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The magnetic dipole moment of a cellular phone

***Abstract**. In the following we measure the magnetic field of a cellular phone. It is found that the magnetic field is comparable to that of the earth's magnetic field at 6,3 cm above the phone. However, the field is not uniform as the earth's magnetic field but bears the unique distribution of a magnetic field induced by a magnetic dipole. The dipole moment is calculated.*
Recent claims regarding the safety of cellular phones suggest that weak static magnetic fields are induced around the phone, and this field and its gradients may pose a health risk to the user. An experiment was conducted to measure the induced static magnetic field around a cellular phone. 65 μT variations and 18 μT/cm gradients were measured in the magnetic field at about 6 cm from the phone. The influence the measured magnetic fields may have on the user is beyond the scope of this research.

***Streszczenie.** W pracy mierzymy pole magnetyczne od telefonu komórkowego Stwierdzono, że pole magnetyczne telefonu przyjmuje wartości porównywalne z wartościami ziemskiego pola magnetycznego dla odległości około 6,3 cm od telefonu. Jednakże, pole nie ma rozkładu jednostajnego podobnie jak ziemskie pole magnetyczne, lecz wykazuje unikalny rozkład. Wyznaczono moment dipolowy. W najnowszych pracach dotyczących bezpieczeństwa użytkowania telefonów komórkowych twierdzi się, że słabe pola magnetyczne są indukowane wokół telefonu i że pola te mogą stanowić zagrożenie dla użytkownika. Przeprowadzono eksperyment w celu zmierzenia indukowanego statycznego pola magnetycznego wokół telefonu komórkowego. Z pomiarów uzyskano wartości zmienności indukcji na poziomie 65 μT oraz gradienty na poziomie 18 μT/cm dla odległości około 6 cm od telefonu. Określenie wpływu, jaki mogłyby mieć pola o tego typu charakterystyce na użytkownika nie jest przedmiotem rozważań w niniejszej pracy. (**Dipolowy moment magnetyczny telefonu komórkowego**)*

Keywords: cellular phone, health risk, dipole moment.
Słowa kluczowe: telefon komórkowy, narażenie zdrowia, moment dipolowy.

Introduction

As the cellular phone becomes a dominant tool in everyday life, suspicions regarding biological influences it might have on the users become relevant. Many investigations were carried out using a direct approach [1-4] as well as using statistical approach [5,6], most of them pointing out the influence that the radiated radio frequency may or may not have on the user. A different claim that has been recently heard is about an influence on the user of the static magnetic field induced by the phone [6-9].

According to this claim, spatial gradients of the static magnetic field are induced in close proximity to the phone (within ~25 cm around the phone), and the exposure to these gradients may be harmful. This claim is strong enough to drive researchers to perform experiments, develop unique patented tools [10] and even to suggest and develop practical solutions to this effect. Before solutions are suggested, there is a need to accurately describe the static magnetic field near the cellular phone, and evaluate quantitatively the gradients if found. In this study an experimental measurement accompanied by an analytical model of the induced static magnetic field near a cellular phone are presented. The induced magnetic field profile is described and some spatial induced gradients are indeed found. It should be noted that the possible biological influence such magnetic field gradients may or may not have on the user is beyond the scope of this research.

Experimental Device

A Gauss/Tesla meter (Series 9950 produced by FW BELL) shown in Fig. 1a (see also Figure 1b), was used for the magnetic field measurements. The operating principle of the device is based on the Hall Effect. The device probe allows measurement of a magnetic field in two perpendicular axes, parallel and perpendicular to the probe axis. According to the device specifications it is sensitive to fields up to 0,1 μT. The accuracy of the device is ± 0,2 μT. In practice a jitter of ± 0,2 μT was observed in the device readings. Also, a slow drift in the device reading of up to 2 μT was observed.

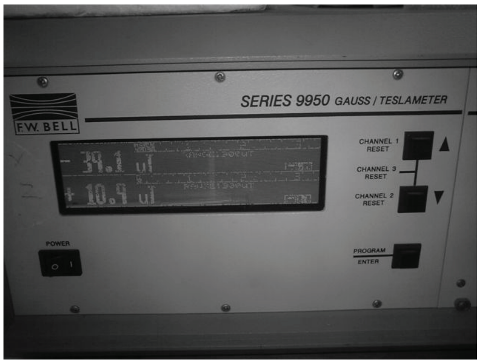
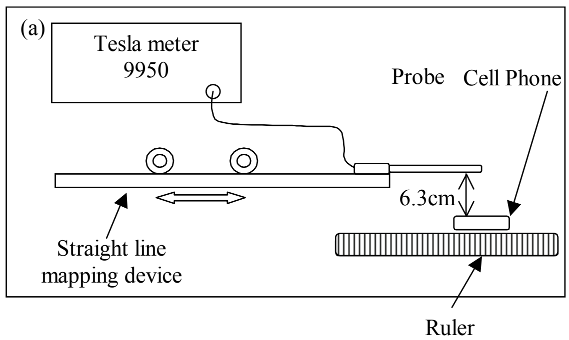


