The Effects of the Ground and the User's Body on the Performance of a Mobile Handset Antenna

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ABSTRACT

In this paper, the effects of the whole human body and the ground on the performance of a handset antenna are studied through EM simulation. It is shown that the radiation pattern of a handset antenna is very complicated and the SAR level inside the head is increased in a more realistic model including the partial ground, the whole body and the hand.

INTRODUCTION

With the expansion of current use and anticipated further increases in the use of mobile phones and other personal communication services, there has been considerable research efforts devoted to interactions between antennas on handsets and the human body. These activities are motivated by two factors: 1) a need to evaluate the antenna performance with the presence of the human body; and 2) a need to evaluate the rate of RF energy deposition in the biological tissue, called specific absorption rates (SAR), in order to assess potential health effects and compliance with various RF exposure standards.

Mobile handset antennas are usually analysed and designed with the presence of the user's head model (phantom)[1-4]. However, the mobile handset antenna is always operating in the vicinity of the whole user's body above the ground. It is expected that the radiated wave scatters around not only the user's head, but also the user's body, holding hand and arm. In practice the ground is always present, any energy from the radiating element directed toward the ground undergoes a reflection. The antenna theory indicates that the radiation pattern of a wire antenna above the conducting ground looks like a scallop, i.e. many minor lobes.

Therefore, it is necessary to study the interaction between a handset antenna with the whole human body in a more realistic environment, i.e. including the ground, as shown in Fig. 1. Therefore, in this study, a mobile handset antenna in a more realistic environment, consisting of the whole user's body (including the holding hand and arm) and the ground is studied through FD-TD modelling. Also results obtained in the head only model are presented for the purpose of validation and comparison.

EM SIMULATION AND VALIADATION

The numerical method in the EM simulation package, called CST Microwave Studio, used in our study is the Finite Integral (FI) Algorithm [5]. It is equivalent to the popular FD-TD formulation in time domain.

The FD-TD model consists of a quarter-wavelength monopole mounted on a mobile handset (treated as a metal box), operates at 900MHz, the whole human body and the partial ground, which is shown in Fig.1. In general, the ground is a lossy medium ($s \neq 0$) whose effective conductivity increases with frequency. Therefore it can be treated as a very good conductor above a certain frequency [6-7]. To simplify the analysis, it is assumed that the ground is a perfect electric conductor and flat. The user's head is simulated with the brain equivalent material and the body the muscle equivalent material. The human body consists of a head, a holding hand and the rest of the body, constructed by several cylindrical trunks, simulating a normal man of approximately 1.70m in height. The material of the head model is represented by the brain tissue with a relative permittivity of 41.5, and a conductivity of 0.86 [S/m]. The material property of the body is simulated as that of the muscle, with a relative permittivity of 53 and a conductivity of 1.2[S/m]. The total computation volume is $600mm \times 300mm \times 1800mm$. This results in a total meshing nodes of 2115360 and the samllest grid being 0.1mm. The ground plane is simulated as an electric conductor by applying the electric symmetry boundary condition while the size of the partial ground is $300mm \times 600mm$. The distance between the head and the handset is set to be 5mm. The handset body is modelled as a $30mm \times 50mm \times 120mm$ metal box. A $l/4$ monopole of 900MHz mounted on the top of the handset box, is used as the radiation source.

For the investigation of interactions between the mobile antenna and human body, SAR and far field pattern are the two main parameters used for indicating the effects. At the moment, it is difficult to carry out the direct measurements of SAR and far field pattern for the model consisting of the whole body and partial ground. Thus, the head only model is used to validate against that of the simulation. The head only model is popular among SAR evaluations and antenna designs. This model can be compared with the measurements, although it is not realistic. The EM simulation package, CST-Microwave Studio, has been used to simulate the head only model first. The set-up and meshing scheme are identical to the whole body model, except only the head region is included, as shown in Fig. 1 (a). The simulated radiation pattern with the head only is shown in Fig. 2.

The radiation pattern with the head only is measured inside an anechoic chamber at Nokia (UK). As shown in Fig. 2 (b), the measured pattern on horizontal plane agrees with the simulated one very well [8]. Also the SAR and the total absorbed RF power in the head only model are measured by using the SARTest system, provided by Microwave Consultants Ltd (UK). Again, as shown in Table 1, there is a good agreement between the simulation and measurements [8]. So the numerical method and EM simulation package used in this study have been proved to be adequate and accurate in evaluating the interaction between a handset antenna and the human body.

