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Research Article

Measurement of Electromagnetic Pollution Level and Calculation of Radiation Dose Index throughout Malatya Street in Elbistan District of Kahramanmaraş

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Abstract

The aim of this research is to measure the level of electromagnetic pollution and calculate to radiation dose index (RID) along Malatya Street of Elbistan District of Kahramanmaraş and to raise awareness about this topic. For this purpose, Narda NBM-550 broadband electromagnetic field meter was used to measure the total electric (E) and magnetic (H) field strengths and equivalent plane wave power densities (S) of the environment. For measurements at GSM 900, GSM 1800 and UMTS (~2100) MHz frequencies, Aaronia Spectran HF-60105 V4 Portable Spectrum Analyzer and a laptop computer loaded with MCS coded software were used. In order for the measurements to reach a meaningful result, the measurement time was set to at least six minutes and three measurements were done at each point. The results were compared with the limit values defined by BTK and ICNIRP. The radiation dose index was calculated and it was found as RDI<1.None of the E, H and S values exceeded the limit values defined by international and national institutions such as ICNIRP and BTK.

Keywords: Electromagnetic field, radiation, mobile phone, base station, electric and magnetic field

Kahramanmaraş'ın Elbistan İlçesinin Malatya Caddesi Boyunca Elektromanyetik Kirlilik Düzeyinin Ölçülmesi ve Radyasyon Doz İndeksinin Hesaplanması

Öz

Bu araştırmanın amacı Kahramanmaraş'ın Elbistan İlçesinin Malatya Caddesi boyunca elektromanyetik kirlilik düzeyini ölçmek, radyasyon doz indeksini hesaplamak ve bu konu ile ilgili farkındalık oluşturmaktır. Bu amaçla, ortamın toplam elektrik (E) ve manyetik (H) alan kuvvetlerini ve eşdeğer düzlem dalga güç yoğunluklarını (S) ölçmek için Narda NBM-550 geniş bant elektromanyetik alan ölçer cihazı kullanıldı. GSM 900, GSM 1800 ve UMTS (~2100) MHz frekanslarındaki ölçümler için ise Aaronia Spectran HF-60105 V4 Taşınabilir Spektrum Analizörü ve MCS kodlu yazılım yüklü bir dizüstü bilgisayar kullanıldı. Her bir noktada üç ölçüm alındı. Ek olarak, ölçümlerin anlamlı bir sonuca ulaşması için ölçüm süresi en az altı dakika olarak alınmıştır. Sonuçlar BTK ve ICNIRP tarafından tanımlanan limit değerler ile karşılaştırıldı. Radyasyon doz indeksi hesaplandı ve RDI<1 olarak bulundu. E, H ve S değerlerinin tümü ICNIRP ve BTK gibi uluslararası ve ulusal kurumlar tarafından belirlenen sınır değerlerinin altında kaldı.

Anahtar Kelimeler: Elektromanyetik alan, radyasyon, cep telefonu, baz istasyonu, elektrik ve manyetik alan.

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1. Introduction

Radiation has existed since the beginning of creation as the source of life and will exist forever. In parallel with the development of science and technology, electronic devices produced with the developing industry have increased the radiation exposure of people. Especially in this century, while the devices produced with the dizzying developments in science and technology have made radiation a part of our lives, they have become indispensable to make our lives easier in many areas from healthcare to communication, from industry to defence. While making our lives easier, these brought danger with them. All the electronic devices we use, from X-ray devices used for diagnosis and treatment to laser devices, televisions and mobile phones used for communication purposes, cause us to be exposed to a certain amount of radiation dose. According to their radiation interactions, they are divided into two as ionizing and non-ionizing. Ionizing radiation has enough energy to remove an electron from the atoms of the environment it interacts with, and it contains enough energy to change chemical reactions in the body. X-Rays and gamma rays are forms of ionizing radiation. The non-ionizing radiation does not have enough energy to rip an electron from the atoms of the medium it interacts with. Sources of non-ionizing radiation are microwave ovens, radio waves, cordless phones, wireless networks (Wifi), power lines, and MR.

