A NOVEL ANTENNA FOR LOW-SAR MOBILE HANDSETS

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I. Introduction

An antenna is one of the most important components in a mobile phone handset, which has dual functions: receiving and transmitting signals. Currently, the antenna being used in almost all the commercial handsets is a wire type. It has been sitting on the top of handheld mobile phones from very beginning because of its seemingly adequate performance, low cost and easy realisation. However, latest studies show that this type of antenna, which has no shielding to the user, loses a large fraction of radiated RF power in the user's body, mainly in the head [1-2]. It is obvious that this design of antenna is not ideal in a sense of power efficiency, needless to mention the controversy issue of potential health hazards. So it is highly desirable to design low SAR (Specific Absorption Rate) handset antennas.

In an attempt to incorporate the low-SAR antenna design principle and also satisfy commercial, mechanical and cosmetic constraints, a new design of the monopole antenna for a mobile phone handset is proposed. In this design, a monopole is mounted on the backside of a handset and can be rotated to a position vertical to the human head as shown in Fig.1. The proposed handset antenna design is studied both numerically and experimentally. The main concern in this study is to check the reduction of SAR level in the human head with the new antenna.

For the interaction between the mobile handset antenna and the human head, the exposure level of electric field is not suitable to be considered as the safety reference. Instead, SAR inside the user's body has been agreed to be a proper quantity for the safety reference [3-7]. SAR is defined (ANSI, 1982) as the incremental electromagnetic power (dP) absorbed by an incremental mass (dm) contained in a volume element (dV) of given density (ρ):

$$SAR = \frac{dP}{dm} = \frac{dP}{\rho dV} \qquad (1)$$

And in practice SAR can also be calculated by:

$$SAR = \frac{\sigma E_i^2}{\rho} \qquad (2)$$

where σ is the conductivity of the material.

II. Numerical modelling

Throughout the numerical investigation, MAFIA, a Finite Integration code developed by CST, Germany, has been used. In time domain, Finite Integration method is similar to the Finite-Difference Time-Domain method. The Finite- Difference Time-Domain formulation of EM field problem is a convenient tool for solving scattering problems. It is a direct solution of Maxwell's time-dependent curl equations, it treats the irradiation of the scatter as an initial value problem. FD-TD uses an electric field grid , which is offset both spatially and temporally from a magnetic field grid to obtain

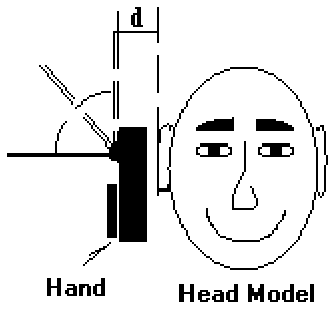

Fig.1 The Rotatable Antenna Model

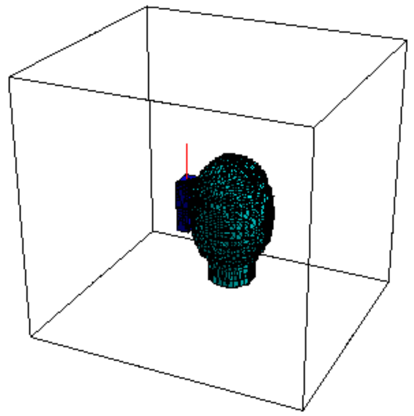

Fig.2 The numerical model

updated equations that yield the present fields throughout the computational domain in terms of the past fields. The updated equations are used in a leapfrog scheme to incrementally march the electric field and magnetic field forward in time.

The numerical model is shown in Fig.2. The head is modelled as an inhomogeneous ellipsoid sat on a cylindrical neck. The ellipsoid radius along the longer axis (z direction) is 13cm, the other two radii are 9cm. The neck is modelled as a circular cylinder, which is 5.5 cm long with a radius of 5 cm. The gap between the head and the handset is chosen to be 5mm. The handset body is modelled as a 30mm* 50mm 120*mm metal box. For the conventional design, a $\lambda/4$ monopole of 900MHz is mounted on the top of the handset box, and for the novel one, the same monopole, being rotated 90 degrees, is mounted on the back of the box, as shown in Fig. 1. The whole calculation space is meshed in 4.5mm grids.

