Electromagnetic fields and their impacts

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Abstract. The main goal of this paper is to briefly recall some different electromagnetic field definitions, some macroscopic sources of electromagnetic fields, electromagnetic fields classification regarding time dependences, and the ways of field determination in concrete cases. After that, all the mechanisms of interaction between electromagnetic field and substance, on atomic level, are described in details. Interaction between substance and electric field is investigated separately from the substance and magnetic field interaction. It is demonstrated that, in all cases of the unique electromagnetic field, total interaction can be treated as a superposition of two separated interactions. Finally, the main electromagnetic fields surrounding us is cited and discussed.

1. Introduction

Our living and working environment is filled with all kinds of electromagnetic fields. Some of them, like the Earth magnetic field, are natural, while the large number of electromagnetic fields are artificial, created by people. Nowadays, in the era of wireless communications, the number of electromagnetic fields with different specifications is growing rapidly.

The influence of electromagnetic fields on everything and everybody inside them could be useful or harmful. For this reason, it is important to be well acquainted with all electromagnetic fields surrounding us, as well as with the mechanisms of their impact on the substances exposed to the electromagnetic fields’ influence.

The aim of the first part of this paper is to briefly remind the audience about the electromagnetic fields definitions, about some macroscopic sources of electromagnetic fields and some methods for the electromagnetic field determination. The second part is dedicated to the interaction between electromagnetic fields and the substances in which electromagnetic field is established, while the third part brings the discussion on the most common electromagnetic fields in our environment.

Some electromagnetic field classifications into groups, with the characteristics of each group are also presented and discussed in this paper, together with some standards defining maximal allowed electric and magnetic field values.
2. Basic electromagnetic fields’ features

2.1. Electromagnetic fields definitions

In any paper concerning electromagnetic fields description, first of all, a definition of electromagnetic field should be presented. The definition of a kind “What is an electromagnetic field” can also be found in the science world. For instance, Einstein defined a field as “regular, geometrical curvature of space”. This definition is correct, because a field really is “regular”, meaning that certain sources always produce the same field. The field is “geometrical” because it is always established in the space; however, it is not always easy to comprehend what “the curvature of space” is.

Actually, this could be understood if one graphically presents the space with no field as the family of parallel, plane surfaces which are not “curved”. On the other hand, if the space with a field is 3D visualized, like a gravitational field shown in Figure 1 [1], or electric field of an electric dipole, presented in Figure 2 [2], the concept of “the curvature of space” could be accepted.

![Figure 1. 3D presentation of a gravitational field](image1)

![Figure 2. 3D presentation of an electric dipole field](image2)

In both images, the “curved” surfaces could be noticed and this could be a graphical explanation of the Einstein’s field definition.

Nevertheless, in the engineering theory and practice, another field definition is much more in use and much easier to imagine. Namely, the most common field definition is through the field consequences, i.e. the force produced by a field [3-5].

For this reason, an electromagnetic field can be defined using the Lorenz’s force expression,

$$\vec{F} = \Delta Q \vec{E} + \Delta Q \vec{v} \times \vec{B}. \quad (1)$$

The electromagnetic field definition can now be presented as follows: If in the certain domain one puts the test charge, $\Delta Q$ and if there is a force defined by (1), acting on the test charge, it could be concluded that in this domain an electromagnetic field exists. Obviously, the electromagnetic field, produced by some external sources, exists independently of the test charge; i.e. the test charge serves only to detect the field. It should be noticed that this implicit definition of electromagnetic field is simple and easily comprehensible.

At the same time, the expression (1) is the basic equation for the force on charges in the electric and magnetic field. In (1) $\vec{E}$ is the electric field strength vector, $\vec{B}$ is the magnetic flux density vector, while $\vec{v}$ is the velocity of moving charges. As mentioned before, $\Delta Q$ is the test charge. By its definition, the geometrical size of the test charge is very small and, at the same time, the charge itself is very small as well; actually, it is so small that the field produced by the test charge is negligible compared to the fields define by $\vec{E}$ and $\vec{B}$.