GSM is defined as the Global Mobile Communication System and it is a mobile communication system. This system, worldwide, was first used worldwide by Finland. Finland has encouraged people to work on GSM, which is an alternative to wired communication, due to its geographic structure, weather conditions and its highly dispersed location, and first experiments on the system began in 1982 (Wargo et al., 2012). Mobile communication systems such as mobile phones are low energy radio frequency transmitters operating in the frequency range of 450 to 2700 MHz and power ranging from 0.1 to 2 watts. Mobile phones only transmit power when turned on. The power drops rapidly with increasing distance from the phone. Therefore, mobile phone users are exposed to radio frequency fields. Cell phones communicate by transmitting radio waves through a network of fixed antennas called base stations. Radiofrequency waves contain electromagnetic fields, but unlike ionizing radiation, such as X-rays and gamma rays, they can neither cause ionization nor break chemical bonds in the human body (WHO, 2002, 2014; ICNIRP, 1998, 2009, 2012; IEEE, 2005; Söğüt, 2016-2017; Söğüt et al., 2017).

While the use of mobile phones has become extremely common in the current century, recently, the age range of mobile phone users in our country has creepily reached the kindergarten levels. According to the researches, approximately 6.9 billion people in the world use mobile phones. On May 31, 2011, the International Agency for Research on Cancer (IARC, 2000), a subsidiary of the World Health Organization (WHO) classified radiofrequency electromagnetic fields as possible carcinogenic to humans due to the increased risk of glioma, a malignant type of brain cancer associated with wireless phone use (Group 2B) (WHO, 2011). Especially after this decision, researches on the negative effects of mobile phones on health have begun. There are many studies in the literature such as the effects of non-ionizing radiation, that is, mobile phones, on fetal and maternal health, and the risk of brain tumor formation in children and adults (Christ et al., 2005; Cardis et al., 2008; Divan et al., 2008; Wiart et al., 2008; Rezk et al., 2008; Schüzet al., 2006; Söderqvist et al., 2011).Especially the exposure to GSM and UMTS base stations and to other wireless technologies has led to a growing concern among the public about potential adverse health effects (Bakker, 2012). However some recent studies have shown that mobile phone radiation can have various adverse effects on human health. There are studies reporting that cell phone use can affect the human nervous system and reproduction, causing DNA damage and behavioral changes (Wargo et al., 2012). The total electromagnetic energy arising from the base stations is not a fixed value, it varies according to the user density. When the number of mobile phones and the number of simultaneous calls in the area of the base station increases, the electromagnetic energy emitted from the base station antenna also increases. Also, the distance between cell phone and base station if it increases, communication with higher output power is made. The mobile phone reaches its highest output power during a call, and after the connection is made, the output power is reduced to the most economical level. The cell phone base stations are a type of microwave device that emits radio frequency radiation (RFR).

The purpose of this research is to measure radiofrequency originated non-ionizing radiation emitted from mobile phones and base stations along Malatya Street in Elbistan, using Narda NBM-550 broadband electromagnetic field meter device and Spectran HF-60105 V4 portable spectrum analyser. In addition, it is to be awareness with related to the electromagnetic pollution.

2. Material and Methods

2.1. Making Measurements

Elbistan is approximately between 37th east meridians and 38th north parallel. There are Darende and Gürün districts in the north, Nurhak and Ekinözü in the south, Malatya province, Doğanşehir and Akçadağ districts in the east and Afşin and Göksun districts in the west of Elbistan. In this study, E, H and S measurements were made the radiofrequency originated radiations emitted from non-ionizing radiation sources at 12 points at 100 m intervals along Malatya Street in Elbistan District of Kahramanmaraş. During measurements, NBM-550 Narda broadband field meter which is EF-0691 coded probe (100 kHz-6 GHz) and Spectran Aaronia HF-60105 V4 Handheld Spectrum Analyzer, having 1 MHz-9.4 GHz frequency range and the frequency filtering feature, were used. As recommended by BTK and ICNIRP, the measurement time was taken for at least 6 minutes to be the measurement values meaningful, and the measurements were repeated three times at each point (BTK, 2011; ICNIRP, 2009). Narda NBM-550 broadband field meter which its EF-0691 coded probe measure the average of all radiofrequency (RF) fields in the environment. With a laptop computer which is loaded MCS software, Spectran HF-60105 V4 portable spectrum analyser, with measurement capacity of E, H and S in GSM900, GSM1800 and UMTS 2100 MHz frequencies, respectively, in selected environments. In Figure 1, the measurement points along the Malatya Street of Elbistan are shown.

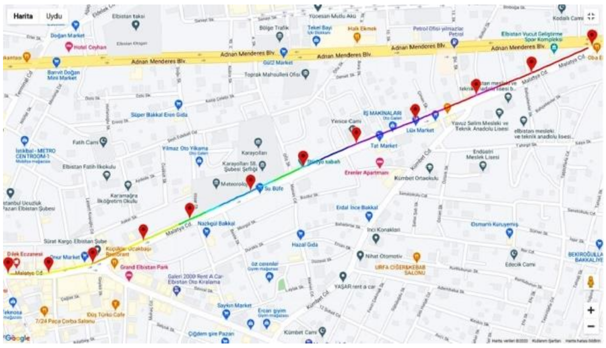

Figure 1. The map of the measurement points along Malatya Stree

In Figure 2, a typical equivalent plane wave power density spectrum taken with the Aaronia Spectran HF-60105 V4 Portable Spectrum Analyzer at (3G) UMTS 2100 MHz frequency is given.

