared to the conventional FDTD algorithm.

#### ACKNOWLEDGMENT

The authors thank two anonymous reviewers for the constructive comments to improve the manuscript.

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#### Statistics of Measured Body Loss for Mobile Phones

Jesper Ø. Nielsen, Gert F. Pedersen, Kim Olesen, and István Z. Kovács

**Abstract**—The variation in body loss for different users of a cellular handset is investigated. Measurements involving 200 test users of mobile communications (GSM) handsets have been performed and statistics are presented for a handset with three types of antennas. Differences in the body loss of up to 10 dB have been observed between users, thus indicating that body loss measurements for handsets should include several test persons. Depending on the antenna type, 8–13 test persons are required to obtain an estimate of the mean body loss with a  $\pm 1$  dB confidence interval at a 90% level.

**Index Terms**—Antenna performance, body loss, handset antennas, mobile communication, radio propagation measurements, user influence.

#### I. INTRODUCTION

The overall performance of a cellular system is strongly dependent on the amount of power transmitted and received by the handsets in the system. To a large extent, the multipath propagation channel existing between a base station and a handset determines the amount of received power. However, the power is also depending on the type of receiving antenna, the shape of the handset, etc. In addition, it is well known that the transmitted or received power is reduced due to the presence of the user, where the ratio of power with and without user is denoted the body loss [1]. The body loss may vary significantly depending on the antenna/handset design [2], [3]. Therefore, minimizing the body loss is an obvious way of improving the performance of future handsets. It is important, however, to note that the body loss may vary considerably

Manuscript received February 15, 2000. This work was supported by the TeleDanmark, Denmark.

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Publisher Item Identifier S 0018-926X(01)05637-X.

TABLE I  
PERCENTILES OF MEASURED BODY LOSS IN dB. THE VALUES  
ARE OBTAINED FROM cdfs OF THE BODY LOSSES MEASURED  
ON ALL LEVELS, EACH NORMALIZED TO THE  
MEAN BODY LOSS FOR THE FLOOR

	10%	25%	50%	75%	90%
Helix	-2.4	-1.0	0.3	1.6	2.1
Whip	-1.9	-0.7	0.0	0.8	2.0
Patch (W)	-2.1	-1.0	0.0	0.7	2.2
Patch (H)	-2.1	-1.0	0.0	0.7	2.2

from one user to another, even for the same handset and mobile environment [2], [4], thus, this needs to be taken into account when measuring the body loss. In this letter, the uncertainty of such measurements is investigated via statistics of the body loss measured for 200 test users of a GSM handset in a realistic propagation environment.

## II. MEASUREMENTS

The measurements were made using a 20-MHz wideband correlation sounder with the transmitter placed on top of a tall building overlooking an urban area; the receiver was placed inside a four-story office building about 700 m away. A center frequency of 1.89 GHz was used and the receiver part of the sounder was connected to a commercially available GSM handset. In addition to the existing whip and helix antennas, the handset was modified to also include an integrated patch antenna designed for minimum radiation toward the user's head. The approximate dimensions of the handset are 53 mm times 134 mm (width times height).

In total, 200 different test users of the handset were involved; 50 on each floor of the building. Each user was asked to hold the handset in speaking position in a way he or she felt normal. During measurements the user walked along a path marked on the floor—a square of about 2 by 4 m—during which about 1000 impulse response measurements were made. Two antennas were measured simultaneously; either the whip and the patch or the helix and the patch. Therefore, two measurement series were obtained for each user each lasting 30 s. From each impulse response the instantaneous received power was computed as detailed in [4].

## III. BODY LOSS VARIATION AMONG USERS

As a measure of the power received when the user is present the average power in dB is used

$$\bar{x}_i = 10 \log_{10} \left[ \frac{1}{N} \sum_{k=0}^{N-1} x_i(k) \right]$$

where  $x_i(k)$  is the instantaneous received power for user  $i$  at time-instant  $k$ , and  $N$  is the number of measurements. From  $\bar{x}_i$  the body loss can be computed by subtracting the mean received power, in dB, for free space conditions. In [4], the mean body loss for all test persons has been reported to be approximately 10 dB, 6 dB, and 3 dB for the helix, whip and patch antennas, respectively. Here the focus is on the variation in the body loss among the users. In the following the data for the four floors have been combined after subtracting the mean value for each floor, where the data for each antenna type are normalized separately. After this procedure, the four collections of data, one for each antenna measurement, may be viewed as the outcomes of a random variable. Table I shows percentiles obtained from the data, where it is noted that the helix has the largest spread in body loss and the whip the smallest spread. Note, furthermore, that the figures for the patch measured together with the whip, Patch (W), are identical to the figures for