Observing (1), two more conclusions can be derived. The electric field force acts on positive charges in the direction of $\vec{E}$, adding kinetic energy to the charges and accelerating them, while the
magnetic field force acts perpendicularly to the directions of moving particles, attending to change the moving direction, with no possibilities for accelerating them and adding any kinetic energy to them.

Moreover, due to relevant physical values which can be reached in nature, in the case of time constant electromagnetic fields, the first part of (1) is larger than the second part. This means that the influence of time constant magnetic field on time constant current distribution can be neglected.

2.2. Macroscopic sources of electromagnetic fields
The real sources of all macroscopic events in electrical engineering theory and practice are elementary charges, i.e. electrons and protons, considering the simple Bohr’s model of atom. Actually, in macroscopic electromagnetic fields theory, the sources are defined as a simultaneous action of a large number of elementary charged particles, distributed in space. For this reason, as the macroscopic electromagnetic field sources, two macroscopic quantities are defined, in order to describe the average performances of elementary charges. These quantities are [3-5]:

- Volume charge density, \( \rho(x,y,z,t) = (dQ)_{\text{a.dv}} \) / dV

- Current density vector, \( \mathbf{J}(x,y,z,t) = NQ\mathbf{v} = N(-Q(-\mathbf{v}) = \rho\mathbf{v} \).

In the above expressions, dV is a so-called „Physically small volume“ or “Elementary volume”, small enough to represent a point and large enough to encounter the large number of elementary charges; \( N \) is the concentration of moving charges; \( Q \) is the macroscopic charge of each moving particle; and \( \mathbf{v} \) is the velocity of moving charged particles.

2.3. Expression for vectors \( \mathbf{E} \) and \( \mathbf{B} \) produced by known electromagnetic fields sources
Let us consider the domain, with the volume \( v' \), in which all electromagnetic field sources are, and let us denote all the quantities concerning these sources with a prime, as demonstrated in Figure 3.

![Figure 3](image)

**Figure 3.** Domain with sources, \( v' \) and the point P in which electromagnetic field vectors are expressed

According to Figure 3, adopting the origin, denoted by 0, the position of the point \( P' \), in which the sources \( \rho(r',t) \) and \( \mathbf{J}(r',t) \) are known values, is defined by the position vector \( \mathbf{r}' \), while the position of the point P, in which the electromagnetic field vectors \( \mathbf{E} \) and \( \mathbf{B} \) are calculated, is defined by the position vector \( \mathbf{r} \).

If the system presented in Figure 3 is in vacuum, the expressions for vectors \( \mathbf{E} \) and \( \mathbf{B} \) are as follows [3-5]:
In the above equations, the physical constants for vacuum are the following: 
\(\varepsilon_0\) – permittivity of vacuum, \(\varepsilon_0 = (8.85419 \pm 0.00002) \times 10^{-12} \text{ F/m (As/Vm)},\)
\(\mu_0\) – permeability of vacuum, \(\mu_0 = 4\pi \times 10^{-7} \text{ H/m (Vs/Am)}\).
\(c_0\) – light speed in vacuum, \(c_0 = 1/\sqrt{\varepsilon_0\mu_0}\), \(c_0 = (2.997924 \pm 0.000003) \times 10^8 \text{ m/s}\).

Another important fact, called the retardation effect, can also be noticed in (2). Due to the finite speed of the electromagnetic field establishing, it is obvious in (2) that the field vectors in the point P, at the time \(t\), are not produced by sources at the same time, but acting at the previous time, \(t - R/c_0\).

The electromagnetic field vectors are frequently defined through the potentials, mostly through the Lorenz’s electric scalar potential, \(V\) and magnetic vector potential, \(\vec{A}\), connected by the Lorenz’s condition [3], [4],

\[ \nabla \cdot \vec{A} = -\varepsilon_0\mu_0 \frac{\partial V}{\partial t}. \]  
(3)

If the electromagnetic field sources in the volume \(v'\) are known, electric scalar potential, \(V\) and magnetic vector potential, \(\vec{A}\) are the solutions of partial differential equations [3-5],

\[ \Delta V - \varepsilon_0\mu_0 \frac{\partial^2 V}{\partial t^2} = -\rho/\varepsilon_0, \]  
(4)

\[ \Delta \vec{A} - \varepsilon_0\mu_0 \frac{\partial^2 \vec{A}}{\partial t^2} = -\mu_0 \vec{J}. \]