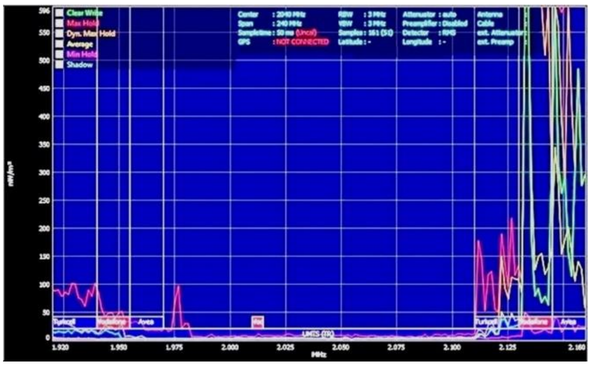

Figure 2. A typical spectrum of the equivalent plane wave power density taken with Aaronia Spectran HF-60105 V4 Portable Spectrum Analyser at (3G) UMTS 2100 MHz frequency.

A 1:10000 scale radiation pollution map, created by the inverse distance weighted interpolation method of the equivalent plane wave power density values of the points measured with the NBM-550 Narda broadband electromagnetic field meter device and EF 0691 coded probe, is given in Figure 3.

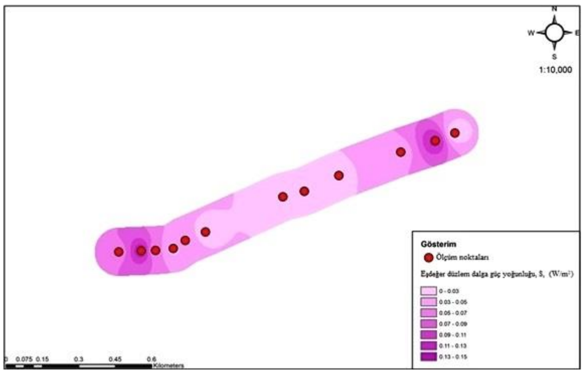

Figure 3. Pollution level of the equivalent plane wave power density measured by NARDA NBM-550 broadband electromagnetic meter and probe coded EF0691 along Malatya Street in Elbistan.

2.2. Calculation of Power Density, Radiation Dose and Radiation Dose Index*:* Power per unit area normal to the direction of propagation, usually expressed in units of watts per square meter (W/m^2) or, for convenience, units such as mill watts per square centimetre (mW/cm^2) or microwatts per square centimetre (μW/cm^2).(IEEE Std C95.1, 1999; BTK, 2011).For plane waves, power density, electric field (E) and magnetic field strength (H) are related by the impedance of free space, i.e., 377Ω. In particular,

$$S = \frac{E^2}{377} = 377\ H^2 \quad (1)$$

where E and H are expressed in units of V/m and A/m, respectively, and S in units of W/m^2. Although many measurement instruments indicate power density units, the actual quantities measured are E or E^2, or H or H^2 (IEEE Std C95.1, 1999; BTK, 2011).The value of the Poynting vector or power density averaged over any time T can be written as follows (Szmigielski and Kubacki, 2000).

$$S_{av} = \frac{1}{T}\sum_i S_i t_i (2)$$

where, S_i is the values of samples Poynting's vector or power density over time t_i, and t_i the sampled time, is during t_i the value of S_i must be different from zero and remain constant for the whole period of t_i. T may be taken as equal to time of work shift T = 8 h for those working in workplaces on the street, but however, T=8760 h should be taken for those living in houses on the street for a year. The average value of E over any time T can be written as follows (Szmigielski and Kubacki, 2000; Olsen and Griner, 1989).

$$E_{av} = \sqrt{\frac{1}{T}\sum E_i t_i} \tag{3}$$

where E_i is values of sampled rms (root mean square) electric field strength during time t_i, and t_i sampled time is during ti the value of E_i has to be different from zero and remain constant for the whole period of t_i. Radiation dose (RD) can be written in (Wxh)/m^2 unit, depending on the S_i or E_i values as follows (Szmigielski and Kubacki, 2000).

