SETSCI Conference Indexing System,
Volume 3 (2018), 505-509

ISAS 2018-Winter
2nd International Symposium on Innovative Approaches in Scientific Studies
November 30 – December 2, 2018, Samsun, Turkey

Analysis of Electromagnetic Radiation in Daily Life

Umut Özkaya[1*], Levent Seyfi [2+] and Ercan Yaldız [3]

[1]Department of Electrical and Electronics Engineering/Konya Technical University, Konya, Turkey
[2]Department of Electrical and Electronics Engineering/Konya Technical University, Konya, Turkey
[3]Department of Electrical and Electronics Engineering/Konya Technical University, Konya, Turkey
[*]Corresponding author: uozkaya@selcuk.edu.tr
[+]Speaker: uozkaya@selcuk.edu.tr
Presentation/Paper Type: Oral / Full paper

Abstract **–** Along with development of electronics and software technology, amount of electromagnetic (EM) radiation, which expose to people, has significantly risen. For people who uses or do not use technology, it is of great importance that they should have enough information about EM radiation exposing them. So, not only EM radiation is described, but also effects of EM radiation sources are researched in this study. EM radiation is mainly divided into two parts as ionizing and non-ionizing radiation. Technologies which we mostly use in daily life and whose radiation we are exposed to are chiefly telecommunication systems. EM radiation emitted by these systems is non-ionizing type due to their low energy levels. However, exposure of ionizing EM radiation is almost not present and its exposure is personally arisen at only special situations. As examples for this type of EM radiation, medical radiography and security screening systems using x-ray may be said. In this context, each person needs to be informed about these topics and cautious for human health. In respect of health of next generation, definition, types and sources of EM radiation have great importance to be learnt.

Keywords – Ionizing Radiation, Nonionizing Radiation, Electromagnetic Radiation Sources, Electromagnetic Field, Electromagnetic Spectrum

I. Introduction

Nowadays, uses and necessity of electrical energy are increasing due to industrialization and development of technology. All electrical equipment's emit the electromagnetic field in various frequency bands. Television, electric razors (shaver), electric blankets, computer monitors, photocopier machines, microwave ovens, wireless phones, cellular phones, and food processor and many more examples may be given as sources of electromagnetic fields in daily life [1]. Many people use WLAN (Wireless Local Area Network) technology, Bluetooth, MMS (Multimedia Message Service), SMS (Short Message Service), Video Call (Video Interview). The use of GSM has reached the highest level. Many electrical devices, which make life easier and are used for our daily needs, increase the electromagnetic field radiation where we are in [2]. Thus, many researches focused on measurements of the electromagnetic radiation levels [3-8].

II. Materials and Method

A. Electromagnetic Field

Electromagnetic fields occur when electric and magnetic fields which are varying with respect to time come together. As the frequency increases, the wavelength decreases and the energy emitted in the field increases.

Electric and magnetic fields which are static are naturally occur in nature. The natural magnetic field is located in the north-south direction around the earth's sphere and consists of undulating waves that help birds and fish to navigate. The natural electric field is occurred by lightning in local part of the atmosphere. Electromagnetic fields, which are emitted from man-made sources as well as natural electric and magnetic fields, have covered the whole environment in daily life [8].

B. Electromagnetic Radiation

EM radiation is mainly divided into two parts as ionizing and non-ionizing radiation. Ionizing Radiation is EM wave with high frequency (higher than 10^{14} Hz) which have capability to ionize atomic bonds in cell molecules. For example, X-ray and gamma rays and some sources of ultraviolet (UV) rays are assessed in this class. Excessive exposure to this effect can lead to hazardous conditions such as damage to living cells and also DNA chain [9].

Non-ionizing EM radiation have not enough energy to separate atomic bonds. These are visible light, infrared, RF (Radio Frequency), microwave, static and magnetic waves. In other words, they are distributed in range from 1 Hz to 10^{14} Hz. However, these waves cause thermal effects on human body depending on distance, frequency power and time. It is claimed that carcinogenic effect has not been proven yet.