Considering the system shown in Figure 3, electric scalar potential, \(V\) and magnetic vector potential, \(\vec{A}\) are retarded potentials [3], [4], [6],

\[ V(r,t) = \frac{1}{4\pi\varepsilon_0} \int \frac{\rho(\vec{r}',t-R/c_0)}{R^3} dV', \]  
(5)

\[ \vec{A}(r,t) = \frac{\mu_0}{4\pi} \int \frac{\vec{J}(\vec{r}',t-R/c_0)}{R} dV'. \]

In the above equations, \(c_0\) is the light speed in vacuum; \(c_0 = 1/\sqrt{\varepsilon_0\mu_0}\); it is on this fact that Maxwell based the hypothesis that the light is also an electromagnetic field (wave).

Electromagnetic field vectors, electric field strength vector and magnetic flux density vector are defined by potentials as [3-5],

\[ \vec{E}(\vec{r},t) = -\nabla V(\vec{r},t) - \frac{\partial \vec{A}(\vec{r},t)}{\partial t}, \quad \vec{B}(\vec{r},t) = \nabla \times \vec{A}. \]  
(6)

From both expressions, (2) and (6), it can be concluded that, in general, the electric field, defined by the electric field strength vector, has both components, conservative and rotational, while the magnetic field expressed by the magnetic flux density vector is a thoroughly rotational field. The second part of the electric field strength vector is the so-called induced electric field strength vector.
2.4. Classification of electromagnetic fields regarding their time varying behavior

Electromagnetic fields can be either time constant or time varying. If the sources which produce electromagnetic fields are not varying in time, the electromagnetic fields themselves are also time constant. The general characteristic of any time constant electromagnetic field is that the electric field can always be separated from the magnetic field. In the case when the macroscopic charges are not moving, they produce an electrostatic field and in this case the magnetic field does not exist. In the case when the charges move uniformly, producing the time constant current, it can be shown that the influence of the time constant magnetic field on the current distribution is negligible. Consequently, in this case as well the electric field can be observed independently of the magnetic field.

Time constant electric field is always a conservative one, meaning that the work along any closed path is equal to zero, i.e. the integral of the conservative field strength vector, along any closed path, is equal to zero, too,

\[ \oint C \mathbf{E} \cdot d\mathbf{l} = 0. \]  
(7)

A completely different situation is when the electromagnetic field sources are time varying, producing the time varying field. Due to the electromagnetic induction, the electric field strength vector obtains the rotational component, too, produced by the time varying magnetic field. On the other hand, a magnetic field can also be caused by the time varying electric field. For this reason, time varying electric and magnetic fields cannot be treated separately; they are only the components of the unique electromagnetic field. Usually, it can be defined that the time varying electric field is always followed by the time varying magnetic field and vice versa.

It is also usual that time varying electromagnetic fields are classified in two groups, depending on the field retardation. If the field retardation can be neglected, the electromagnetic field is time slow varying, or quasi-static, or a quasi-stationary electromagnetic field. On the other hand, if the field retardation cannot be neglected, the field is time fast varying, or it is an electromagnetic wave.

When the time variations of the sources are periodic, the frequency, \( f \) and the wave length, \( \lambda \) are defined and the relation between those two quantities in vacuum is

\[ \lambda = \frac{c_0}{f}. \]  
(8)

If the electromagnetic field sources vary in time as a harmonic function, i.e. sin or cosine function of time, the complex approach can be adopted and the partial differential equations (4) could be accepted as the complex ones [3], [4],

\[ \Delta \mathcal{V} + \omega^2 \varepsilon_0 \mu_0 \mathcal{V} = -\mathcal{P}/\varepsilon_0, \]  
\[ \Delta \mathcal{A} + \omega^2 \varepsilon_0 \mu_0 \mathcal{A} = -\mu_0 \mathcal{J}, \]  
(9)

defining the complex electric scalar potential and complex magnetic vector potential [3], [4], [6],

\[ \mathcal{V}(\mathbf{r}) = \frac{1}{4\pi\varepsilon_0} \int_{S'} \frac{\mathcal{P}(\mathbf{r'}) e^{-j|\mathbf{r} - \mathbf{r'}|}}{R} d\mathbf{v}', \]  
\[ \mathcal{A}(\mathbf{r}) = \frac{\mu_0}{4\pi} \int_{S'} \frac{\mathcal{J}(\mathbf{r'}) e^{-j|\mathbf{r} - \mathbf{r'}|}}{R} d\mathbf{v}'. \]  
(10)

