Measurement Of The Magnitude And Direction Of The Electric Field Of A Mobile Phone In The Near Field

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The interaction of mobile phone radiation with humans has been the subject of considerable research for many years. The efforts have been directed primarily to investigating the magnitude of the electric field of the microwave radiation. However the direction of the electric field has also been associated with the effectiveness of its interaction with a living cell. In this work measurements are presented of both the magnitude and the direction of the electric field vector of a commonly used mobile phone **in the near field**. In particular measurements have been taken at distances from 1 cm to 12 cm from the surface of the mobile phone, next to the patch antenna, both in the forward direction (towards the skin) and backwards (towards the hand). The EP600 3-dimensional electric field probe has been used for the measurements. It is concluded that at distances practically in contact with the mobile phone, the magnitude of the electric field in the forward direction (towards the skin) is up to four times weaker than it is backwards (towards the hand). It is also concluded that the direction of the electric field of the microwave radiation deviates substantially from the far field geometry (being perpendicular to the propagation direction, ie being parallel to the skin) and turns towards the skin, direction which has been associated with an enhanced interaction with the cell.

electric field, mobile phone, near field

1. INTRODUCTION

The worldwide intensive use of mobile phones has been accompanied by concern for the microwave radiation it emits. The effects of interaction of the mobile phone microwave radiation with human tissue are distinguished into two main categories, that is thermal and non thermal effects. Thermal effects are based on the rise in tissue temperature, that radiation at the mobile phone frequencies can cause. Heating effects are proportional to the microwave power, the phone radiates. Regulations limit the maximum microwave power that mobile phones can emit. To date no significant tissue heating has been reported in the literature, which was shown to be caused by the microwave radiation alone, that is after excluding the heating caused by the thermal infrared radiation emitted at the operating temperatures of the mobile phone (Anderson and Rowley 2007). Furthermore the emitted microwave power is self-regulated to the minimum level required for the communication. Non thermal effects however span a much wider area of possible routes for the interaction of rf fields with human cells. One of those is the proposal that electromagnetic fields act through an interaction mediated at the plasma membrane that affects enzyme activities and signal transduction pathways. It has been shown that the geometry and relative orientation of the cell, with respect to the external rf field, significantly affect the value of the electric field induced in the

membrane and cytoplasm (Sebastian et al 2001). Moreover experimental setups have been proposed for studies and experiments related to the radio frequency effects on biological cells and organs (Boriraksantikul et al 2009).

Measurements of the magnitude of the rf electric field of a mobile phone, near the phone surface have been presented in the past (Usman et al 2009). It therefore becomes of interest, to also know the direction of the electric field of the mobile phone very close to the phone.

In this work an experimental determination is presented, of both the magnitude and the direction of the rf electric field of a mobile phone, at distances very close to the phone, that is within the 'near-field' region, which is the region of phone direct operation. The measurements reveal, for the first time to our knowledge, that the electric field has a large component parallel to the propagation direction, thus 'cutting-through' the human tissue at the cheek. This contrasts with the propagation of e-m waves in the 'far-field' region, in which the electric field is normal to the propagation direction, thus parallel to the cheek tissue.

2. MATERIALS AND METHODS

The measuring apparatus consists of an ordinary mobile phone (Nokia, model 2330 classic) and a 3 axial electric field probe, of Narda, model EP 600 (Fig.1). A PC is used for data storage.

Figure1 Experimental setup. Here the 3-axis electric field probe 'sees' the rear side of phone.

The phone is kept vertical and at a fixed position. The probe is kept at the height of the antenna, the position of which was identified from the data sheet of the phone. The phone strip antenna is located towards the rear cover, near the loudspeaker (the holes for which can be seen in Fig.1) and extends over the whole width of the cover. The 3-axes electric field probe is positioned with one axis perpendicular to the antenna. In Fig1 it is the y-axis, hence the plane of the other two axes , the x-z plane, remains parallel to the 'strip' antenna plane.