Two types of effect, which can be classified thermal and non-thermal, occurs in organism impacted by these waves. EM energy absorbed by the body is converted to heat which causes to increase human temperature gradually. Charged particles in body are moved by using force in electric fields. Body gets hotter because of resistance to these movements. Temperature in body continues to increase until balance of body is provided by blood circulation and perspiration. On the other hand, non-thermal effects have been investigated. It is supposed that they have chemical and psychological risks. Although transmitters used for Radio-TV and communication in range of RF spectrum provides benefits for community, each of them is source of continous exposure involuntarily. In our country,

these sources were firstly established in Istanbul in 1927, in Ankara in 1928 and then in Izmir in 1950. They were gradually seemed in other cities after 1960s. By growing up usage of mobile phone, number of base stations has been increased in city centers and streets. For this reason, public attention has been started to focus on them [10].

C. Electromagnetic Spectrum

The electromagnetic spectrum is a sequence containing all known electromagnetic waves from gamma rays to radio waves. It is shown in Fig. 1, the electromagnetic waves vary with wave length or frequency in the spectrum. The highest frequency waves have the greatest energy.

.

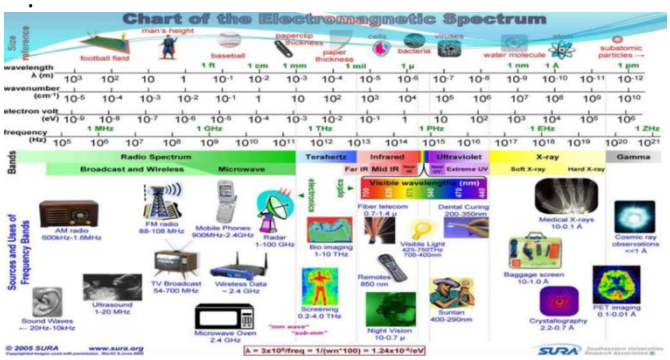

Fig. 1 The chart of EM Spectrum

General definitions for contents of the spectrum are given below;

Gamma rays: They have smaller wavelengths than 0.01 nanometers and contain waves with wavelengths less than the diameter of an atomic nucleus. They are located in the highest energy and have frequency region in electromagnetic spectrum.

X-rays: They are rays with a wavelength between 0.01 and 10 nanometers (up to the size of an atom).

Ultraviolet (UV) radiation: They have wavelengths between 10 and 310 nanometers (about the size of a virus). Short wavelength ultraviolet rays can be harmful.

Visible light: It has wavelengths between 400 and 700 nanometers (one molecule to one cell size). This small part of the electromagnetic spectrum, which is defined as light, can be seen through the human eye. This section has colors that start with purple and finish with red.

Infrared (IR) radiation: Its wavelengths range from 710 nanometers to 1 millimeter (with a needle and a small seed as long as it is tall).

Microwave radiation: Its wavelengths vary between 1 mm and 1 meter. It is a radio wave with very short wavelengths used on radars. It is also used in microwave ovens and for long distance communications that do not require a cable.

Radio waves: They are long waves of 1 millimeter. Because they have the longest wavelength, they also have the lowest energy. The sources of these waves are electrical oscillations [11]. All objects radiate within the frequency spectrum. For example; about 60% of body heat is excreted by infrared radiation. The so-called thermal camera is nothing more than a receiver sensitive to infrared frequencies. Above the visible light frequency is the ionizing radiation region, with ultraviolet, x and gamma rays in this region [9].

D. Electromagnetic Field Resources

Some EM resources that appear in daily life are as follows;

- Terrestrial TV and radio broadcasts: AM, FM, TV
- Communication broadcasts: Telecom, satellite, GPS, radar
- Electricity distribution: Electricity transmission lines, electric trains
- High voltage lines
- High frequency industrial, medical and research equipment: X-Ray, heaters

Electrically operated devices create electromagnetic fields in their surroundings. Microwave ovens, washing machines, vacuum cleaners, hair dryers, water heaters and all electrical household appliances create electromagnetic fields [11].

FM radio transmitters in the frequency range 88-108 MHz, VHF TV transmitters in the frequency range 174 - 230 MHz and UHF TV transmitters in the frequency range 470-860 MHz It is important because they are usually inhabited by settlements in major cities, inevitably in residential areas, and has output power starting at 100 W and reaching 50 kW [12].

The GSM cellular communication system, which has been increasing in number in recent years, is broadcasting at 900 MHz and 1800 MHz It is operated with a large number of GSM Base Stations in order to provide the desired usage efficiency in terms of coverage and traffic load expectancy, which causes an intense EM field especially in the settlement areas. Due to increasing subscriber demand and diversifying services, the number of units and systems that emit RF in cellular systems increases day by day in and around the residential areas, resulting in the formation of EM field sources and intensity in the environment. The power dissipated from these devices through environment may reach 400 W. As the number of users increases, it is inevitable that the number of base stations will increase.