In the above equations, the phase coefficient for vacuum is defined as [3-5],
\[
\beta_0 = \frac{\omega}{c_0} = \omega \sqrt{\varepsilon_0 \mu_0}, \quad \omega = 2\pi f.
\]

From known values of complex potentials, the complex electric field strength vector and complex magnetic flux density vectors are \([3-5]\),

\[
\vec{E} = -\nabla V - j\omega \vec{A}, \quad \vec{B} = \nabla \times \vec{A}.
\]

In the electrical engineering practice, the majority of electromagnetic fields are periodic, harmonic functions of time. For this reason, it is usual that time varying electromagnetic fields are classified according to the frequency, as it is presented in Table 1 \([7]\).

| Number of ranges \(N\) | Frequency range (lower limit included, upper limit excluded) | Name of the range | Abbreviation | Wave-length range | Name of the wave-length range | Abbreviation |
|-------------------------|---------------------------------------------------------------|-------------------|--------------|------------------|-------------------------------|--------------|
| 1.                      | 3Hz to 30 Hz                                                  | Extremely Low Frequencies | ELF         | 100,000 km to 10,000 km | Decameter                    |              |
| 2.                      | 30 Hz to 300 Hz                                               | Low Frequencies    | ELF         | 10,000 km to 1,000 km | Megameter                    |              |
| 3.                      | 300Hz to 3kHz                                                 | Super Low Frequencies | SLF         | 1,000 km to 100 km   | Hectometer                   |              |
| 4.                      | 3 kHz to 30 kHz                                               | Very Low Frequencies | VLF         | 100 km to 10 km    | Myriameter                   | B.Mam        |
| 5.                      | 30 kHz to 300 kHz                                             | Low Frequencies    | LF          | 10 km to 1 km      | Kilometer                    | B.km         |
| 6.                      | 300 kHz to 3 MHz                                              | Middle Frequencies | MF          | 1 km to 100 m      | Hectometer                   | B.hm         |
| 7.                      | 3 MHz to 30 MHz                                               | High Frequencies   | HF          | 100 m to 10 m      | Decameter                    | B.dam        |
| 8.                      | 30 MHz to 300 MHz                                             | Very High Frequencies | VHF       | 10 m to 1 m        | Meter                        | B.m          |
| 9.                      | 300 MHz to 3 GHz                                              | Ultra High Frequencies | UHF      | 1 m to 10 cm       | Decimeter                    | B.dm         |
| 10.                     | 3 GHz to 30 GHz                                               | Super High Frequencies | SHF      | 10 cm to 1 cm      | Centimeter                   | B.cm         |
| 11.                     | 30GHz do 300GHz                                               | Extremely High Frequencies | EHF    | 1 cm to 1 mm       | Milimeter                    | B.mm         |
| 12.                     | 300 GHz to 3,000 GHz                                          |                      |             | 1 mm to 0.1 mm     | Sub-milimeter                |              |
| 13.                     | > 3,000 GHz                                                   |                      |             | < 0.1 mm           | Light (Optical)              |              |

As it can be observed in Table 1, under certain conditions all time varying electromagnetic fields could be treated as electromagnetic waves. For this reason, the term “radiation”, usually applied for electromagnetic waves, can conditionally be applied for all time varying electromagnetic fields.
3. Electromagnetic fields in a substance

When an electromagnetic field is present in a substance, an interaction between the field and the substance occurs. This means that the field modifies the substance, provoking the movement of free or bound charges. The modified substance produces its own electromagnetic field, which superposes the existing field and changes it. In observing these interactions, the electric field interaction can be explained separately from the magnetic field interaction.