$$D = \sum S_i t_i \tag{4}$$

$$D = \frac{1}{Z_0}\sum E_i^2 t_i \ and \ Z_0 = 377\Omega \tag{5}$$

$$D = S_{av}T \tag{6}$$

$$D = \frac{1}{Z_0} E_{av}^2 \, T \tag{7}$$

In assessment of RF/MW exposure, radiation dose index (RDI) can be calculated with the following equations (Szmigielski and Kubacki, 2000).

$$RDI = \frac{D}{D_n} \tag{8}$$

D_n maximum permissible radiation dose (RD) can be calculated from obtained EM safety standards with the following equations.

$$D_n = S_n T \quad or \quad D_n = \frac{1}{Z_0} E_n^2 T \tag{9}$$

where S_n and E_n are respective values of S or E determined in safety standards for EM frequencies for which the RDI is calculated.

$$RDI = \frac{\sum S_i t_i}{S_n \, T} \quad or \ RDI = \frac{\sum E_i^2 t_i}{E_n T} \tag{10}$$

3. Results and Discussion

Elbistan is one of the largest districts of Kahramanmaraş in terms of population and surface area, apart from the central districts, and approximately is between 37th east meridian and 38th north parallel. The measurement area of the study is Malatya Street of Elbistan District of Kahramanmaraş, and it is a length of approximately 1200 m. In this street, the equivalent plane wave power density (S) and the electric (E)-magnetic field (H) strength and generated by radiofrequency originated radiations released from non-ionizing radiation sources at 12 points at 100 m intervals were measured. A laptop with the MCS software program installed and Spectre HF 60105 V4 portable spectrum analyser were used to measure one by one E, H and S values in GSM900, GSM1800 and (3G) UMTS2100 MHz frequencies. In addition, Narda NM-550 Broadband EMF meter which is EF-0691 coded probe were used to measure effective value of all the electric field strength in environment because there is more than one transmitter in the environment where measurement were made in the street. All of the measured values such as E, H and S values are smaller than that of the limit values defined by International Commission on Non-Ionizing Radiation Protection (ICNIRP), Information Technology and Communications Authority of Turkey (BTK) and ARPANSA (ICNIRP, 1998-2009; BTK, 2011, ARPANSA, 2002). People from these locations may be exposed to the possible hazardous effects of electromagnetic pollution. In Malatya Street, in which electromagnetic field strength was measured, many workplaces such as restaurants, patisseries, bakeries, electricians, plumbers, barbers, law offices and AVM serve to the local public. Even though small radiation energy present in this area, people are constantly exposed to radiation. Moreover, the children in the younger age groups are more affected than the adults by this electromagnetic radiation (Wargo et al., 2012). Therefore, it is important to find out how these children are affected by this electromagnetic field. In childhood RF radiation exposure are worrisome for several reasons, one reason is that a child's brain absorbs significantly more radiation than an adult's brain (Wargo et al., 2012). Another reason is that children's anatomical differences may allow greater exposure of their brain regions from cell phone radio frequency (RF) because of differences in electrical conductivity in their bone marrow (Christ et al., 2010). In other words, children may be potentially more susceptible to RF effects because of their developing nervous systems, increased levels of cell division, undeveloped immune systems, thinner skulls, and more conductive brain tissue (Kheifets et al., 2005). Limit values defined by ARPANSA, ICNIRP and BTK for electric (E)-magnetic field (H) strength and the equivalent plane wave power density (S) are given in Table 1.

Table 1. Limit values defined by BTK, ICNIRP and ARPANSA for electric (E) and magnetic field (H) strength and equivalent plane wave power density (S)

	ICNIRP, 1998			BTK, 2011			ARPANSA, 2002		
	E V/m	**H** A/m	**S** W/m²	**E** V/m	**H** A/m	**S** W/m²	**E** V/m	**H** A/m	**S** W/m²
	61.40	0.163	10	61.40	0.163	10	61.40	0.163	10
GSM 900 MHz	41.25	0.111	4.5	41.25	0.111	4.5	41.10	0.110	4.5
GSM 1800 MHz	58.34	0.157	9	58.34	0.157	9	58.12	0.154	9
GSM 2100 MHz	61	0.16	10	61	0.16	10	61.40	0.163	10

As can be seen from Table 2 and Figure 4, in the measurements made in 2020 year with Narda NBM-550 EMA meter, the highest electric field and magnetic field intensity were determined at the 1st measurement point (MP) as 7.010 V/m and 0.019 A/m, respectively. The largest S value was measured at the 1st MP as 0.131 W/m^2.The values of the smallest E, H and S were measured at the 12th MP as 2.060 V/m, 5 mA/m and 11 mW/m^2, respectively. A comparison of S value measured in 2017 and 2020 years along the Malatya Street of Elbistan is given in Figure 4. As seen From Table 2, in the measurements made with Narda NBM-550 EMA meter in 2017 year, the highest E, H and S values was measured at the 6th MP as 9.700 V/m, 25.729 mA/m and 249.575 mW/m^2, respectively.