Base stations are typically placed in towers 10-30 m high. In general, each tower has three antennas covering a horizontal angle of 120°.

As mobile phones are also an important EM radiation source, the situation is more serious. Because we locate it very near our head, it needs more attention when using [12].

The GSM cellular system has three types of communication equipment depending on coverage area such as macro, micro and pico level.

- For the GSM900 system, which is also used in Turkey, macro cells can serve an area of 25-35 km radius. The output power of GSM900 base station antennas in macro cells can be 40-60 W.
- Micro cells are installed in places like airports, big shopping malls. It covers areas with a radius of a few hundred meters and the output power is lower than macro cells (around 5-10 W for GSM900).
- Pico cells are mostly used for in-building communications and has a few watts for output power [13].

X-rays are similar to light rays, except that they are more energetic than light rays and are invisible to the human eye. Frequency of X-rays ranges from 3×10^{16} Hz to 3×10^{19} Hz.

X-rays are used for security and in computerized tomography, rontgen for medical diagnosing. X-ray devices, which are used for security, are devices that provide information about the content by passing objects through a fixed X-ray source. X-Ray devices have an X-ray source and

a detector group that detects the beam in front of this source. The objects are placed on the way of these rays and the rays passing through the objects are detected by the detectors. Rontgen is the oldest of the radiological diagnostic methods. The main feature that allows X-rays to be used in diagnostic radiography is the ability to penetrate the tissue. Computerized tomography is the most advanced of X-ray devices. With this device, physicians have the ability to take a cross-sectional view of a certain area of the body as it is in the MR device [14].

As long as many electrically operated devices or systems are used, the dissipation radiates EM energy in varying rates. Some of the systems and devices that radiate EM fields are as follows:

- Energy Transmission Lines (ETL) and transformer stations,
- Electric trains,
- Cathode Ray Tube (CRT) displays used in TVs and computers,
- Induction furnaces and welding machines used in the industry,
- All kinds of electrical household appliances (iron, microwave ovens, cordless phones, electric blankets, refrigerators, etc.) used in our homes,
- Various RF systems operating in industry
- Radar systems (continuous and pulsed)
- Satellite communication systems
- Personnel communication systems (Cordless telephone, Wi-Fi, Bluetooth, etc.)

E. Some Measurement Values

The above-mentioned EM source devices and systems generate EM pollution as shown in Table 1 and Table 2.

Table 1. Electric field values of EM sources in the environment (Operating voltage = 110 V, Operating frequency = 60 Hz, Distance = 30 cm) [9]

Device	Maximum Electric Field (V / m)
Natural electric field during lightning	20000
380kV transmission Line	6000
110kV transmission line	2000
10kV transmission line	500
Electric blanket	500
Electric iron	200
Electric shaver	100
Hair dryer	50
Electric cable	5

Table 2. Magnetic field values of EM sources in the environment (Operating voltage = 110 V, Operating frequency = 60 Hz, Distance = 30 cm) [9]

Device	Maximum Magnetic Field (A / m)
Ovens and hair dryers	2000
Electric shaver	1000
Drill	500
Vacuum cleaner and toaster	100
Earth's natural magnetic field (static)	30
380 kV transmission line	30
110 kV transmission line	15
10 kV transmission line	10
Electric cable	5

Also, the mean electric field value originated from the applications whose frequencies are from 100kHz to 3 GHz is around 0.3 V/m [3,4]. The radiation sources and their frequency ranges are given in Table 3. They are FM radio, TV, and cellular phone broadcasts, DECT, 3G (Cellular), and WIFI respectively.

Table 3. EM field sources and their frequency ranges [5]

EM field Source	Frequency Range
FM	88-108 MHz
VHF4	174-230 MHz
UHF5	470-790 MHz
UHF4	790-862 MHz
GSM900	870-960 MHz
GSM1800	1.77-1.85 GHz
DECT	1.88-1.9 GHz
3G	2-2.2 GHz
WI-FI	2.4-2.4835 GHz
4G	2.6 GHz

F. Limit Values for Electromagnetic Radiation

Limit levels of time-varying electric fields determined for general public by ICNIRP are given in Table 4.