The interaction between electric field and a substance depends on the conductive nature of the substance; the interaction differs inside the conductors with a large number of free (unbound) charges and the insulators, in which the majority of charges are bound.

3.1. Interaction of electric field and the substance

3.1.1. Electrostatic induction. In the case when a conductor is placed in an electric field, the field provokes the movement of free charges as the consequence of the first part of the Lorenz force, (1). The positive charges move in the electric field strength vector direction, while the negative charges move in the opposite direction. This movement of free charges is known as the electrostatic induction, and it is presented in Figure 4.

![Figure 4. Conductive body inside an electric field – electrostatic induction](image)

The free charges, positioned at the conductor body’s surface, produce their own electric field, which cancels the external field inside the body. This effect is widely applied in the Faraday’s cage case, determining that the inside domain is perfectly protected against the electrostatic field and very well protected against any other electric field.

3.1.2. Electric polarization. If an insulator (dielectric) is placed inside the electric field, the first part of the Lorenz force, (1), displaces the bound charges at the atomic or molecular level; this effect is referred to as an electric polarization. The electric polarization can be electronic, dipole or ionic, depending on the atomic structure of material. Inside materials with non-polar atoms, the electronic polarization occurs, as presented in Figure 5.
The first part of the Lorenz force produces the movement of positive bound charges in the direction of the electric field strength vector and the movement of negative bound charges in the opposite direction. As the result of this action, the atom is deformed and it acts as an electric dipole; hence it can be treated as a microscopic dipole, with the dipole moment rotating it in the field direction, as shown in Figure 6. There is also a force dragging it into the domain of the stronger field, presented as well in Figure 6.

Actually, Figure 6 graphically represents the dipole polarization occurring in the case of a substance with polar molecules, like, for instance, water.

The electric field produces the torque on polar molecules, which rotates the molecule to the electric field strength vector direction and the force toward the domain with the higher electric field strength vector magnitudes. The third form of polarization appears inside some of the materials with crystalline structures. An external electric field deforms the structure at the atomic level and thus the deformed structure acts as a large number of microscopic dipoles.

There are several possibilities to describe polarization at the macroscopic level; the most applied is the involvement of the dielectric permittivity, as the material property. The dielectric permittivity is defined as the product of dielectric relative permittivity, and the permittivity of the vacuum,

$$\varepsilon = \varepsilon_r \varepsilon_0. \quad (13)$$

3.2. Interaction of magnetic field and the substance

If a closed contour with the current is placed in a magnetic field, the field produces a torque, trying to rotate the contour and position it perpendicular to the magnetic flux density vector. Although there is no contour with the current at the atomic level, the orbit spin could be treated as the small, microscopic current contour on which the magnetic field produces the torque. In the absence of the magnetic field, the orbits of electrons are randomly arranged, producing no resultant magnetic field.
The exceptions are only magnetized ferromagnetic materials, in which there are strong interactions between neighboring atoms and the thorough orientation of electron’s orbits inside material’s domains. These domains, the so-called Weiss domains, could be even several cubic centimeters large.

When a substance is exposed to a magnetic field, the field has the intention to rotate all electrons’ orbits to the plane perpendicular to the magnetic flux density vector; this situation is known as the magnetization of material. The principle of the magnetization process at the atomic level, before and after the impact of the magnetic field, is presented in Figure 7.

The Coulomb forces between electrons oppose the magnetization process and the most of materials cannot be significantly magnetized. The significant magnetization is possible only inside ferromagnetic materials, like iron, nickel, cobalt and their alloys, some rear earths like gadolinium, and ferrimagnetic materials like ferrites.

![Figure 7. Principle of magnetization process](image)

\[
\begin{align*}
\vec{B}(t) &= 0 \quad \sum \vec{m}_e = 0 \\
\otimes \vec{B}(t) &\neq 0 \quad \sum \vec{m}_e \neq 0 \otimes
\end{align*}
\]

The interaction between the magnetic field and a substance can also be described in several ways; the most applied, similar to the case of the electric field, is introducing the permeability of a material as the material’s characteristic.