RESULTS AND ANALYSIS

The radiation pattern of the whole body model is shown in Fig. 3. The lobes are split into many lobes, ‘scallops’. Comparing the pattern on the vertical plane with the case of the head only model (Fig. 2 (a) and Fig. 3(b)), the null caused by the head absorption is now filled with some minor lobes. So there might be a slight improvement in the coverage. The patterns on the horizontal plane look identical in both head only and whole body models (Figs 2(b) and 3(c)).

As shown in Fig. 4, when the arm and hand holding the handset are taken into account, the highest SAR area is located at the hand because the it holds the handset. The highest SAR value is 6.06 W/kg (1 gram average) or 4.4 W/kg (10 gram average). The peak SAR value inside the head model is 5.26W/kg (1 gram average) or 3.82W/kg (10 gram average). the comparison of the absorbed power and peak SAR between the head only model and the full model is shown in Table 1.

CONCLUSIONS

The far field radiation pattern of a handset antenna is revealed to be very complicated in a more realistic model including the partial ground, the whole body and the hand. As shown in Fig. 4, the radiation pattern is fragmented into many minor lobes. This feature of the far field pattern is due to the reflection from the ground and scattering around the whole human body.

It is also revealed in the simulation that the SAR level inside the head is increased when the ground effect is taken into account. This is due to reflections from the partial ground, which enhances the electric field strength inside the head. This finding is very important for compliance test of mobile handsets. The common SAR measurement system, i.e. a probe with a phantom, is a desktop system, which ignores the ground effect. Hence the current compliance test system may underestimate the SAR value inside the head by a factor of 20% ~35%. It is also found from the simulation that the holding hand has a profound effect on the SAR distribution inside the body. The highest SAR area is now inside the hand since it holds the body of the handset, being part of the radiator.

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REFERENCE:

[1]. J. Toftgard, S. N. Hornsleth, and J. B. Andersen, Effects on portable antennas of the presence of a Person. IEEE Trans on Antennas and Propagation. Vol. **41**: pp. 739-746.Jun., 1993.

[2]. H. R. Chuang, Human Operator Coupling Effects on Radiation Characteristics of a Portable Communication Dipole Antenna. IEEE Trans on Antennas and Propagation. Vol. **42**: pp. 556-560.Apr., 1994.

[3]. M. A. Jensen and Y. Rahmat-Samii, EM Interaction of Handset Antennas and a Human in Personal Communications. IEEE Proceeding. Vol. **83**.Jan., 1995.

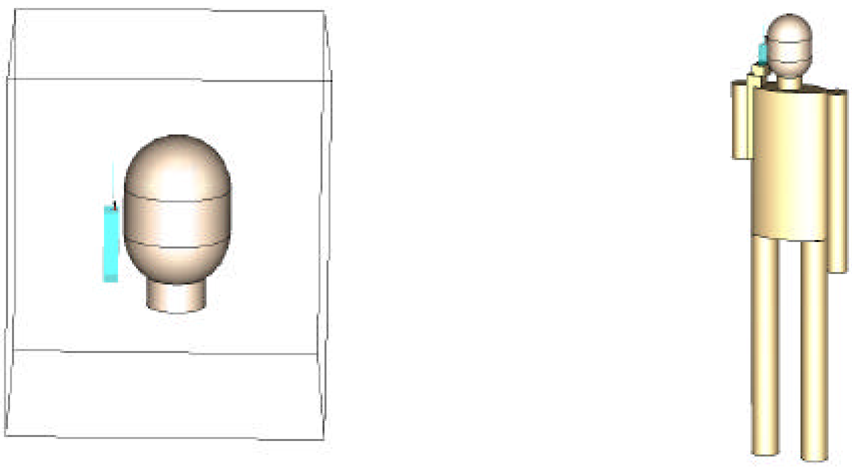
[4]. V.Hombach, K. Meier, M. Burkhardt, E. Kuhn, and N. Kuster, The dependence of EM energy absorption upon human head modeling at 900 MHz. IEEE Transactions on Microwave Theory and Techniques. Vol. **44**(10): pp. 1865 -1873.Oct., 1996.

[5]. CST, Manu of Microwave Studio version3, 2001.

[6]. K. Fujimoto and J. R. James, Mobile antenna systems handbook. 1994, Boston: Artech House.