Table 4. Limit levels for general public exposure to time-varying electric fields determined by ICNIRP [15]

Frequency range, f	**Electric field strength (V/ m)**
up to 1 Hz	—
1–8 Hz	10,000
8–25 Hz	10,000
0.025–0.8 kHz	$250/f$
0.8–3 kHz	$250/f$
3–150 kHz	87
0.15–1 MHz	87
1–10 MHz	$87/f^{1/2}$
10–400 MHz	28
400–2,000 MHz	$1.375f^{1/2}$
2–300 GHz	61

In Turkey, a regulation protecting health of general public due to adverse effect of non-ionizing EM radiation, as shown in Table 5, was organized by the Ministry of Environment and Urbanization in 2010.

Table 5: Limit values protecting health of general public due to adverse effect of non-ionizing EM radiation, organized by the Ministry of Environment and Urbanization in Turkey, in 2010 [16]

Frequency range, f	**Electric field strength E(V/m)**
Up to 1 Hz	-
1 Hz-8 Hz	10 000
8 Hz-25 Hz	10 000
0.025 kHz-0.8 kHz	750/f
0.8 kHz-3 kHz	250/f
3 kHz- 150 kHz	87
0.15 MHz- 1 MHz	87
1 MHz- 10 MHz	$87/f^{0.5}$
10 MHz-400 MHz	28
400 MHz-2000 MHz	$1.375f^{0.5}$
2 GHz-300 GHz	61

In 2015, a revision on the limit values at frequencies from 10 kHz to 60 GHz, as shown in Table 6, was carried out by Information and Communication Technologies Authority of Turkey. The limit values were decreased compared to the values given in Table 5.

Table 6. Determination of limit values of EM radiation originated from electronic communication devices by Information and Communication Technologies Authority of TURKEY in 2015 [17]

Frequency range, f (MHz)	**Electric field strength (V/m)**
0.01-0.15	65.25
0.15- 1	65.25
1- 10	$65.25/f^{0.5}$
10-400	21
400-2000	$1.03f^{0.5}$
2000-60000	45.75

The limit values of the EM sources in 100 kHz-3 GHz frequency band are calculated based on data as shown in Table 6.

In 2018, A new revision on the limit values at frequencies from 10kHz to 94 GHz, as shown in Table 7, was carried out by Information and Communication Technologies Authority of TURKEY.

Table 7. Regulation on the amendment of the regulation on the determination, control and supervision of the exposure limit values of electromagnetic field intensity from electronic communication devices by information and communication technologies authority of turkey in 2018 [18]

Frequency range, f (MHz)	**Electric field strength (V/m)**
0.01-0.15	65.25
0.15- 1	65.25
1- 10	$65.25/f^{0.5}$
10-400	21
400-789	$1.03f^{0.5}$
790-2000	$0.96f^{0.5}$
2000-94000	42.93

The limit values determined by the national and international foundations are calculated and given with respect to the frequency bands in Table 8. Here, the variation of national limits from 2010 to 2018 in some frequency bands (which are boldly written) can be seen.

Table 8. Calculated electric field limit values for the frequency bands from national and international foundations

EM field Source	**ICNIRP**	**National Oldest Limits (2010)**	**National Updated Limits (2015)**	**National Latest Limits (2018)**
	(V/m)			
FM	28	28	**21**	21
VHF4	28	28	**21**	21
UHF5	34	34	**25**	25
UHF4	39	39	**29**	**27**
GSM900	41	41	**31**	**29**
GSM1800	58	58	**44**	**41**
DECT	60	60	**45**	**42**
3G	61	61	**45.75**	**42.93**
WI-FI	61	61	**45.75**	**42.93**
4G	61	61	**45.75**	**42.93**

III. CONCLUSION

The use of EM waves as a result of the development of technology is increasing day by day. However, the negative effects on the human health results from the establishment of many stations are being discussed. In this study, the electromagnetic field radiations were investigated. From the gamma rays to the radio waves, the characteristics of the electromagnetic spectrum is the sequence containing all known electromagnetic waves, ionizing and non-ionizing radiation. Electromagnetic field sources were investigated.

REFERENCES

[1] Nihan Merve Sarıkaya, Bir işyerinde elektromanyetik alan ölçümü yapılması ve sonuçlarının iş sağlığı ve güvenliği açısından değerlendirilmesi, İş sağlığı ve güvenliği uzmanlık tezi, 2014.

[2] Tolga İnce, Elektromanyetik Kirlilik, Gazi Üniversitesi Yüksek Lisans Tezi, 2007.