Measurements, of the three components of the electric field vector, were taken, with the probe at several distances from the mobile phone, both for the front lobe of the antenna(rear side of the phone, facing the hand, as in Fig.1) and for the back lobe (front side of the phone, facing the skin) . The distances covered the near-field region (typically of ~3 cm (for the wavelength of the mobile phone and the dimension of the   antenna) and were extended to ~ 12 cm. The phone was kept at a fixed position during the measurements, to minimize signal strength changes due to stray reflections. The mobile phone was operated in 'call' mode (it was called and was left ringing but not answered throughout each measurement). During the calling period the voltages from all 3 Cartesian sensors of the probe, were sampled repeatedly and the corresponding component of the electric field at that direction, was stored, for a period of between 30-60 sec, after which, the average value of the readings was taken. The raw data were converted from Cartesian (x, y, z) to spherical (r, θ, φ) coordinates, so that the magnitude and the orientation of the electric field vector could be determined.

3. RESULTS AND DISCUSSION

3.1   Electric field at the rear side of the phone.

The results of a typical run are shown in Fig 2. In this position the probe 'sees' the electric field of the main lobe of the antenna, which is the field that the palm of the hand of the phone user would also 'see'.

All 3 electric field components that were measured were within the linear response range for the 3 axis probe and at least one order of magnitude above its noise level.

Electric field at the rear side of the phone

80
70
60
◆E(V/m) 50
■θ-deg 40
▲φ-deg 30
20
10
0
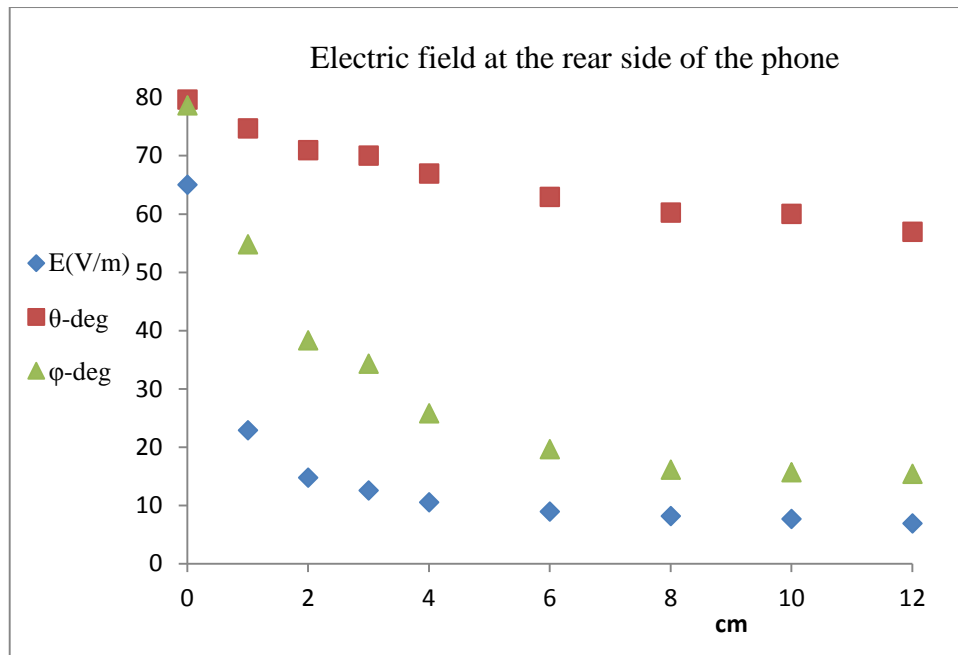
0   2   4   6   8   10   12
cm

Figure 2. Electric field at various distances from the phone rear side. The plots express (in spherical coordinates)   the magnitude and direction of the field.

The graph (Fig 2) shows that:

a) the magnitude of the electric field falls rapidly with distance ,up to about 3 cm and then stays practically constant.

b) the angle θ, of the electric field vector with the z axis,   changes appreciably as the phone-probe distance increases, from 80^0 to 60^0.

c) Such a change is more pronounced for the angle φ, of the projection of the electric field on the x-y plane with the x-axis. In particular φ is being reduced from 80^0 to 15^0.

It can   be seen that, at short distances , the electric field vector forms a large angle both with the z-axis and the x-y plane. This means that the electric field must also form a large angle with the x-z plane . As the x-z plane is the antenna plane, it means that the field is not parallel to the antenna.

