Coupling Effects Between a Cellular Phone and Metallic Eyeglasses: Field Enhancement in the Eye Region

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Abstract

In this work, the effects of eyeglasses with a metallic frame on the electromagnetic field emitted by a cellular phone antenna have been investigated experimentally. The obtained results, also validated by numerical modeling, suggest that the coupling between the antenna and the metallic frame can locally enhance the field intensity. In particular, the high values of the electric field in the eye region call for further analysis, in order to prevent possible health hazard.

Introduction

The recent development of the wireless telecommunication technology, and the dramatic diffusion of mobile phones, have allowed a spectacular growth of the wireless-telephone market. At the same time, the increasing presence of radio-base stations in urban areas, and the near-field radiation emitted by handled wireless telephones, have created [1] and still creates [2] public concern about the possible health effects caused by these devices. As the antenna of a wireless telephone is located very close to the user's head, this configuration has been widely investigated in the past, to evaluate both the distribution of the power absorption in the head tissues [3]-[4] and the operator's influence on the antenna parameters (say gain, radiation pattern, and input impedance, for example) [5]-[6]. In fact, near-field coupling between the antenna and the user causes the head to absorb a significant amount of the radiated power, thus decreasing the signal strength sent to the radio-base station and generating possible health hazards for the person. Both of these topics have been investigated extensively by experiments and theoretical approaches, and different solutions have been presented to reduce the coupling between the antenna and the user's-head, thus obtaining a mitigation of those undesired effects [7].

In this work, the attention is addressed to the evaluation of the electromagnetic (e.m.) emission in the near field region of a mobile phone antenna, whenever the user wears eyeglasses with a metallic frame. The interest in this scenario arises from the fact that the currents, induced by the e.m. field on the metallic support, transform the latter in a new antenna which, by interference (coupling) with the original one, could significantly modify the near-field pattern. As a consequence, this may give rise to local field enhancement, particularly in the ocular region, in turn exposing the crystalline lens to (undesired) high values of field intensity. As this part of the eye is not subject to a blood flux able to remove the generated heat, sensible temperature increasing could result and effects detrimental to the user could take place. Results show that, to prevent health hazards, some precautions should be taken.

Investigated scenario

Fig. 1 describes the geometry of the investigated scenario, with the cellular phone held by a right-hand person (by symmetry, also left-hand users are subject to similar effects). In this stage of the study, the pursued goal was to determine whether the presence of metallic "wires" (the eyeglasses frame) in the near-field region could originate any effect of local field enhancement close to the user's eyes. To this end, a simplified model has been considered, where any e.m. effect arising from the presence of the user's head tissues has been neglect. This model has allowed to employ a simulator based on the Method Of Moments (MOM) [8] for this preliminary investigation, as well as a simple experimental set-up.

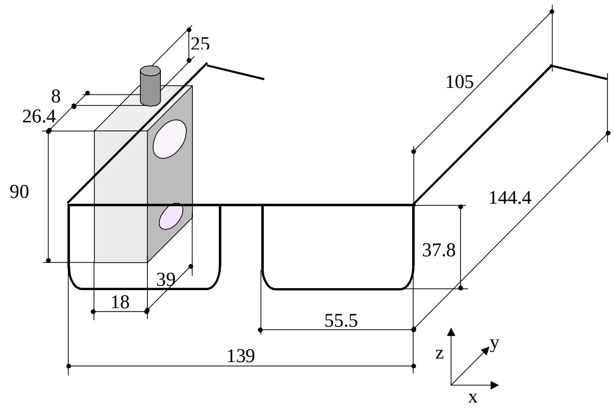

Figure 1. Geometry of the simplified investigated scenario (dimensions are in millimeters). The base of the mobile phone antenna is localized 60mm from the plane of the lenses, 10mm from the right horizontal bar of the eyeglasses**.**

To take into account also the presence of the head, other approaches for the numerical investigations, and more complicated set-up for the measurements, should be used.

MOM Simulations

The simplified scenario described in the previous paragraph has been analysed using a MOM simulator based on the well known Numerical Electromagnetic Code (NEC) algorithm. The box of the cellular has been modelled by means of a metallic surface whereas, in order to describe the structure of the metallic eyeglasses, 130 wire segments of different lengths have been considered. Since the coupling between the mobile phone and the metallic eyeglasses is sensitive to the geometry and the characteristics of the antenna, modelling of this element requires particular care. In the performed simulations, an helix antenna (4 loops of 8 mm diameter and 20 mm overall height, positioned 5 mm above the phone box), described by means of 57 metallic segments, has been considered. At the operating frequency of 900 MHz, the antenna impedance turns out to be adequate to match a 50 Ω generator with a Standing Wave Ratio (SWR) ≤ 1.3, thus guaranteeing the correct excitation by the simulated generator.

