Exposure to electromagnetic fields is not a new phenomenon. However, during the 20th century, environmental exposure to man-made electromagnetic fields has been steadily increasing as growing electricity demand, ever-advancing technologies and changes in social behavior have created more and more artificial sources. With the including of artificial electromagnetic field resources in most part of our both Daily and work life, exposure to radiation has become order and got emphasize more. While the researches continuing on this topic, in this issue we will touch on “Non-Ionizing Radiation” classified “Electromagnetic field” that holds an important place in terms of occupational health and safety.

WHAT IS THE RADIATION?

Radiation is electromagnetic waves or particles (photons) in the form of publication or the transmission of energy. Radiation can be divided into two different groups as ionizing and non-ionizing radiation.

IONIZING RADIATION

Ionization is cut off the electron from atoms and molecules. Energetic particles (photons) of the electromagnetic waves can cause ionization by cutting off electrons colliding with the object. Gamma and x-rays having that kind of ionizing effect carries the energy that can destroy genetic material of the cell which DNA and any little detriment effect occurred in DNA may cause cancer. Therefore ionizing radiations are very dangerous for human health. What about non-ionizing radiations, electromagnetic field, ie?

NON-IONIZING RADIATION

Given in figure 1, the electromagnetic spectrum shown in the x-rays, located just below the UV rays, infrared rays, microwaves, low-frequency waves, the RF waves “Non-Ionizing Radiation” is defined as. Mobile phones and base stations cause electromagnetic waves is located within non-ionizing radiation zone.
ELECTROMAGNETIC FIELD CHARACTERISTICS

The concept of electromagnetic field is quite complicated in point of understanding and it has to be well-understood especially by those who carry out the measurements. In this regard, it is highly important that the relationship between electric field and magnetic field which are the components of electromagnetic fields to be understood and their properties to be known. Electromagnetic fields (EMF) have the components of electric field and magnetic field and they spread out perpendicular to the plane which is formed by these two fields as it is seen in figure 2.

![Electromagnetic Spectrum](image)

**Figure 1 Electromagnetic Spectrum**

**RELATION BETWEEN ELECTRIC FIELD – MAGNETIC FIELD**

The relation between electric field and magnetic field may be likened to the relation between voltage and current. The relation between the two fields is shown in Table-1. Propagation of electromagnetic waves through space, the energy source is transferred to the recipients. This amount of energy is depended on the power of the EM (electromagnetic) wave’s component. In Co.1.1, the power density of the EM waves is associated with the components of EM wave’s forces. Again look at the Co. 1.1, we can see that the power of the EM waves are decreased to source which is the square of the distance.

\[ P_d (\text{watt/meter}^2) = E(\text{volt/meter}) \times H(\text{ampere/meter}) \]  

1.1
### Electric field (E)  
Consist of an electrical charge (voltage).  
“E.g. A night light is plugged in but the power cord of the off night light produces electric field.”

<table>
<thead>
<tr>
<th>Unit: V/m or kV/m</th>
</tr>
</thead>
</table>

### Magnetic field (H)  
Consist of an electric current.  
“E.g. A night light is plugged in and the power cord of the on night light produces magnetic field.”

<table>
<thead>
<tr>
<th>Unit: A/m</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>The power of the electric field is decreased away from the source.</th>
<th>The power of the magnetic field is decreased away from the source.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction of exposure is easy and can be prevented by closing with an any conductor.</td>
<td>More difficult to reduce exposure and many substances are in sufficient to prevent the magnetic field.</td>
</tr>
</tbody>
</table>

Table 1 Relation between electric field and magnetic field

### DEFINITIONS AND SOME RELATED TERMS

Wavelength (λ): Wavelength is the distance between two different points at same level in the adjacent cycles of a waveform.

Frequency (f): Frequency is the number of occurrences of a repeating event per unit time (typically 1 second)

Near-field region: Nearly all the name given to the region adjacent to the source. Electric field strength and magnetic field strength is completely independent of each other in this region.

Far-field region: It is the name given to distances exceeding approximately 3 wavelengths from the source. In this region electric field and magnetic field regions are perpendicular to both each other and wave propagation direction (figure2)

### WHAT ARE THE SOURCES OF ELECTROMAGNETIC FIELD (EMF) ?

When it is said radiation, first thing that comes to mind is mobile phones. However, apart from the mobile phones there are many radiation and electromagnetic field sources in our surroundings. These sources can be investigated under the two titles as natural source and artificial source. However since our topic is occupational health and safety, we will touch upon the artificial sources which might lead to occupational exposure.

For those who work in front of computer in office environment or banks, exposures to electromagnetic field resulting from the monitors are in question. In addition to this, all electronic devices and wireless phones running in the office still produce exposure to electromagnetic field. The easiest and the most effective way of decreasing this exposure is replace of the old computer monitors especially used with new generation LCD or LED monitors and removal of old type CRT monitors. In the cases where this is impossible, the exposure can be reduced by watching over the distance between the side & back part of these monitors and the seating for persons so that they are not too close and by right designing of the office environment.
There are different sources of EM fields by which workers of industry are exposed.