As in the case of the interaction between the electric field and the material, the material permeability is defined as the product of material relative permeability, and the permeability of the vacuum,

\[
\mu = \mu_r \mu_0.
\]  (14)

Comparing the electric and magnetic material characteristics, it should be emphasized that the relative permittivity is always larger than 1, while the relative permeability can be less, equal or larger than 1.

It should also be noticed that all described interactions between the material and electromagnetic fields exist in time constant or time varying electromagnetic fields, acting on steady or moving charges.

3.3. Interaction of time varying electromagnetic field and the substance

In the case of time fast varying electromagnetic fields, even the lightest charged particles, like electrons, cannot follow the electromagnetic fields changing in synchronism; however, there is always some retardation. During the moving charged particles direction changing, due to the electromagnetic field vectors direction changing, a part of energy transfers to heat. These electrical energy losses are called polarization losses and the typical example of this transfer happens inside microwave ovens.

Similar behavior of elementary charged particles, exposed to a time varying magnetic field, can be noticed in ferromagnetic or ferrimagnetic materials. The electrons’ orbits also cannot follow the magnetic fields changing in synchronism, so more or less significant retardation could be expected, defining the so-called hysteresis losses.
3.4. Joule’s effect - heating losses

In all conducting materials with the current, except in the superconductivity cases, the so-called Joule’s effect appears. Namely, during the moving of charged particles through the conductors’ structure, the successive collisions of these particles with steady (uncharged) or near-steady (heavy ions) particles appear, as shown in Figure 8.

\[ \dot{e}_{\text{ind}}(t) = \oint_{C} \vec{E}_{\text{ind}} \cdot d\vec{l}. \]  

(15)

The induced electromotive force can be the consequence of the time varying magnetic field acting on a solid, steady system. In this case, the effect is called the static electromagnetic induction, and the static induced electromotive force is produced by the induced electric field strength vector, defined as,

\[ \vec{E}_{\text{ind}} = -\frac{\partial \vec{A}}{\partial t}. \]  

(16)

The other possibility of the induced electromotive force appearing is the situation when a system moves or/and deforms in the time constant magnetic field. This case is known as the dynamic electromagnetic induction, and the dynamic induced electromotive force is produced by the induced electric field strength vector defined as,

\[ \dot{\vec{E}}_{\text{ind}} = \vec{v} \times \vec{B}. \]  

(17)
where \( \vec{v} \) is the velocity of the moving system.

Naturally, the induced electromotive force can be the consequence of combined effects, moving or/and deforming system in the time varying magnetic field.

The induced electromotive force has the character of voltage and it superposes to all voltages and potentials produced by other sources. This means that the induced electromotive force has an influence on all electric and electronic equipment in vicinity, as well as on all living organisms in which, as it is well known, the electric potentials exist as well.

If the time varying magnetic field and, consequently, the induced electric field and induced electromotive force appear inside the conductive material, induced currents will occur as well. These currents, known as eddy currents or Foucault’s currents, superpose other existing currents, changing the previous current distribution. The non-uniform current distribution, due to eddy currents inside a single conductor, is known as the skin effect and the non-uniform current distribution, due to the time varying magnetic field produced by a neighboring conductor known as the proximity effect. Eddy currents are also followed by Joule’s heating losses, depicted as eddy current losses. Moreover, as any other currents, eddy currents produce the magnetic field, which superposes the already existing time varying magnetic field. As the consequence, again a non-uniform magnetic field distribution appears inside any magnetic circuit; this non-uniform distribution is also called the skin effect.

The significance of the skin effect and proximity effects depends on how fast magnetic field time variations are (or on frequency in the case of periodical time varying fields), as well as on the conductivity and the permeability of the material in which the system is placed.

### 5. Electromagnetic fields we are mostly exposed to

#### 5.1. Outdoor exposure

Most of all electromagnetic fields that we might encounter are positioned outdoor.

There are many possibilities of the exposure to ELF (Extremely Low Frequencies), mostly to the industrial frequency of 50 Hz (60 Hz), produced by the electrical energy transmission and distribution systems, including the corresponding transformers. Some photos of these examples are demonstrated in Figure 9.