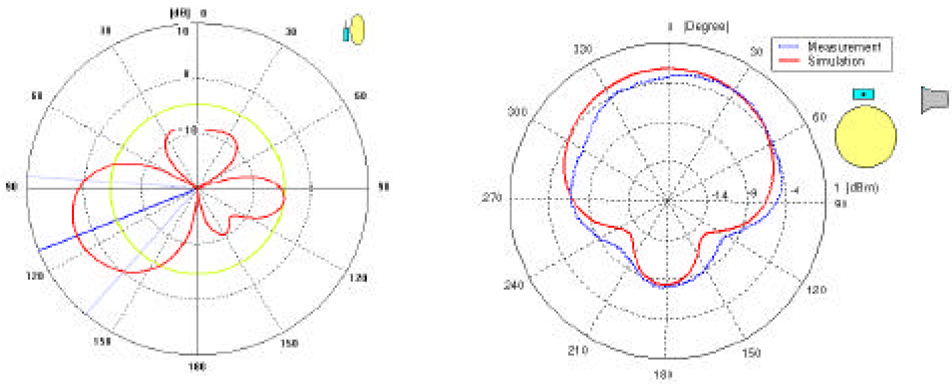
[7]. R. W. P. King and S. S. Sandler. The propagation of electromagnetic waves generated by a vertical electric dipole in the presence of two- and three-layered regions. in Antennas and Propagation Society International Symposium. pp. 400 -403, 1993.

[8]. Zhou Wang, Design of Low-SAR Antennas for Mobile Communications Devices, PhD Thesis, University of London, 2001.



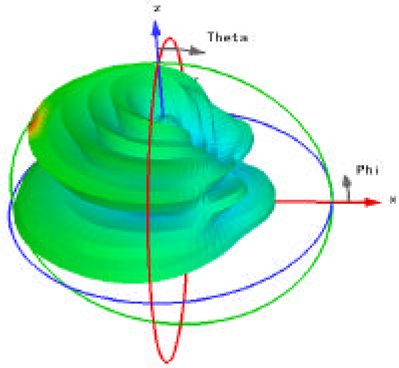
(a) **(b)**

Fig.1 (a) The head only in free space model; (b) The whole human body and the ground model.

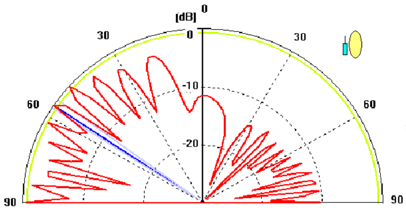


(a) **(b)**

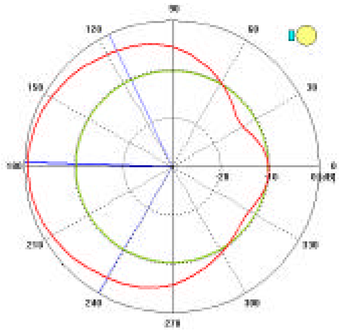
Fig. 2 The radiation pattern of a handset antenna in the presence of a head. a) Far field pattern in vertical plane. b) Measured and modelled far field patterns (E_q component) at the horizontal plane.



a). Side view 3D plot

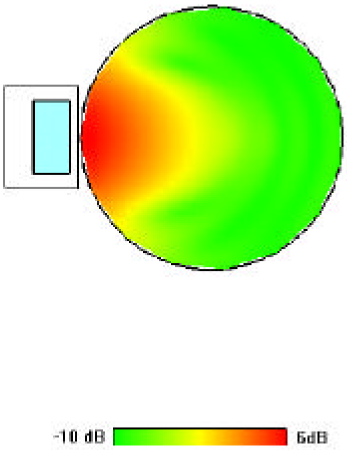


b) 2D plot in ϕ =0 plane

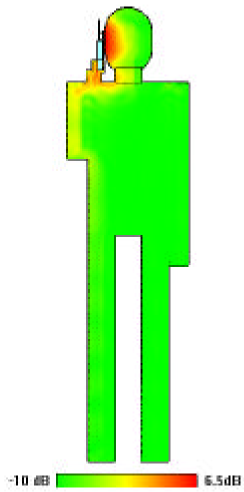


c) 2D plot in θ = 90 plane

Fig. 3 The far field pattern in 3D and 2D plots



(a)



(b)

Fig. 4 SAR distribution (10g average) inside (a) the head (the top of the handset) and (b) the whole body

Model	The head only		The body, the hand and the ground	
	simulation	measurement	Whole body	Head part
Relative absorbed RF power	31.9%	33.7%	39.4%	32.2%
Peak SAR (W/kg)	3.32	3.5	4.4	3.82

Table 1: Comparison of absorbed power and peak SAR