If these sources will list the most common ones:

1. Dielectric Heaters and Welding Machines,
2. Devices are used with heating by induction
3. Microwave Drying Machines,
4. Electric Welding Machines,
5. Transformers.

Related risk assessment concerning the prevention and reduction of exposure to EM field in industrial workplaces should definitely be performed once in a year, suitable precautions should be taken by making required measurements. You can find the detailed information regarding this issue in oncoming parts.

We can say that occupational group which has the most exposure to EM field is health sector. Especially, devices, which spread out electromagnetic field such as MRI devices used in hospitals, RF sources used in physiotherapy cause occupational exposure to workers in health sector.

Finally, being the most common and the most known EM field sources mobile phones, base stations, radio &TV transmitters, antennas and radars are the other important EM field sources which affect worker health besides public health and cause occupational exposure to those working in this sector.

**BIOLOGICAL AND HEALTH EFFECTS OF ELECTROMAGNETIC FIELDS**

We mentioned previous sections of this paper that is the natural EM field sources. The sun that illuminates our world, we live on earth, even our bodies are also actually a natural source of electromagnetic field. The sun’s rays which vibrate $10^{12}$ times per second are electromagnetic waves. Our body, on the other hand, dissipates 60% of our body temperature as infrared electromagnetic waves, vibrating less than $10^{12}$ in a second in other words having a frequency of $10^{12}$ Hz, to be able to balance body temperature in 37°C.

In this case, electromagnetic waves are the physical phenomena which are inherent in our lives and even essential for us to maintain our lives. Because of our bodies is in compliance with electromagnetic fields that exist in nature. However, sources of artificial EM field which emerge with technological developments are distorted and damaged this EM compatibility between man and nature. Consequently, harmful aspects of EM fields are emerged.

Biological effects can be described as the changes of environmental factors or the changes in our bodies as a result of a stimulus. E.g. listen to music, read to book or making exercise are biological effects created at various levels in our body. It may be argued that the harmful effects?

The human body has a complex structure and changing is an in evitable part of our life. However, our body has not an adequate compensation mechanism for all biological effects. Therefore, some long-term exposures can cause health hazard.
In the studies of International Non-Ionizing Radiation Protection Committee (ICNIRP), the World Health Organization (WHO) and the Institute of Electrical and Electronics Engineers (IEEE), it is deduced that in the body of people that are directly or indirectly exposed to EM fields, there can be seen some effects occur depending on the power absorbed by the body [1]. Experiment performed on healthy people, the level of a home atmosphere or environment EM field was not found significant harmful effect of short-term exposure [2]. Although the level of harmful exposures are thought to be restricted by national and international guidelines. (See. “Topic; Exposure Limit Values and Current Standards”)

In another study made in 1998 by ICNIRPS, long-term health consequences of various interactions of EM fields and the body remains unproven.[1],[4]. However, we still approached this issue cautiously and caution is advised to obtain accurate results. As for current debates, they continue on whether low levels of long-term exposure cause biological effects.

According to the results mentioned above, most research is understood that children most affected by exposure to electromagnetic fields. In 1996, the U.S. National Academy of Sciences (U.S. National Academy of Science) in children living in areas near high-voltage lines 1.5 times more "leukemia" to the announced of encountering.

A research of Non-Ionizing Radiation Protection Committee (ICNIRP) on the subject is very important in this sense. Besides that, INTERPHONE study that is conducted by International Agency for Researches on Cancer (IARC) is again one of the most important studies which is about the effects of electromagnetic waves on human health and world is waiting for.

Below you will find the websites of some international commissions that make studies and researches on this topic.


TO BE PROTECTED FROM EM FIELD HAZARDS

To be protected from the hazardous effects of chronically exposure type EM fields, worker’s incurring to EM fields can be minimized by using proper technical measurements whatever the exposure degree is. It should be applied various protective measurements, which are technical and suited to workplace in order to prevent exposure of workers to strong EM fields in workplaces. Good applications can be understood by using solutions and tools employed in various industries.

According to the study Karpowicz and Gryz made, occupational and non-occupational exposures are different in terms of the assessment of EM fields [1].Occupational exposure is the exposure to high level fields which is inhibited in common living places and these fields as it is seen in figure 3 are the strong EM fields which is formed on tools used in workplace. Non-occupational exposure on the other hand is the exposure to low EM fields which are located far from the strong EM field sources. There is no case requiring to limit this type of
exposure whether person is worker or not. Special protection measures can be taken for young workers and pregnant women. Non-occupational exposure degrees should be in accordance with the exposure degrees for common society.

Workers which are within the scope of “occupational exposure” must be determined. Minimizing their exposure plays key role to prevent electromagnetic field damages in workplaces. If the electromagnetic field source is determined, marked and if workers are informed about potential losses that can be emerged around the source, availability of the device can be ensured. At the same time, workers should be monitored in terms of health (especially in areas with more exposure) and training should be given workers periodically to work safely against electromagnetic field.