Fig. 1a: A Gauss/Tesla meter (Series 9950 produced by FW BELL).

a)



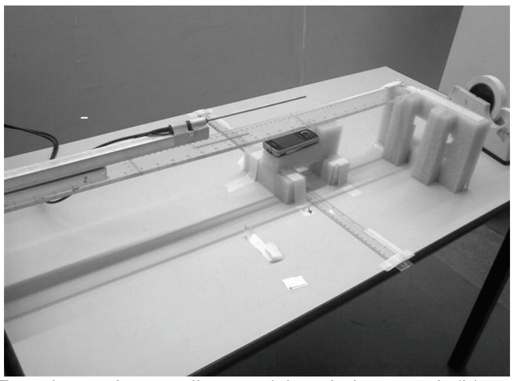


Fig. 1b: Experimental setup diagram (a) and photograph (b).

Experimental Setup

The experimental setup based on the Tesla meter is shown in Fig. 1b. The Hall probe was fixed in a mapping device allowing the probe a controllable movement in a straight line above the phone. The probe was moved in small steps and the magnetic field above the phone was recorded in 2 directions: along the probe axis and perpendicular to the probe, directed downwards towards the phone. The distance of the scanning line from the phone was 6,3 cm. Figure 1c gives a more comprehensive view of the probe's trajectory.

A mapping device is used to map the magnetic field above the cellular phone.

Results

The measurement results are presented in Fig. 2. An influence of the phone on the magnetic field is seen in both of the measured directions. Variations of ~65 μT are seen. The magnetic field gradient reaches ~18 μT/cm.

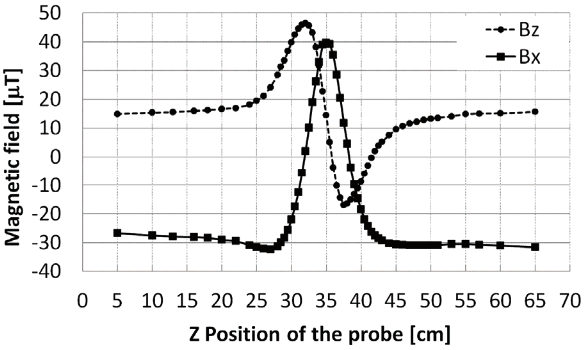


Fig. 2: Measured magnetic field in a straight line 6.3 cm above the phone.

In a second set of measurements the phone was moved to a distance of 10 cm from the measuring line. Similar results were measured but with a lower amplitude of ~20 μT in the magnetic field variations. The gradients in the magnetic field were also decreased to ~3.5 μT/cm. The same measurements were carried out with other types of cell phones and similar results were measured.

Analysis

Clearly the cellular phone affects the static magnetic field in its surrounding environment. Two possible explanations are suggested: 1) The Earth's magnetic field aligns the magnetic dipoles of the cellular phone which in turn create a static magnetic field that was measured, and 2) There is a small magnetism of the phone itself, that is added to the earth magnetic field. An estimation of the first possibility is as follows.

The magnetization $\vec{M}$ (magnetic dipole density) induced by a uniform magnetic field (= magnetic flux density in vacuum $\vec{B}_0$) can be approximated as [11]:

$$\vec{M} \cong 3\left(\frac{\mu-1}{\mu+2}\right)\vec{B}_0 \qquad (1)$$

in which μ is the relative magnetic permeability in the phone. The total magnetic dipole $\vec{m}$ is given by $\vec{m} = \vec{M}V$ in which V is the device volume. An ideal dipole is known [11] to generate a magnetic field of the form:

$$\vec{B} = \frac{3\hat{n}(\hat{n}\cdot\hat{m}) - \hat{m}}{|\vec{x}|^3} m \qquad (2)$$

in which $\vec{x}$ is the relative position of the dipole with respect to the location of the probe and $\hat{n} = \frac{\vec{x}}{|\vec{x}|}$. The magnetic dipole of size $m = |\vec{m}|$ has direction $\hat{m} = \frac{\vec{m}}{m}$. The unit direction vector was parameterized using the standard spherical angles ϕ, θ such that $\hat{m} = (\sin\theta\cos\phi, \cos\theta\sin\phi, \sin\phi)$. The data of figure 2 was fitted to the dipole model and the best fit parameters are: m = 6685 μT cm^3, θ = 4,71 radians and ϕ = -0,08 radians. Figure 3 and 4 show both experimental and theoretical data, it can be easily seen that there is excellent matching.