The results of the numerical simulation are given in followed figures. Fig.3 and Fig.4 show the field distributions of the conventional and novel designs, respectively. It clearly indicates the peak of the EM field has been shifted away from the head region with the new design. Fig.5 gives the comparison between conventional and new antenna designs. With the conventional design, about 31.9 percent of power radiated from the antenna is absorbed by the head; while with the novel one, only 6.1 percent of radiated power radiated is absorbed by the head. So the numerical modelling predicts a substantial reduction of the RF power absorption inside the head with the new design.

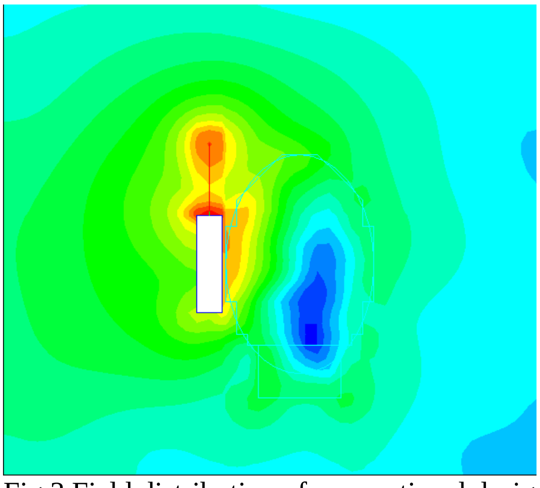

Fig.3 Field distribution of conventional design obtained innumerical modelling

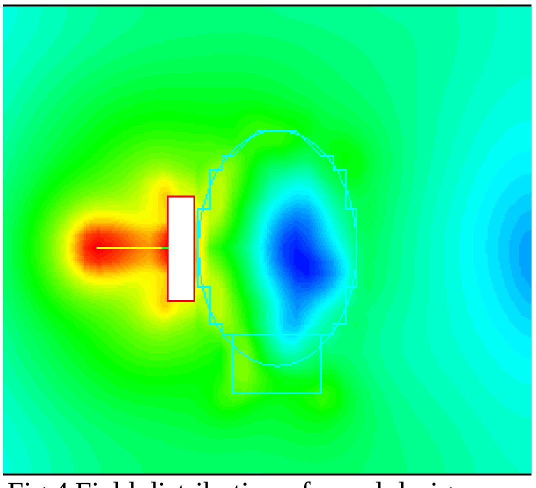

Fig.4 Field distribution of novel design obtained in numerical modelling

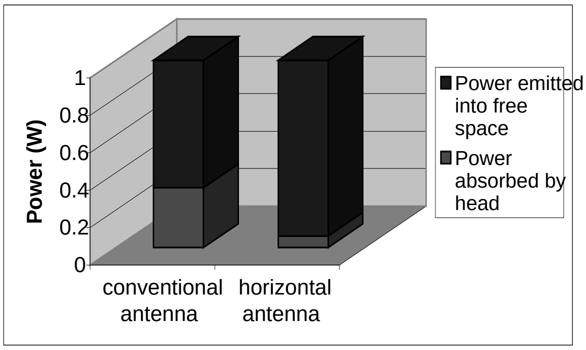

Fig.5 Comparison between conventional antenna design and improved antenna design

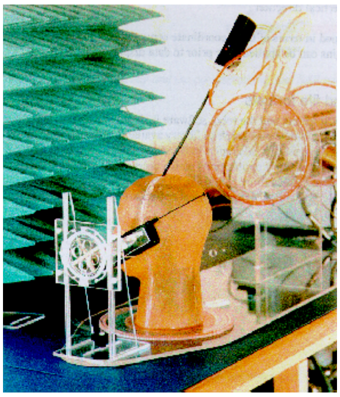
Fig.6 Experimental measurement system

III. Experimental Measurements

The measurement of SAR is carried out on a SAR test system as shown in Fig.6, which is developed by SARTest Ltd, UK. The system consists of a robotic arm, an electric field probe, a phantom head filled with the brain tissue simulating liquid and a controlling PC. The phantom shell is made of a bone simulating material. The shape of the head is based on an 'average' male head. Through a 35mm diameter hole on the top of the phantom, the robotic arm can insert and position the probe to a desired location for measurement. The dimensions of the phantom head are: 22 cm high, 17.5cm wide from left ear to right ear and 20 cm thick from face to back of head. The neck is an ellipse like cylinder, which is 7 cm high with radius = 5 cm in short axis and radius = 6.2 cm in long axis. Inside the phantom, the 900MHz brain simulation liquid is filled with ε_r =41.5 and σ= 0.86. The entire measurement system is computerised and the probe scans automatically a volume within the phantom at pre-defined incremental spatial points. A typical SAR measurement scans total 15*9*11=1485 points with Δx=4mm, Δy=7mm and Δz=4mm. The E-field probe picks up the values of field strength at these points first. Then, the build-in program on the PC converts them into SAR values according to Eq (2). Fig.7 and Fig.8 show the measured SAR distributions of the conventional design and the novel one. It is noticed that there is also a substantial reduction in the measured peak SAR value with the novel design.

