Folded-Loop Antennas for Handset Terminal at 2.0 GHz Band

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ABSTRACT

Folded-loop handset antennas for mobile communications are analyzed by using the FDTD method. In particular, the effect of the human body on the characteristics of the antennas is discussed. The doubly folded loop antennas are found to reduce the peak SAR averaged over 1g and 10g of tissues by 30 - 60 %, while radiation characteristics are comparable with those of the monopole antenna.

INTRODUCTION

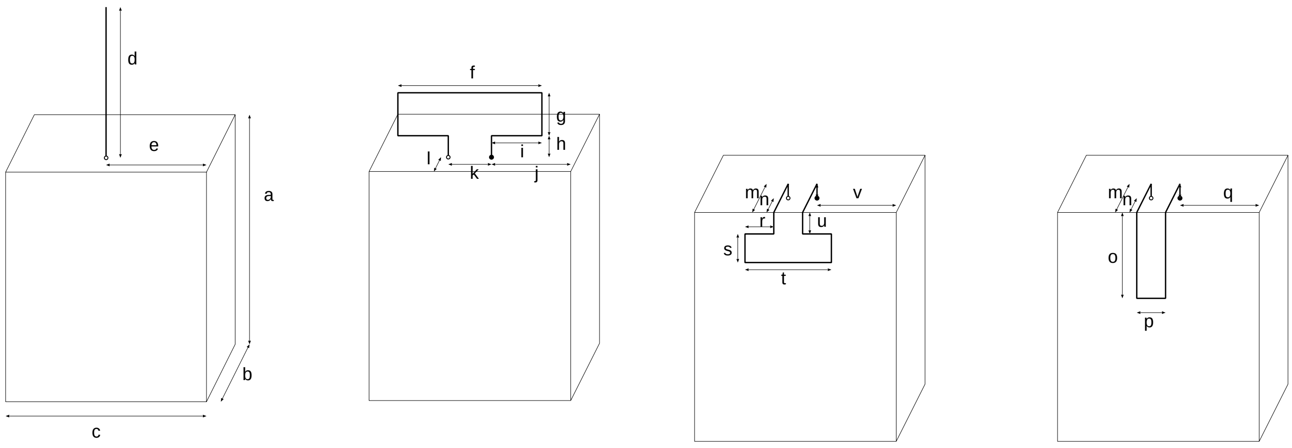
In recent years, there has been some increasing public concern about the interaction between electromagnetic (EM) waves and a human body. In particular, much attention has been paid to EM wave exposures from handset antennas, because they are used in close proximity to the human head. Thus, safety guidelines for EM wave exposures have been proposed by several organizations. The limit for near-field exposures in public environments is 2 W/kg for any tissue averaged over 10 g (e.g., [1]). According to recent results, there does not always seem to exist a sufficient margin for this limit when mobile telephones are used, and thus a lot of work on the SAR compliance has been carried out in the last several years [2]. In accordance with such assessments, the influence of the human head on radiation characteristics of handset antennas has also been investigated. As one of the main results, a considerable amount of the EM power emitted from a handset antenna has been found to be absorbed in the human head, leading to a significant modification of the antenna pattern. Therefore, it is desirable to design handset antennas with the influence of the human body taken into account for realizing a low-SAR, high-efficiency, and omni-directional antenna.

Only a few loop antennas have been proposed for mobile telephones [3, 4]. Katsibas et al. investigated wire and printed folded loop antennas mounted on a conducting box [3]. Kumon and Tukiji [4] proposed a doubly folded monopole antenna for reducing the antenna size compared with that in [1]. In the analysis of these antennas, however, the effect of the human body has not been taken into account.

In this paper, loop antennas for handset application are analyzed by using the FDTD method. Particularly, the performance of the antennas in the presence of the human head and hand is discussed. Then, the configuration of the antennas is specified for reducing the peak SAR averaged over 1g and 10g of tissues.

MODEL AND METHOD FOR THE ANALYSIS

The human head model used in this paper is almost the same as that developed in [5] except for some minor modifications. It consists of $96 \times 110 \times 125$ cubic cells, whose side cell length is 2.0 mm. This model is comprised of 18 tissues, that is, bone (skull), cartilage, cornea, sclera, lens, aqueous humor, vitreous humor, muscle, skin, fat, white matter, grey matter, cerebellum, dura, nerve, tongue, C.S.F. (cerebrospinal fluid), and blood. The FDTD method is used for investigating the interaction between the human body model and handset antennas. In order to incorporate the inhomogeneous head model into the FDTD scheme, the dielectric properties of the tissues are required. They are determined with the aid of the 4–Cole–Cole extrapolation [6]. The hand model is assumed to be comprised of the 2/3 muscle. The elevation angle of the tilted antenna is chosen to be 60 degrees. For a set of parameters, the matched frequencies for the antennas (A)-(D) are within 2.1-2.2 GHz (see



(a) (b) (c) (d)

Figure 1: Configuration of various antennas : (A)monopole antenna, (B)folded loop antenna, (C) a doubly folded loop antenna (D)another doubly folded antenna (a=104mm, b=20mm, c=40mm, d=36mm, e=20mm, f=40mm, g=12mm, h=12mm, i=10mm, j=10mm, k=20mm, l=2mm, m=4mm, n=2mm, o=26mm, p=4mm, q=18mm, r=8mm, s=8mm, t=20mm, u=4mm, v=18mm)

Fig. 1).

RESULTS

Figure 1 shows the geometry of (a) a monopole antenna, (b) a folded loop antenna [1], (c) a doubly folded loop antenna on the basis of (b), and (d) a doubly folded monopole antenna [4] on a metallic box. For proper comparison, the dimension of the metallic box and the feeding point of the antenna are fixed in the following calculations. It should be noted that the metallic box is coated by a plastic with the relative permittivity of 1.6. The output power of the antennas is assumed to be 0.6 W.