Experimental Set-Up

To prevent the influence on the experiments of external e.m. sources, and avoid the effects of undesired field reflections due to objects surrounding the investigated scenario, the measurements have been performed inside a $6m \times 10m \times 6m$ anechoic chamber using a Schaffner EMC20 electric-field probe. For the antenna configuration considered here, the mobile phone behaves mainly like an electric field source. Therefore, only the electric field components have been measured by employing an automatic data acquisition system where the probe is moved by means of a scanner driven by a computer.

Since the dimensions of the available field sensor does not allow the spatial resolution needed by this kind of experiment a rescaled model, nine times bigger than the original one, has been used in the measurement set-up. The frequency and the power emitted by the source have been modified accordingly (the latter one in such a way to maintain the same power density of the original scenario). Therefore, as the studied regime refers to a GSM (**G**lobal **S**ystem for **M**obile Communications) phone working at 900 MHz in a low power (200mW) emission state, a 100 MHz Radio Frequency (RF) generator (Rode & Schwartz SML 03 RF) emitting 16.2 W (81×200m W) has been used for the experiments.

The cellular telephone has been realized using a wood structure covered by a 0.5 mm metal sheet. The helix antenna has been reproduced by means of a 6 mm copper wire rolled up on a PVC support (Ø=62 mm), to form a 230 mm coil. The measured SWR on the RF output port ranges from 1.3 (antenna in vertical position) to 1.4 (antenna in horizontal position) thus guaranteeing, also in the experimental set-up, the irradiation of the desired excited power. Finally, the eyeglass metallic frame was built by means of a Ø=12 mm copper tube.

Results

To evaluate the influence of the antenna position respect to the metallic frame on the electric field increment measured in the ocular region, many experiments and simulations have been performed. For brevity, only the most significant results are reported here. In the first set-up, the phone has been placed vertically (as in Fig. 1), with the base of the antenna positioned, in the rescaled model, 540 mm from the plane of the lenses and 90 mm from the metallic support of the eyeglasses (corresponding to 60 and 10 mm, respectively, in the original scenario). This configuration has been initially chosen as a reference scenario to check how the experiment and the numerical modelling fit each other. To this end, the measured electric field has been compared with the simulated one, with reference to two distinct 1000 mm long (110 mm in the original scenario) linear scans performed, with 50 mm spatial resolution, along two horizontal lines parallel to the lens plane. Results are reported in Fig. 2. As shown in the inset, the two scan lines lie at 170 mm (about 20 mm in the original scenario) from the lens plane, outside (henceforth external scan) and inside (henceforth internal scan) the metallic structure, respectively.

In order to evaluate the accuracy of the numerical description of the implemented transmitter (antenna + mobile phone), the measured and simulated data pertaining to both scans in a scenario (labelled SC-1 in Fig. 2) without the eyeglasses have been compared first. Then, to examine the effect induced by the metallic frame, the eyeglasses have been reintroduced in both the simulated and the measured scenarios (labelled SC-2). As far as the external scan is concerned (see top panel in Fig. 2), the effect of local field enhancement owing to the presence of the eyeglasses is clearly evident. The confidence on this result relies also on the good agreement between the data and the simulations, exhibited both with (SC-2) and without (SC-1) eyeglasses. Such agreement is confirmed also for the internal scan (bottom panel in Fig. 2), where no significant field enhancement has been detected. The latter is not, however, a general conclusion.

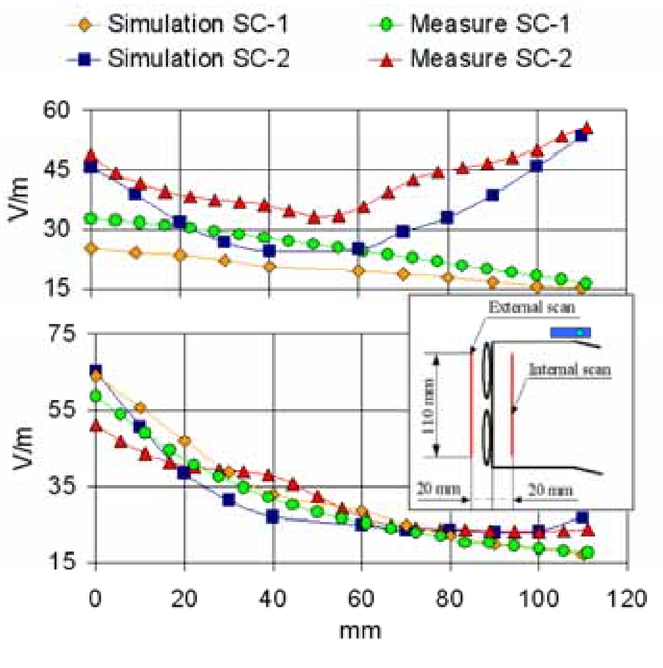

Figure 2. Comparisons between the simulated and measured electric field values (V/m) vs. field probe position (in units of the original model) for the external (top) and the internal (bottom) scan, without (SC-1) and with (SC-2) the eyeglasses. Here the cellular is placed vertically.