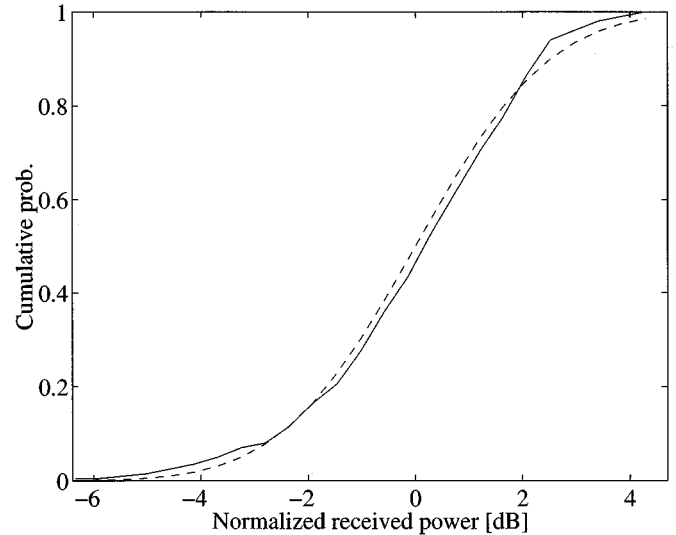


Fig. 1. Comparison of the empirical cdf (solid line) and a fitted Gaussian cdf (dashed line) of the normalized body loss observed with the helix antenna.

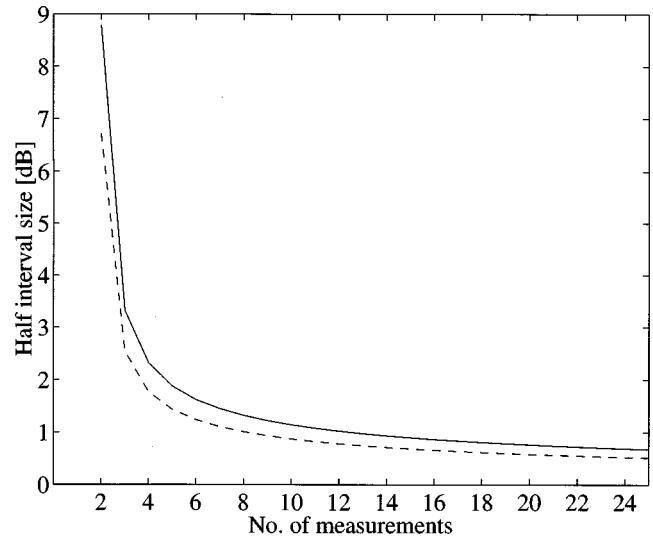


Fig. 2. Two-sided 90% confidence interval size for the sample mean body loss as function of the number of body loss measurements for the whip (dashed) and the helix (solid).

the patch measured together with the helix, Patch (H). This indicates that the measurements are repeatable.

## IV. MEAN BODY LOSS CONFIDENCE INTERVAL

In assessing a handset it is important to realize that body loss measurements are highly dependent on the user, as evidenced by the above percentiles. The mean body loss can serve as a useful guide that may be estimated by the sample mean of body loss measurements conducted with different test users. Such estimates should be accompanied by confidence intervals allowing assessment of the estimate quality. Often confidence intervals are based on the knowledge that the measured quantity has a Gaussian cumulative distribution function (cdf). Due to the way the body loss is computed, it can be expected to be approximately Gaussian distributed. However, because of the limited power transmitted the body loss cannot be strictly Gaussian. On the other hand, comparing the cdfs of the measured body loss to fitted Gaussian cdfs suggests that the Gaussian approximation is reasonable. Fig. 1

shows the fit for the helix antenna, which appears to have the worst fit of the four antennas. Using the Gaussian assumption, two-sided confidence intervals for mean body loss estimations can be computed, as shown in Fig. 2 for a confidence level of 90%. As an example, to obtain an interval of  $\pm 1$  dB about eight measurements are needed for the whip antenna, whereas the helix requires about 13 measurements, and the patch about nine. The figure shows results only for the whip and the helix. Similar curves for the patch antenna measurements are in-between the two curves shown.

## V. CONCLUSION

Results from body loss measurements involving 200 test users have been presented for an outdoor to indoor urban propagation scenario. The body loss variation among users may be considered random and cdfs have been estimated for three different handset antennas. The measurements show that the distributions can be approximated reasonably as Gaussian. Assuming Gaussian distributions, about eight test persons

are required for a mean body loss estimation for the whip antenna with a 90% confidence interval of  $\pm 1$  dB, whereas about 13 test persons are necessary for the helix antenna, and about nine for the patch. The helix antenna, thus, results in a larger spread in body loss than both the whip and the patch antenna.

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