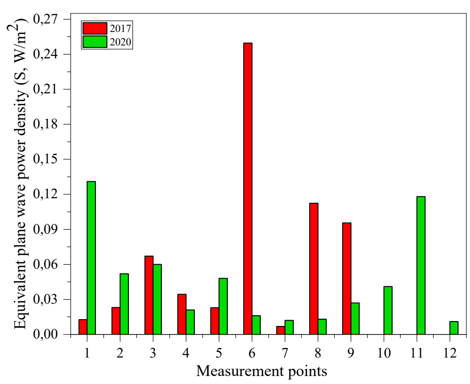

Figure 4. Comparison of S measured by Narda NBM-550 broadband electromagnetic field intensity meter in 2017 and 2020 years along the Malatya street of Elbistan

Table 2. Electric field (E) and magnetic field strength (H) and equivalent plane wave power density (S) values measured with Narda NBM-550 broadband electromagnetic field meter along Malatya Street of Elbistan (mean ±σ, n=3).

	GPS coordinates		The measurement values in 2020 years			The measurement values in 2017 years		
	Latitude (N)	Longitude (E)	E (V/m)	H (mA/m)	S (mW/m^2)	E (V/m)	H (mA/m)	S (mW/m^2)
1.MP	$38^0$12'7.1"	$37^0$11'30.9"	7.010 ±0.161	19.000 ±3.420x10^{-4}	131.000 ±3.013 x10^{-3}	2.190 ±0.030	5.810 ±1.162x10^{-4}	12.700 ±3.810 x10^{-4}
2.MP	$38^0$12'7.3"	$37^0$11'34.7"	4.410 ± 0.137	12.000 ±2.760 x10^{-4}	52.000 ±1.129 x10^{-3}	2.950 ±0.052	7.825 ±1.409x10^{-4}	23.100 ±6.930 x10^{-4}
3.MP	$38^0$12'7.4"	$37^0$11'37.1"	4.740 ±0.131	13.000 ±3.510 x10^{-4}	60.000 ±1.248 x10^{-3}	1.590 ±0.024	4.217 ±0.717x10^{-4}	6.706 ±1.542 x10^{-4}
4.MP	$38^0$12'7.7"	$37^0$11'40.1"	2.810 ±0.058	7.000 ±1.920 x10^{-4}	21.000 ±4.389 x10^{-4}	3.600 ±0.039	9.549 ±1.814 x10^{-4}	34.400 ±8.600 x10^{-4}
5.MP	$38^0$12'8.8"	$37^0$11'42.1"	4.270 ±0.137	11.000 ±1.538 x10^{-4}	48.000 ±5.270 x10^{-4}	2.940 ±0.031	7.798 ±1.091 x10^{-4}	22.900 ±8.015 x10^{-4}
6.MP	$38^0$12'10.0"	$37^0$11'45.5"	2.450 ±0.060	6.000 ±7.380 x10^{-5}	16.000 ±4.640 x10^{-4}	9.700 ±0.162	25.729 ±18.010 x10^{-4}	249.575 ±0.012
7.MP	$38^0$12'14.9"	$37^0$11'58.5"	2.110 ±0.040	6.000 ±7.080 x10^{-5}	12.000 ±8.472 x10^{-4}	1.610 ±0.020	4.271 ±2.563 x10^{-4}	6.876 ±2.576 x10^{-4}
8.MP	$38^0$12'15.7"	$37^0$12'2.1"	2.220 ±0.048	6.000 ±6.360 x10^{-5}	13.000 ±6.591 x10^{-4}	6.510 ±0.090	17.267 ±13.811 x10^{-4}	112.414 ±32,000 x10^{-4}
9.MP	$38^0$12'17.9"	$37^0$12'7.9"	3.190 ±0.083	8.000 ±9.920 x10^{-5}	27.000 ±6.695 x10^{-4}	6.000 ±0.090	15.915 ±2.546 x10^{-4}	95.491 ±40,110 x10^{-4}
10.MP	$38^0$12'21.2"	$37^0$12'18.3"	3.940 ±0.098	1.000 ±1.180 x10^{-4}	41.000 ±4.469 x10^{-4}			
11.MP	$38^0$12'22.8"	$37^0$12'24.1"	6.680 ±0.143	18.000 ±2.178 x10^{-4}	118.000 ±2.454 x10^{-3}			
12.MP	$38^0$12'23.9"	$37^0$12'27.4"	2.060 ±0.037	5.000 ±5.225 x10^{-5}	11.000 ±1.199 x10^{-4}			

