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# Influence of the Human Head in the Radiation of a Mobile Antenna

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**Abstract**— The big proliferation of mobile communication systems has caused an increased concern about the interaction between the human body and the antennas of mobile handsets. In order to study the problem, a multiband antenna was designed, fabricated and measured to operate over two frequency sub bands 900 and 1800 MHz. After that, we simulated the same antenna, but now, in the presence of a human head model to analyze the head's influence. First, the influence of the human head on the radiation efficiency of the antenna has been investigated as a function of the distance between the head and the antenna and with the inclination of the antenna. Furthermore, the relative amount of the electromagnetic power absorbed in the head has been obtained. In this study the electromagnetic analysis has been performed via FDTD (*Finite Difference Time Domain*).

## 1. INTRODUCTION

The cellular phone market has increased substantially during the last decade. The global commercial success of GSM has driven a great variety of cellular mobile radio systems. Along with market growth the possible risks related to the use of cellular phones have become an issue. A lot of research studies have been carried out based on this interaction [1–3], dealing generally with two aspects.

The first aspect is the mobile phone antenna influence on the human body in particular on the head. In fact, when a cellular phone works, the transmitting antenna is placed much closed to the user's head where a substantial part of radiated power is absorbed. It's important to characterize and quantify the distribution of the electromagnetic fields and the energy levels absorbed by the human tissues. In order to characterize the absorbed radiation by the human body, we use the Specific Absorption Rate (SAR) that represents the levels which is absorbed by a mass unit of tissue.

The second aspect is the influence of the user's body on radiation properties of the mobile phone, which is significant from the antenna design point of view. Antenna characteristics that are mostly affected by the presence of the human body are radiation pattern, input impedance and radiation efficiency [4]. The presence of the human body (and more specifically of the head) close to the handset causes generally degradation of its performance in comparison with the operation of the handset alone. The measure of this performance is the radiation efficiency of its antenna.

## 2. ANTENNA FOR GSM 900/1800

In this work, numerical simulations and measurements of a multi band antenna is presented for GSM 900/1800 MHz. The antenna was designed and simulated with the FDTD [6, 7], and a prototype of the final version was fabricated and measured. To obtain an antenna with two resonances we used a single U slot patch antenna [5] with two short pins, as shown in Figure 1. In the same figure, the radiation pattern of the antenna for 1800 MHz is presented.

## 3. INFLUENCE OF THE HUMAN HEAD IN THE RADIATION PROPRIETIES OF THE ANTENNA

In this section, we simulated the antenna in the presence of a human head model and analyze the head's influence. To studying this interaction, it is most important to understand the electromagnetic properties of body tissues. The dielectric properties of body tissues at radio frequencies and microwave frequencies have been examined by several authors. A recent comprehensive study is described in [8]. As a starting point of our research an anatomically-realistic model of the human head has been used. This model is known as SAM (Specific Anthropomorphic Mannequin), and uses a grid of  $5 \times 5 \times 5$  mm. It is as most approximate to real heterogeneous human head as recommended in safety standards. The EM simulation is performed using FDTD method, which allows processing of the complicated heterogeneous geometries. It's important to refer that 3D simulation is time and computational resource consuming.

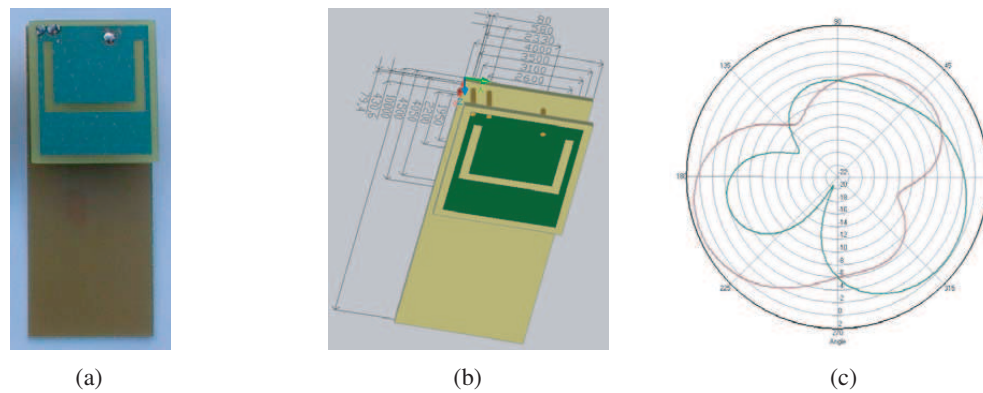


Figure 1: Antenna for GSM 900/1800. (a) Antenna prototype. (b) Antenna dimensions. (c) Radiation pattern for  $\phi = 90^\circ$  (green) and  $\theta = 90^\circ$  (red).

