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Assessment of specific absorption rate reduction in human head using metamaterial

Abstract: In this paper, the specific absorption rate (SAR) reduction in human head with metamaterial attachment is calculated. The finite-difference time-domain (FDTD) method has been used to evaluate the SAR in an anatomically correct model of the human head. We designed the double-negative metamaterials by placing periodic array arrangement of split ring resonators (SRRs). By properly designing and tuning the structural parameters of SRR_S, the effective medium parameters can be made negative at 900 and 1800 MHz band, as presented in this paper. Experimental results show that, with presence of resonators, SAR reduction in the human head is achievable. These results can provide useful insight into the design of safety-compliant mobile communication equipment.

Keywords: antenna; head model; metamaterial; specific absorption rate (SAR).

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1 Introduction

Electromagnetic field (EMF) and the potential harmful effects on the human body are two of the current areas which are heavily reached in the engineering field as well as in the area of engineering around the world. The use of cell phones has increased exponentially in the last 22 years and has become a ubiquitous element in daily life. These devices produce a non-negligible amount of electromagnetic energy in the radiofrequency band, and this fact has raised public concern about the possible health hazards associated with electromagnetic radiation. The effects on human health considered by exposure guidelines at mobile phone frequencies of operation arise from the heating produced by currents induced by electromagnetic fields on media with finite conductivity, such as human tissues [1]. When the body is exposed to high-frequency radiation, the absorption of energy (W) is currently related to thermal effects and it is usually quantified by the specific energy absorption rate (SAR), defined by Eq. (1):

$$\mathrm{SAR}={}^{\mathrm{d}}\!/_{\mathrm{d}t}\left[\frac{\mathrm{d}W}{\mathrm{d}m}\right] \tag{1}$$

As it is clearly mentioned above, SAR represents the power (i.e., the energy rate) absorbed by the unitary mass of substance (m) and it is denoted by watts per kilogram. For mobile phone compliance, the SAR value must not exceed the exposure limits [2, 3].

The interaction between a cellular handset and a human head has been investigated by many published papers which considered the following: first, the effect of the human head on the handset antenna performance including the feed-point impedance, gain, and efficiency [4–6]; and, second, the impact of the antenna electromagnetic (EM) radiation on the user's head due to the absorbed power, which is measured by predicting the induced SAR in the head tissue [7–9].

The most used method to solve the electromagnetic problem in this area is the finite-difference time-domain (FDTD) method [8–12]. Although, in principle, the solution for general geometries does not require any additional effort with respect to the standard method, the technique requires the definition of a discretised space by assigning to each cell its own electromagnetic properties, which is not an easy process [13–16].

Ferrite sheet has been a good material for reducing SAR values [17, 18]. The consequence of ferrite sheet attachment to a cellular mobile handset was also considered in Ref. [19]. This paper claimed to have utilised a mobile phone with a monopole antenna. The current from the monopole antenna flows on all surfaces of the box. Without altering the antenna performance, the ferrite sheet was used to suppress the current flowing in the handset box resulting in a significant reduction of the SAR. Reduction of SAR values has recently been examined by the same method in