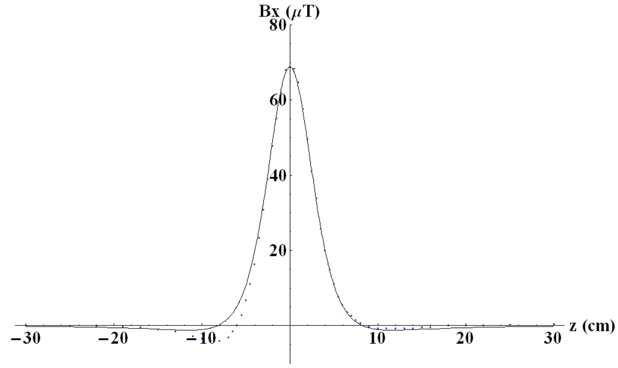


Fig. 3: Theoretical (solid line) and experimental (dots) perpendicular magnetic field of a cellular phone.

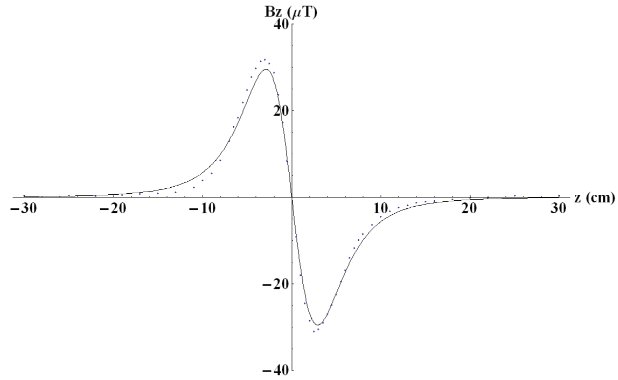


Fig. 4: Theoretical (solid line) and experimental (dots) parallel magnetic field of a cellular phone.

We assume the dimensions of the magnetized media are approximately the dimensions of the cellular phone: Length 10 cm, Width 4,8 cm and Height 1 cm. The volume of magnetized media is then V = 48 cm^3. Assuming that the magnetization is uniform and switching to CGS units we arrive at $M = \frac{m}{V}$ = 1,39 (dipole moment per cm^3). However, trying to match this value to the earth's magnetic field $B_0 \cong 0.5G$ through formula (1) we arrive at a value of μ = - 2,28, which is clearly unphysical. We thus conclude that the mobile phone has a (low) permanent magnetization which is independent of the earth's field.

In order to verify the above understanding, a few more measurements were made without scanning. The cell phone was positioned for magnetic field measurement close to the maximal readings, and a reading was taken. Then, the phone was flipped over. If the assumption for induced field was right, no significant change was to be expected, but if self magnetism of the phone is the cause of the effect, the reading should significantly change. Indeed a significant change was measured. Also, measurements were taken on a phone that was turned off, and on a phone with the battery removed. Moreover, several phone models were checked. All these checks showed similar results.

Conclusion

It is proven that the cellular phone indeed induces a static magnetic field and magnetic field gradients within ~20 cm of its surrounding environment. The amplitude of the induced variations in the magnetic field is several tens of micro-Tesla.

This value can be compared to the magnetic field variations that will be applied to a moving person. For example, when a person is rotating his head, the Earth's magnetic field (that is assumed constant in direction and amplitude) will cause a variation and temporal change of the magnetic field in the person's head. Variations up to twice that of the Earth's magnetic field can be induced, that is up to ~100 μT. Nevertheless, this effect, although similar in amplitude, is different in its nature. While rotating the head in a static constant magnetic field induces a temporal change in the magnetic field inside the head, that is constant along the head, the cell-phone induces a magnetic field that has a spatial gradient in the head but which is constant over time. This fundamental difference must be considered in this comparison.

According to the result, a major question remains: do the proven existing magnetic field gradients, at the magnitudes described above, have any affect on the human head? The answer to this question is left to further research.

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