![Figure 9. Some examples of outdoor ELF electromagnetic fields sources](image-url)
The other kinds of electromagnetic fields existing outdoor are high frequency electromagnetic fields, mostly RF (Radio Frequency) electromagnetic fields. These fields are produced by radio or television broadcasting emitting antennas and, nowadays, particularly by mobile phones base stations. Some of these sources are presented in Figure 10.

![Figure 10. Some examples of outdoor RF electromagnetic fields sources](image1.png)

5.2. Indoor exposure
Inside our living and working places, we can be exposed to both ELF and RF electromagnetic fields. Considering ELF electromagnetic fields, the fields are mostly at 230 V, meaning that the magnetic field is much more significant comparing to the electric field. This implies that the fields are produced mostly by powerful apparatuses, such as all kind of heaters, as shown in Figure 11.

![Figure 11. Some examples of indoor ELF (electro)magnetic fields sources](image2.png)

Some of domestic apparatuses could also produce some indoor HF (High Frequency) electromagnetic fields, like microwave ovens or CRT televisions, but only if they are not well functioning.

5.3. Mobile (Cellular) phone
Finally, outdoor and indoor, always present, always with us, our necessity, our mobile (cellular) phone is also always the source of HF electromagnetic field, frequently, dangerously very close to our head or our heart.
Although today the mobile phone is an almost inevitable part of our lives, it must be applied with certain precaution. Namely, the electric field strength vector magnitude and the magnetic flux density vector magnitude are increasing with the decreased distance from the field source (mobile phone) and the point in which the electromagnetic field is observed (point in our brain) as $1/r^2$, while the radiated electromagnetic wave power increases as $1/r^4$. During the conversation via a mobile phone, the distance between the phone and our brain is very small and the long term consequences could be significant. For this reason, in order to avoid health risks, it is advisable that the conversation using a mobile phone does not last too long. Likewise, an application of headphones or wireless equipments, like “Bluetooth”, is advisable as well.

6. Conclusion
As it could be noticed from everything mentioned above, all electromagnetic fields exert influence on everything positioned inside a domain in which a field exists. With the growing industrialization, the electric energy production and consumption increases, and the electromagnetic fields’ intensities follow this increase, together with all negative effects produced by the electromagnetic fields. Moreover, nowadays some new fields, which did not exist previously, appear and are applied worldwide. The typical example of that are the application of microwave ovens and mobile phones, as well as the applications of electromagnetic fields in medical diagnostics and therapies.

The protection against undesirable electromagnetic fields, such as undesirable radiations of technical systems or the protection of certain domains has become our necessity. The part of contemporary science dealing with these problems is EMC (Electromagnetic Compatibility), developing toward an interdisciplinary approach. A closed collaboration of biologists, medical doctors, physicists and electrical engineers has become inevitable in order to explore in details all electromagnetic fields’ impacts. As a solution of the investigations, the harmful impacts should be eliminated or reduced to the level as small as possible, while the useful impact should be applied in the best possible manner.

According to all this, it is very important to be well acquainted with the electromagnetic fields in our environment, as well as the effects produced by them on electrical or electronic equipments or on living beings. Electromagnetic fields’ influence on electric or electronic systems should be an occupational task for electrical engineers, while the electromagnetic fields’ impact on living beings should bring together the team work of the experts in different fields.

References
[1] ***Available at http://www.esa.int/spaceinimages/Images/2015/09/Spacetime_curvature
[2] ***Available at https://www.maplesoft.com/view.aspx?SI=3707/electricDipole5.gif
[3] Popović B D 1986 Electromagnetics, (in Serbian), Second Edition, Građevinska knjiga, Belgrade, Serbia
[4] Prša M 2016 Electromagnetics, (in Serbian), Prepared for printing, Novi Sad, Serbia
[5] Surutka J 2006 Electromagnetics, (in Serbian), Eighth Edition, Akademska Misao, Belgrade, Serbia
[6] Stojaković M 2001 Mathematical Analysis 2 – Second Part, (in Serbian), Novi Sad, Edition of Faculty of Technical Sciences, Novi Sad, Serbia
[7] Šunjarević M 2004 Outlines of radio communications with radio techniques, (in Serbian), pp 30, Studio LINE, Belgrade, Serbia