MP:the measuring points

The smallest values were measured at the 3th measurement point as 1.590 V/m, 4.217 mA/m and 6.706 mW/m^2, respectively. A comparison of the electric field strength measured by Narda NBM-550 broadband electromagnetic field intensity meter in 2017 and 2020 years along the Malatya street of Elbistan is given in Figure 5.

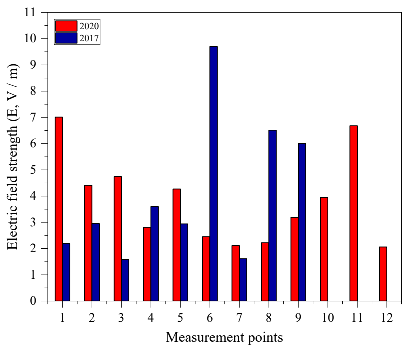

Figure 5. Comparison of E values measured by Narda NBM-550 broadband electromagnetic field intensity meter in 2017 and 2020 years along the Malatya street of Elbistan.

The spatial average values of E, H and S made in the year 2017 (4.170±0.114 V/m, 11.061±3.948x10^{-3} mA/m and 46.124±1.268x10^{-3} mW/m^2, respectively) are 19% higher than the measurement values made in the year 2020 (3.370±0.070 V/m, 8.939±9.272 x10^{-5} mA/m and 30±6.180 x$10^{-4}$$mW/m^2$, respectively). One of the reasons for these differences in measurements may be change in distance to the base station. However, the most important factor is thought to be that the traffic of using phones is reduced due to the fact that the workplaces that are open along the street are not used intensively and the low human crowd due to the Covid-19 outbreak.

Table 3. Measured values with Aaronia Spectran HF-60105 V4 portable spectrum analyser at GSM 900, GSM 1800 and GSM 2100 MHz frequency at 12 points along Malatya street of Elbistan (mean ±σ, n=3)