As the distance increases , the electric field vector decreases in magnitude and it also turns towards the x-z plane. Therefore it becomes nearly parallel to the antenna and perpendicular to the propagation direction, ie it acquires its 'normal' characteristics in the far field region.

3.2   Electric field at the front side of the phone, facing the skin.

 The results of a typical run are shown in Fig 3. In this position the probe 'sees' the electric field of the secondary (rear) lobe of the antenna. Again all 3 electric field components that were measured, were within the linear response range for the 3 axis probe and at least one order of magnitude above its noise level.

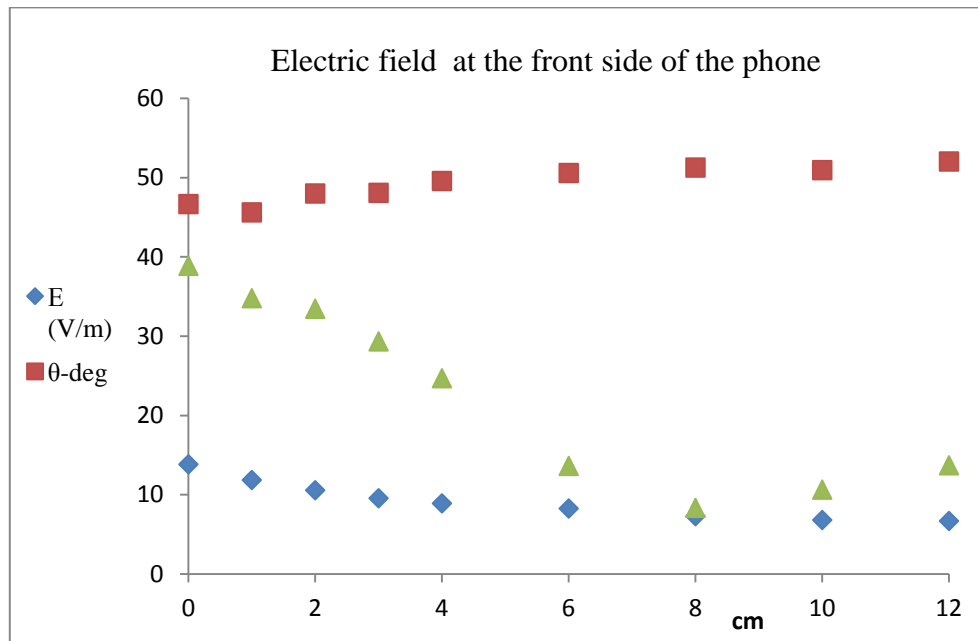Electric field at the front side of the phone

Figure 3. Electric field at various distances from the phone front side. The plots express (in spherical coordinates) the magnitude and direction of the field.

The graph (Fig 3) shows that:

a) the magnitude of the electric field is much smaller , by 4-5 times, on this (front) side than on the rear side. Moreover it does not change appreciably with distance , unlike at the rear side of the phone where it does, presumably because at the rear the probe reaches nearer to the antenna .

b) the angle θ, of the electric field vector with the z axis,   does not changes appreciably with the phone-probe distance , unlike it did at the rear side.

c) the angle φ, of   the projection of the electric field on the x-y plane with the x-axis decreases significantly from 40^0 to 10^0, but not as much as it did at the rear.

It can be seen that, at short distances, the electric field vector forms large angle both with the z-axis and the x-y plane (but not as large as on the rear side). This means that the electric field

must also form a large angle with the x-z plane. As the x-z plane is the antenna plane, it means that the field is not parallel to the antenna.

As the distance increases , the electric field vector of roughly constant magnitude, 'writes' a cone around the z-axis as it turns towards the x-z plane. Therefore, it becomes nearly parallel to the antenna and perpendicular to the propagation direction. That is, it acquires its 'normal' characteristics in the far field region, as it did at the rear side.

4. CONCLUSIONS

The above behavior means that in the near field, which corresponds to the position of the phone under normal use,   the electric field seizes to be parallel to the operator cheek and 'cuts through' the cells.

Therefore, in cases where cells   have specific orientation with respect to the electric field direction, a higher field may penetrate inside them, at relative orientations which have been associated with increased effectiveness of the field to tissue interaction.

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