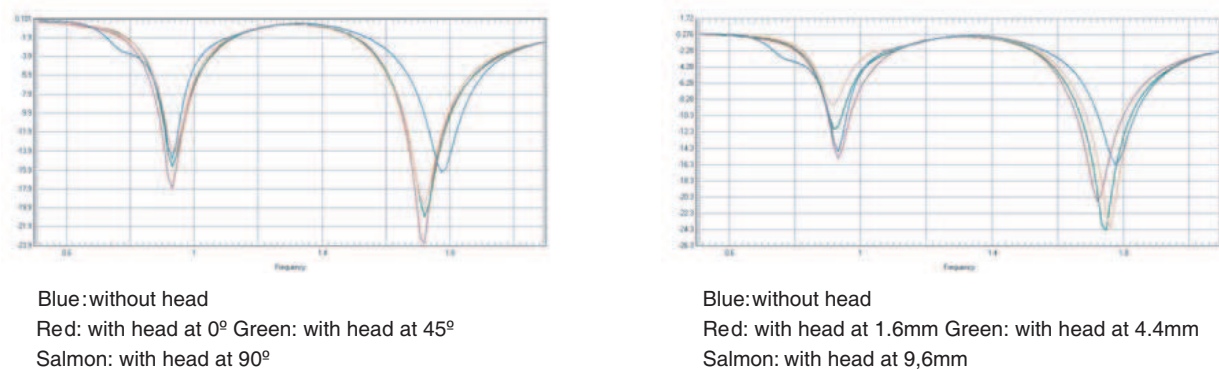


Figure 2: Return loss of the multiband antenna with and without head.

Based on theoretical and experimental results, the influence of the human head on the radiation efficiency of the antenna has been investigated as a function of the distance between the head and the antenna and with the inclination of the antenna. The considered distances were 1.6 mm, 4.4 mm and 9.6 mm. The antenna's inclinations were  $0^\circ$ ,  $45^\circ$ , and  $90^\circ$ . In Figure 2, in the left we present the simulated results of the return loss for an antenna distance of 1.6 mm from the head to the handset, and for handset's inclinations of  $0^\circ$ ,  $45^\circ$ , and  $90^\circ$ . In right, we present the simulated results for an inclination's antenna of  $45^\circ$  and distances of 1.6 mm, 4.4 mm and 9.6 mm.

Analyzing the Figure 2, it's possible to see that for the 900 MHz there are no significant differences in the level of return loss as well as the resonance frequency. For the 1800 there is a shift of resonance frequency to the left about 100 MHz but the level of return loss is improved.

In Figure 3, we present the radiation patterns of the antenna at 1800 MHz for  $\theta = 90$ . In the left the distance from the antenna to head is 1.6 mm and the inclination is  $0^\circ$ ,  $45^\circ$ , and  $90^\circ$ . In the right, the antenna inclination is  $45^\circ$  and the distances are 1.6 mm, 4.4 mm and 9.6 mm. In Figure 4 we present the same results but for the plane  $\phi = 90$ . From the Figure 3 and Figure 4, we conclude that radiation patterns are much modified with the antenna inclination, moreover, with the distance there are no significant alterations, but the head presence change the radiation pattern.

#### 4. SAR AS FREQUENCY FUNCTION

Furthermore, the relative amount of the electromagnetic power absorbed in the head has been obtained. The measurement of this type on the inside of the human body is extremely complicated and due to this fact, it is imperative the use of numerical methods. In this work, also presents the value of SAR as a function of handset's inclinations and the distance between the head and the handset, at the two frequencies, as we can see in the Figure 5. Investigations have shown that the SAR value depends on excitation frequency. The SAR for 900 MHz is more than double that obtained for 1800 MHz. There are no significant differences in SAR values between different inclinations of the handset, however when the distance from the head to antenna increase the SAR