MP	GSM 900 MHz			GSM 1800 MHz			GSM 2100 MHz		
	E mV/m	H μA/m	S μW/m^2	E mV/m	H μA/m	S μW/m^2	E mV/m	H μA/m	S μW/m^2
1.MP	318.700 ±4.684 x10^{-3}	845.800 ±1.472 x10^{-5}	269.500 ±0.474 x10^{-5}	353.600 ±7.072x10^{-3}	938.600 ±1.821 x10^{-5}	331.900 ±0.658 x10^{-5}	437.500 ±5.906 x10^{-3}	1161.200 ±1.753 x10^{-5}	508.000 ±1.066 x10^{-5}
2.MP	306.100 ±4.469 x10^{-3}	812.500 ±1.178 x10^{-5}	248.700 ±0.425 x10^{-5}	111.000 ±2.775 x10^{-3}	294.500 ±0.565 x10^{-5}	32.680 ±0.062 x10^{-5}	1599.000 ±0.025	4244.400 ±6.069 x10^{-5}	6786.600 ±13.437 x10^{-5}
3.MP	137.700 ±2.574 x10^{-3}	365.500 ±0.629 x10^{-5}	50.330 ±0.067 x10^{-5}	92.380 ±1.663 x10^{-3}	245.200 ±0.449 x10^{-5}	22.650 ±0.037 x10^{-5}	333.200 ±4.731 x10^{-3}	884.600 ±1.212 x10^{-5}	294.800 ±0.515 x10^{-5}
4.MP	184.000 ±2.355 x10^{-3}	488.500 ±0.801 x10^{-5}	89.910 ±0.174 x10^{-5}	236.100 ±6.847 x10^{-3}	626.800 ±1.385 x10^{-5}	148.000 ± 0.024 x10^{-5}	249.100 ±4.110 x10^{-3}	661.100 ±1.064 x10^{-5}	164.700 ±0.272 x10^{-5}
5.MP	50.800 ±0.947 x10^{-3}	134.900 ±0.182 x10^{-5}	6.850 ±0.009 x10^{-5}	27.380 ±0.657 x10^{-3}	72.690 ±0.119 x10^{-5}	1.990 ±0.004 x10^{-5}	112.100 ±1.842 x10^{-3}	297.600 ±0.407 x10^{-5}	33.370 ±0.041 x10^{-5}
6.MP	84.120 ±1.362 x10^{-3}	223.300 ±0.406 x10^{-5}	18.780 ±0.031 x10^{-5}	33.070 ±0.529 x10^{-3}	87.770 ±0.171 x10^{-5}	2.910 ±0.004 x10^{-5}	110.500 ±1.635 x10^{-3}	293.300 ±0.498 x10^{-5}	32.420 ±0.047 x10^{-5}
7.MP	23.610 ±0.335 x10^{-3}	62.660 ±0.091 x10^{-5}	1.490 ±0.002 x10^{-5}	20.790 ±0.233 x10^{-3}	55.180 ±0.102 x10^{-5}	1.150 ±0.002 x10^{-5}	30.550 ±0.403 x10^{-3}	81.090 ±0.112 x10^{-5}	2.477 ±0.003 x10^{-5}
8.MP	134.600 ±1.662 x10^{-3}	357.400 ±0.636 x10^{-5}	48.110 ±0.073 x10^{-5}	40.010 ±0.540 x10^{-3}	106.200 ±0.154 x10^{-5}	4.250 ±0.007 x10^{-5}	87.700 ±1.578 x10^{-3}	259.300 ±0.378	25.340 ±0.047 x10^{-5}
9.MP	194.100 ±3.454 x10^{-3}	515.200 ±0.839 x10^{-5}	100.000 ±0.141 x10^{-5}	53.660 ±1.449 x10^{-3}	142.400 ±0.224 x10^{-5}	7.650 ±0.011 x10^{-5}	259.300 ±4.174 x10^{-3}	688.200 ±1.150 x10^{-5}	178.400 ±0.375 x10^{-5}
10.MP	660.800 ±9.845 x10^{-3}	1754.00 ±2.894 x10^{-5}	1159.100 ±1.947 x10^{-5}	39.420 ±0.634 x10^{-3}	104.600 ±0.141 x10^{-5}	4.130 ±0.007 x10^{-5}	323.300 ±4.332 x10^{-3}	858.300 ±1.321 x10^{-5}	227.500 ±0.378 x10^{-5}
11.MP	90.420 ±1.464 x10^{-3}	240.00 ±0.427 x10^{-5}	21.700 ±0.030 x10^{-5}	54.880 ±1.152 x10^{-3}	145.700 ±0.179 x10^{-5}	7.990 ± 0.014 x10^{-5}	58.640 ±0.850 x10^{-3}	155.700 ±0.256 x10^{-5}	9.140 ±0.011 x10^{-5}
12.MP	101.200 ±1.578 x10^{-3}	268.600 ±0.443 x10^{-5}	27.190 ±0.037 x10^{-5}	43.990 ±0.708 x10^{-3}	116.680 ±0.144 x10^{-5}	5.140 ± 0.006 x10^{-5}	43.220 ±0.695 x10^{-3}	114.700 ±0.178 x10^{-5}	4.960 ±0.009 x10^{-5}

MP:the measuring points

Measurements made with Aaronia Spectran HF-60105 V4 portable spectrum analyzer at GSM 900, GSM 1800 and (UMTS) GSM 2100 MHz frequencies are given in Table 3. As seen from Table 3, in the measurements of S, E and H values at GSM 900, GSM 1800 and UMTS 2100 MHz frequencies, the largest E value (1599 mV/m) was measured at the UMTS (2100) MHz frequency at the 2th point, while the smallest E value (20.79 mV/m) was measured at the GSM1800 MHz frequency at the 7th point. The largest H value (4244.4 μA/m) was measured at the UMTS (2100) MHz frequency at the 2th point, while the smallest H value (55.18 μA/m) was measured at the GSM1800 MHz frequency at the 7th point. The highest value of S (6786.6 μW/m^2) was measured at the UMTS (2100) MHz frequency at the 2th point, while the lowest value (1.15 W/m^2) was measured at the GSM1800 MHz frequency at the 7th point. Figure 6 shows the comparison of E values measured with the Aaronia Spectran HF-60105 V4 portable spectrum analyzer at GSM 900, GSM 1800 and 3G (UMTS) 2100 MHz frequencies.