Table 1: The radiation efficiency, the power absorbed in the head and hand, and the peak SARs averaged over 1g and 10g of tissues [W/kg] for various antennas.

Ant.	P_{rad}	P_{abs} head	P_{abs} hand	SAR 1g	SAR 10g
(A)	0.565	0.232	0.203	3.26	2.32
(B)	0.536	0.248	0.215	3.54	2.48
(C)	0.551	0.148	0.301	2.51	1.22
(D)	0.578	0.101	0.321	1.63	0.737

Table 1 shows the radiation efficiency, the power absorbed in the head and the hand, and the peak SARs averaged over 1g and 10g of tissues. As seen from this table, the amounts of the power absorbed in the head for the antennas (A) and (B) are larger than those for (C) and (D), while the radiation efficiencies of all these antennas are comparable. This is because the EM power emitted by the doubly folded loop antennas is absorbed in the hand, instead of the head. Similarly, the peak SARs averaged over 1g and 10g of tissues for the antennas (C) and (D) are smaller than those due to a monopole antenna by 30-60 %. The reason for this decreased SAR is that the metallic box on which antennas are mounted behaves as a reflector. In some way, this is expected

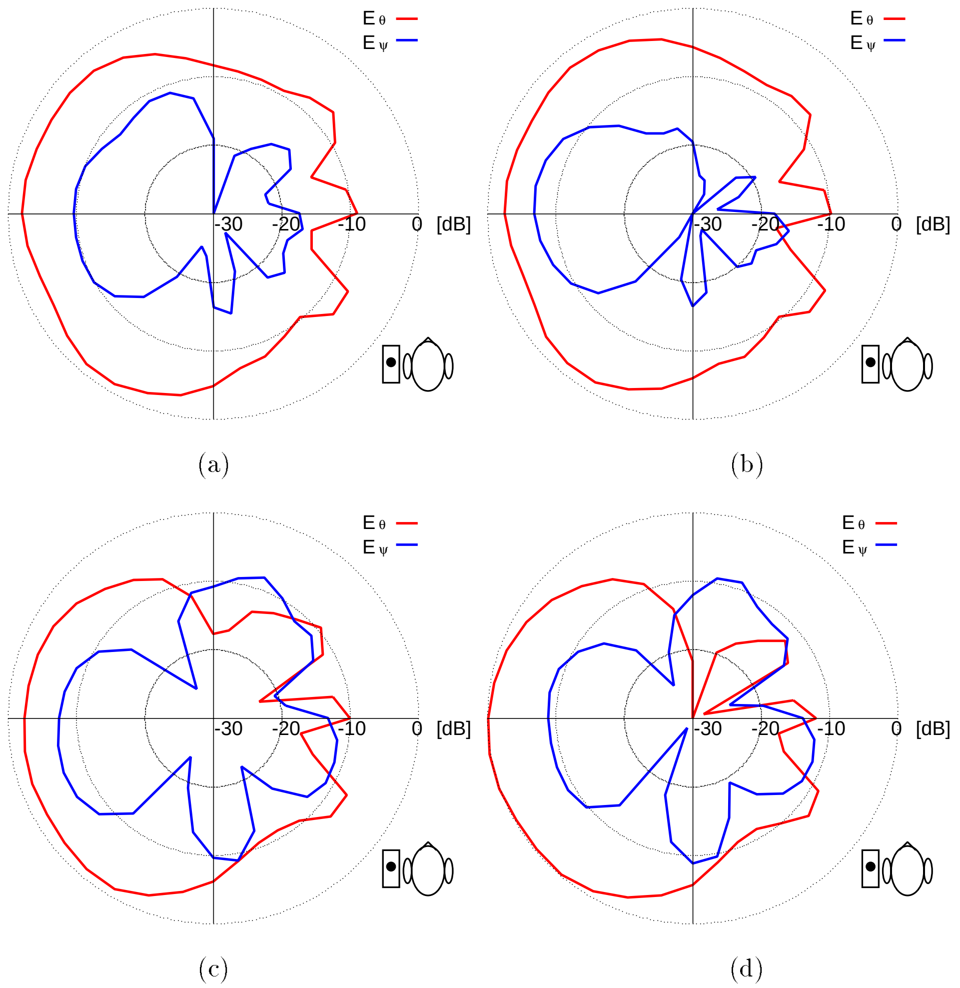


Figure 2: Radiation patterns of the antennas in the presence of the human head and hand model.

from the results for back PIFA [7] (at 900 MHz). On the other hand, the SAR due to the folded loop antenna (B) is slightly larger than for the monopole antenna (A), because of the concentration of the EM fields. This is expected from [8], which discusses the SAR due to the helix antenna.

Figure 2 shows the radiation pattern of the antennas on the horizontal plane in the presence of the human head and hand models. As seen from this figure, no significant difference is observed among these four antennas.

Finally, we comment on the input impedance or the resonant frequency of the antenna (D) modified by the human body. No significant modification in the input impedance of the antenna is observed (at most several ten MHz), even when the human hand touchs the wire of the antenna.

SUMMARY

The folded-loop handset antennas for mobile communications have been analyzed by using the FDTD method. In particular, the effect of the human body on the characteristics of the antennas have been discussed. The doubly folded loop antennas for handsets has been found to reduce the peak SARs averaged over 1g and 10g of tissue by 30 - 60 %, as compared with a monopole antenna, while the radiation characteristics are comparable to those of the latter antenna.

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