Other sets of data have shown that the physics of the coupling phenomenon is very complicated and the enhancement depends critically on the antenna position. As anticipated, the phenomenon has been deeply investigated by considering different positions of the cellular phone, so to identify the local field enhancement in typical operating conditions. Results show that the crucial parameter for the field focalisation in the eye region is the angle between the antenna and the eyeglasses. The maximum coupling between the considered antenna and the metallic frame occurs when the mobile phone is parallel to the metallic eyeglasses bars, with a relatively weak dependence on their mutual distance.

When the antenna is parallel to the metallic bar, the data obtained by performing linear scans along directions orthogonal to the lens plane (so to penetrate ideally in the eye region, see the geometry in the inset of Fig. 3), have highlighted a strong enhancement of the electric field values in SC-2 as compared with the ones obtained without the eyeglasses (i.e., SC-1). The results obtained from two scans (corresponding to left and right eye lines, respectively) are reported in Fig. 3. For the right eye (the one closer to the antenna) supposed to be positioned about 20 mm from the lens plane, we have measured a field value of 78.3 V/m corresponding to 2.12 times the value observed without the eyeglasses), whereas the left eye exhibits a value of 48.4 V/m, more than 2.86 times above the value in the absence of the eyeglasses.

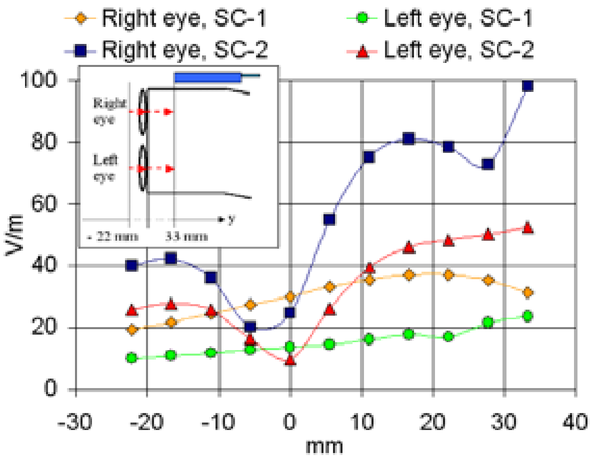

Figure 3. Measured electric field values (right side scan and left side scan) vs. the field probe position (real model) for a 55 mm linear scan along the *y* axis without (SC-1) and with (SC-2) the eyeglasses. Here the cellular is placed horizontally.

Conclusions

The enhancement induced by metallic eyeglasses on the electric field emitted by a cellular telephone has been investigated numerically and experimentally. Significant local increase of the electric field have been detected. This can be especially relevant in the eye region, where hazardous situations can be envisaged.

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REFERENCES

1. "Cellular telephone radiation blamed for brain tumor", *Microwave News*, vol. 12,May/June, 1992.
2. "Mobile phone – Brain Tumor Risk in the limelighth again", *Microwave News,* vol. 19, May/June, 1999.
3. Q. Balzano, O. Garay, T. Manning, "Electromagnetic Energy Exposure of the Users of Portable Cellular Telephones", *IEEE Trans. Veh. Technol.*, 1995, 44, (3), pp. 390-402.
4. A.D. Tinniswood, C.M. Furse, O.P. Gandhi, "Computations of SAR Distributions for Two Anatomically Based Models of the Human Head using CAD files of Commercial Telephones and the Parallelized FDTD Code", *IEEE Trans. Ant. Prop.*, 1998, 46, (6), pp. 829-833.
5. M.A. Jensen, Y.Rahmat-Samii, "Performance Analysis of Antennas for Hand-Held Transceivers Using FDTD", *IEEE Trans. Ant. Prop.*, 1993, 42, (8), pp. 1106-1113.
6. J. Toftgard, S.N. Hornsleth, J.B. Andersen, "Effects on Portable Antennas of the Presence of a Person", *IEEE Trans. Ant. Prop.*, 1993, 41, (6), pp. 739-746.
7. R.G. Vaughan, N.L. Scott, "Evaluation of Antenna Configurations for Reduced Power Absorption in the Head", *IEEE Trans. Veh. Technol.*, 1999, 48, (5), pp. 1371-1380.
8. R.F. Harrington, *Field Computation by Moment Method*, Macmillian, New York, 1968.