[3] Levent Seyfi, Measurement of electromagnetic radiation with respect to the hours and days of a week at 100kHz–3GHz frequency band in a Turkish dwelling, *Measurement*, Vol.46 (9), pp. 3002-3009, November 2013.

[4] Levent Seyfi, Ercan Yaldız, Can Nacaroğlu, Analyzing mobile phone electromagnetic radiation, *Electronics World*, Vol. 122(1962), pp.40-43. June 2016.

[5] Genç, O., Bayrak, M., and Yaldız, E. (2010). Analysis of the Effects of GSM Bands to the Electromagnetic Pollution in the RF Spectrum *Progress In Electromagnetics Research, PIER 101, 17-32.*

[6] Çetin Kurnaz, Murat Cem Bozkurt Measurement and Evaluation of Electromagnetic Pollution Levels in Ünye District of Ordu, *Journal of New Results in Science*, 5, 12, 11 / 2016

[7] Begüm Korunur Engiz, Çetin Kurnaz Long-Term Electromagnetic Field Measurement and Assessment for a Shopping Mall, *Radiation Protection Dosimetry*, 11 / 2016.

[8] Derya Gürğan, Levent Seyfi, Determination and Analysis of Electromagnetic Pollution at Two Shopping Malls in Konya at 100 kHz-3 GHz Frequency, *International Journal of Environmental Science and Development (IJESD)*, Vol. 9, No:9, September 2018, pp. 266-269.

[9] Nihan Merve Sarıkaya, Bir işyerinde elektromanyetik alan ölçümü yapılması ve sonuçlarının iş sağlığı ve güvenliği açısından değerlendirilmesi, İş sağlığı ve güvenliği uzmanlık tezi, 2014.

[10] İnan Güler, Tamer Çetin, A. Rıza Özdemir, Nedim Uçar, Türkiye Elektromanyetik Alan Maruziyet Raporu, Bilgi Teknolojileri ve İletişim Kurumu, Sektörel Araştırma ve Stratejiler Dairesi Başkanlığı, 2010.

[11] Sema Palamutçu, Nermin Dağ, Fonksiyonel tekstiller I: Elektromanyetik kalkanlama amaçlı tekstil yüzeyleri, *Tekstil Teknolojileri Elektronik Dergisi*, Cilt: 3, No: 1, (87-101), 2009.

[12] Tolga İnce, Elektromanyetik Kirlilik, Gazi Üniversitesi Yüksek Lisans Tezi, 2007.

[13] Gülbin Dural, Elektromanyetik Dalgalar ve İnsan Sağlığı, ODTÜ Fen Bilimleri Enstitüsü Müdürü, Elektrik Elektronik Müh. Böl. Öğretim Üyesi, 2013.

[14] Tuğçe Arslan, X-Işınları ve Kullanım Alanları, Gazi Üniversitesi Tezi, 2010.

[15] Ahlbom, A., Bergqvist, U., Bernhardt, J. H., Ce´sarini, J. P., & Court, L. A. (1998). Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, And Electromagnetic Fields (Up to 300 GHz). *Health Physics Society*, 74 (4), 494-522.

[16] Çevre ve Şehircilik Bakanlığından: "İyonlaştırıcı Olmayan Radyasyonun Olumsuz Etkilerinden Çevre Ve Halkın Sağlığının Korunmasına Yönelik Alınması Gereken Tedbirlere İlişkin Yönetmelik". http://www.resmigazete.gov.tr/eskiler/2010/07/20100724-3.htm (17.02.2017)

[17] Bilgi Teknolojileri ve İletişim Kurumundan: "Elektronik Haberleşme Cihazlarından Kaynaklanan Elektromanyetik Alan Şiddetinin Uluslararası Standartlara Göre Maruziyet Limit Değerlerinin Belirlenmesi, Kontrolü Ve Denetimi Hakkında Yönetmelikte Değişiklik Yapilmasina Dair Yönetmelik" http://www.resmigazete.gov.tr/eskiler/2015/10/20151009-2.htm (17.02.2017).

[18] Information Technologies and Communications Authority (ICTA), "Regulation on the Amendment of the Regulation on the Determination, Control and Supervision of the Exposure Limit Values of Electromagnetic Field Intensity from Electronic Communication

Devices by International Standards," Official Gazette Issue: 30394, 17 April 2018. http://www.resmigazete.gov.tr/eskiler/2018/04/20180417-2.htm (Accessed in April 2018)