Figure 3 Representation of electromagnetic field emitted from a source according to degree of risk

- **EM Field Source**
- **Prohibited Area Higher Degree of Risk**
- **Occupational Exposure Higher Degree of Risk**
- **Non-Occupational Exposure Lower Degree of Risk**
Marking of electromagnetic field sources is a good implementation of warning workers against danger. Figure 4.a and Figure 4.b are typical marking examples. These warnings are important for especially pregnant ladies or persons that have implant on their bodies. Persons that have high sensitivity against electromagnetic fields for example a person who has electronic implant on his/her body must be cautioned against electromagnetic fields even if that are at non-occupational exposure level. Figure 4.c and 4.d are some warning signs.

When setting up or making a new device, electromagnetic field security conditions should be considered and device must be marked in accordance with the level of electromagnetic field.

**PERSONAL PROTECTIVE EQUIPMENT USAGE**

Clothes that protect workers from electromagnetic field are alternative method to decrease exposure degrees. This choice is the best solution when employees forced to work in a strong electromagnetic fields and when they are close to the source too. In such cases, protective clothes preserve employee from exposure against electromagnetic danger. Figure 5 shows an example of such an employee dressed in protective clothing.

But any cloth may not provide sufficient protection against various electromagnetic sources. Dielectric seats, switches, handles, carpets etc. isolate the workplace or workers against electromagnetic fields and provide protection against danger.
EXPOSURE LIMIT VALUES AND CURRENT DIRECTIVES

Despite the fact that there is no accurate research result on long-run effects of electromagnetic field exposure, as a precautionary measure some limit exposure values were determined by considering short-run effects until proven. By the European Union Council directives and standards, some restrictions are imposed on both public health and also occupational health and security.

The directive 1999/519/EC, which is published by European Council in 12.06.1999, bears advisory qualification on restriction of public exposure to electromagnetic fields and brings some limit values.

Depending upon the framework directive 89/391/EC, which is published by European Council in the field of occupational health and safety, some directives are issued related to physical agents. Afterwards vibration (2002/44/EC) and noise; electromagnetic fields as a physical agent has issued by the same Council in Directive 2004/40/EC in 19.04.2004. This directive has brought some limit values related to workers’ exposure to electromagnetic fields regarding to minimum health and safety requirements as an obligation. However, in this directive long-term effects of electromagnetic fields are not considered.

The time given to the member countries in order to harmonization of the directive 2004/40/EC has been postponed until 30.04.2012. In the meantime, admitting of these limit values by whole member countries of European Union and harmonizing them to their legislations is expected.

Related limit values can be obtained from Tables 2 and 3. It seems from the tables that limit values are held higher for the public health. So, why limit values for public health are so high whilst occupational exposure limit values are so low?

It can be explained basically by two reasons. Firstly, in the workplace environment where the electromagnetic risk to be present has been determined and how much exposure caused by it is known. Besides, workers are more conscious on the effects of exposure to electromagnetic fields than any person. So, these values are low because of controlled exposure in workplaces is on the carpet. Secondly, workers have chance to protect themselves whether by using...
personal protective equipment or by precautions as a result of risk assessments in workplace. But when thinking for the public, it is surely not possible for public to go around dressed on protective clothes. And it is one another reason for the high values.

Table 2 Electric Field, Magnetic Field and Some Simple Restrictions on EM Field (Public Health)

<table>
<thead>
<tr>
<th>Frequency range</th>
<th>Magnetic flux density (mT)</th>
<th>Current density (mA/m²)</th>
<th>Whole body average SAR (W/kg)</th>
<th>Localised SAR (head and trunk) (W/kg)</th>
<th>Localised SAR (limbs) (W/kg)</th>
<th>Power density S (W/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Hz</td>
<td>40</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>&gt;0-1 Hz</td>
<td>—</td>
<td>8</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1-4 Hz</td>
<td>—</td>
<td>8/f</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>4-1 000 Hz</td>
<td>—</td>
<td>2</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>1 000 Hz-100 kHz</td>
<td>—</td>
<td>1/f500</td>
<td>—</td>
<td>2/10</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>100 kHz-10 MHz</td>
<td>—</td>
<td>1/f500</td>
<td>0.08</td>
<td>2/10</td>
<td>4</td>
<td>—</td>
</tr>
<tr>
<td>10 MHz-10 GHz</td>
<td>—</td>
<td>—</td>
<td>0.08</td>
<td>2</td>
<td>4</td>
<td>—</td>
</tr>
<tr>
<td>10-300 GHz</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>10</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 3 Occupational Exposure Limit Values [4]

As a consequence, danger assessment and reduction in a workplace is related to application of occupational health and security rules of the company that undertakes to fulfill the requirements of occupational health and security. (OHS-MS) In any case, identifying electromagnetic field sources and determining differences between them correctly is important on taking precautions.

Due to widely existence of electromagnetic fields in workplaces, identifying of workers on which the protective activities must be intensified is the most important thing. These identified workers must be informed to use electromagnetic field sources safely. And these
workers must be assured that they don’t have any contraindication. Besides, exposure level in workplace must be controlled periodically.

Employees except identified workers shouldn’t be in the section where electromagnetic field source is present. Young workers and pregnant women mustn’t sustain to occupational exposure absolutely.

References