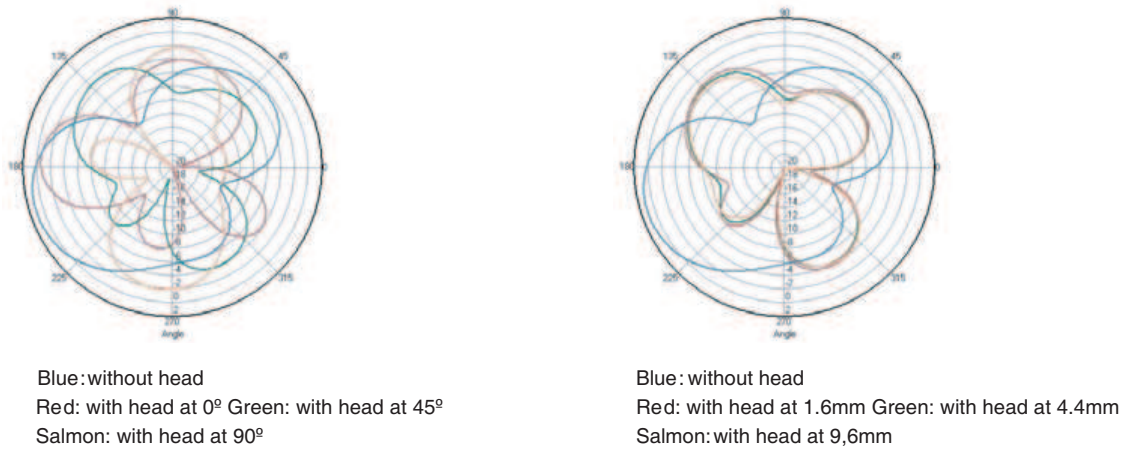


Figure 3: Radiation pattern of the antenna with and without head —  $xoy$  plane.

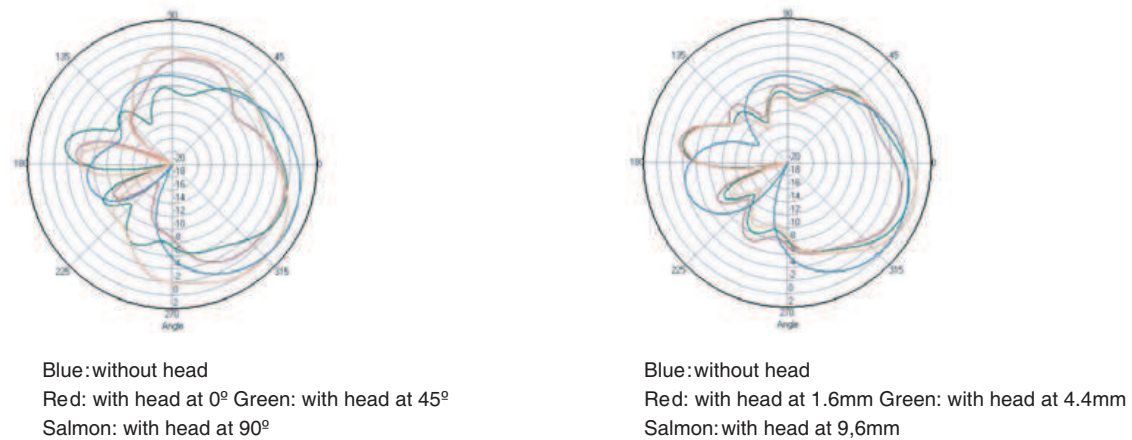


Figure 4: Radiation pattern of the antenna with and without head —  $yOz$  plane.

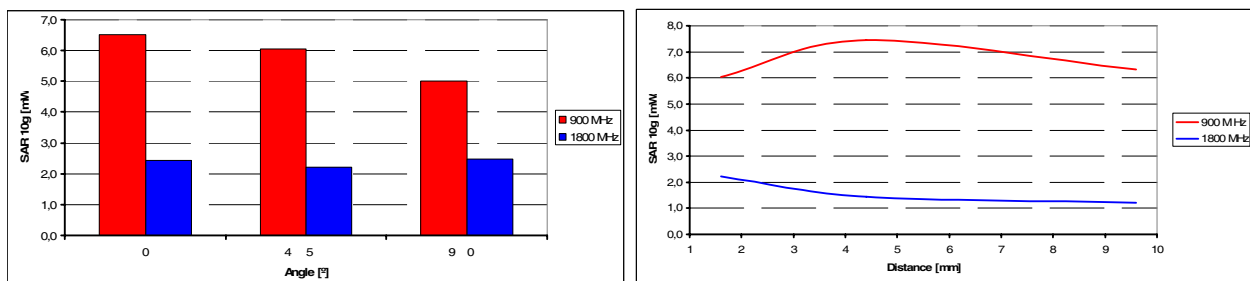


Figure 5: SAR as frequency function.

level tends to decrease but that decrease is not significant.

## 5. CONCLUSIONS

In this paper we present the influence of human head in the radiation patterns and in the return loss of a multiband antenna. It's possible to conclude that the radiation patterns have a strong change with the handset inclination, but the omnidirectional behavior remains. Moreover, with the distance there are no significant alterations, but the head presence changes the radiation pattern. In relation to the return loss the human head presence lead a shift in the resonance frequency especially for the 1800 MHz. Investigations have shown also that the SAR level depends on excitation frequency, and for 1800 MHz this value is lower than for 900 MHz.

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