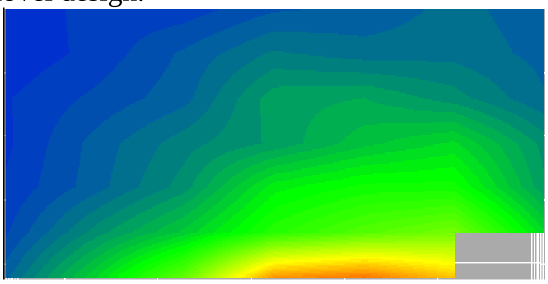
Fig.7 Experimental SAR distribution of conventional design at the middle horizontal plane, SAR peak value = 3.5W/Kg

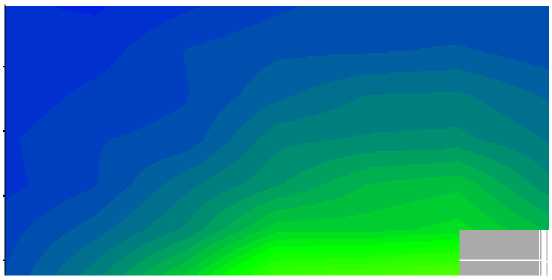
Fig.8 Experimental SAR distribution of novel design at the middle horizontal plane, SAR peak value = 1.2 W/Kg

In order to obtain the total absorbed power inside the whole phantom, further data processing has to be preformed. Since experimental and numerical studies shows that the SAR value decreases exponentially with the distance to the radiation source. After a careful calibration against the existing ETH results [5], an emperical formula is derived to extrapolate all the values in unmeasured volume in side the phantom:

$$SAR(x) = SAR_0 e^{-ax} \qquad (3)$$

where SAR_0 is a characteristic value, being equal to 24.68, a=0.077 and x is the distance to the source.

According to Eq. (1), the total absorbed power can be calculated by

$$P = \int_V SAR(x, y, z) \cdot dm = \sum SAR(x, y, z) \cdot \Delta m \qquad (4)$$

Table 1 summarises our numerical and experimental studies on the conventional and new antenna designs. The experimental results show that about 33.7 percent of power radiated from the antenna is absorbed by the head with conventional design, while with the novel one, only 10.4 percent of radiated power is absorbed by the head. This again shows a substantial reduction of the absorbed power in the head with the new design, which agrees well with the numerical prediction.

Table 1. The comparison of absorbed power ratio between two designs

	Modelling (P_{abs}/P_{in})	Experiment (P_{abs}/P_{in})
Conventional Design	31.9%	33.7%
Novel Design	6.1%	10.4%

IV. Discussions

Both numerical modelling and experimental study demonstrate that our rotated handset antenna can reduce the peak SAR level and the total absorbed RF power in the human head by a factor of 67% (two-third) compared with the case in the conventional handset antenna. The slight difference between the simulation results and experimental results is mainly due to the fact that the two phantom models are not exactly identical.
The performance issues of the novel handset antenna have also been studied through numerical modelling. When a more realistic operating environment is considered, i.e. including the scattering from the whole human body and the reflection of the ground and etc, the radiation pattern of the new design is not worse than that of the conventional one. So it is fair to say that this new design provides a simple and effective solution for low-SAR mobile handsets.

Acknowledgement

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