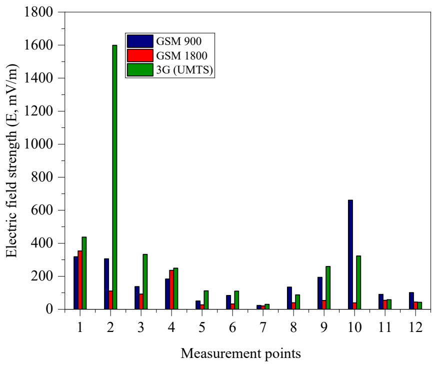

Figure 6. A comparison of E values measured by the Aaronia Spectran HF-60105 V4 portable spectrum analyzer at GSM 900, GSM 1800 and 3G (UMTS) 2100 MHz frequencies

The E, H and S values were measured as small at some measurement points and large at some measurement points. The reason for this may be that the distance of the measurement points to the base stations and the intensity of mobile phone usage at the time of measurement are different. Because the increase in the intensity of using the mobile phone at the time of measurement means the increase in the measurement values of the electric and magnetic field strength and the equivalent plane wave power density. Cell phones run at lower power when they are closer to the base station. However, as cell phones move further away from the base station or the signal strength gets weaker; the cell phones operate at higher power to connect to the base stations. In this case, mobile phone users are exposed to more radiation.

In 2017, the radiation dose (D) and radiation dose index (RDI) calculated from the measurements made with Narda NBM-550 EMF meter device and EF0691 coded probe is 14% higher than the radiation dose (D) and radiation dose index (RDI) calculated from the measurements made in 2020.Calculated D and RDI values from measurements for the GSM900 MHz frequency with Aaronia Spectran HF-60105 V4 portable spectrum analyzer and a laptop with MCS software are $9.677x10^{-6}Wh/m^2$ and $2.680x10^{-7}$, respectively. D and RDI values calculated from the measurements made for the GSM 1800 MHz frequency are $2.255x10^{-6}$ Wh/m^2 and $3.122x10^{-8}$, respectively. D and RDI values calculated for the measurements made for the UMTS, GSM 2100 MHz frequency are 2.446 10-5 Wh/m^2 and $3.098x10^{-7}$, respectively. According to the RDI values, the RDI value at GSM 2100 MHz frequencies is 13% greater than the GSM 900 MHz frequency and about 90% larger than the GSM 1800 MHz frequency. According to the RDI values, the RDI value at GSM 2100 MHz frequencies is 13% greater than the GSM 900 MHz frequency and about 90% larger than the GSM 1800 MHz frequency. However, since the RDI values calculated from the measurements made by both Narda NBM-550 EMF meter device and Aaronia Spectran HF-60105 V4 portable spectrum analyzer are smaller than one, the RF originated radiation exposure is much lower than the allowed values. While RDI<1 indicates lower exposure levels than allowed, RDI>1 indicates unacceptably high field exposure.

4. Conclusion

In this Study, Spectran HF-60105 V4 portable spectrum analyzer which having the feature of the frequency filtering (1 MHz-9.4 GHz) and Narda NBM-550 broadband EMF meter devices which having EF0691 isotropic probe (100 kHz-6 GHz) were used to measure the electrical-magnetic field strength and the equivalent plane wave power densities along Malatya Street of Elbistan District of Kahramanmaraş. Two different devices having different characteristics were used in the measurements. One of the devices, Spectran Aaronia HF-60105 V4 Handheld Spectrum Analyser, has a frequency filtering feature and only makes measurements on selected frequencies such as GSM 900, GSM 1800 and GSM 2100.The other device also, Narda NBM-550 broadband EMF meter having EF-0691 coded probe, makes measurement of the total electromagnetic field strength in the environment.

As seen from Table 1-3, all of the values obtained from measurements are smaller than the limit values determined for non-ionizing radiations of radiofrequency origin defined by national and international institutions such as BTK, ARPANSA and ICNIRP (BTK, 201; ARPANSA, 2002 and ICNIRP, 1998). In spite of the obtained results in this research are below the limit values, during measurements it was determined that people were worried about the base stations and similar constructions emitting non-ionizing radiation. Namely, the public anxiety was related to specific topics. In general, cell phones and base stations for mobile communication are not considered as a major risk factor to children's health. But, most of the parents who live in the vicinity of base stations consider this situation as dangerous for their children. While research on the negative effects of non-ionizing radiation exposure on human health is still on going, there are also studies in the literature stating that non-ionizing radiation will affect the human nervous system and reproduction, cause DNA damage and behavioral changes or behavioral dependence (Christ et al., 2010; Söğüt et al., 2017). Some researchers have also reported some effects of mobile phone use, including exposure to radiofrequency (RF) fields, changes in brain activity, reaction times, and sleep patterns. Current, research efforts have focused on whether the negative effects of exposure to low-level non-ionizing radiation are long-term or not (Agarwal et al., 2009).

The radiation dose and radiation dose index were calculated based on the eight-hour exposure time for the employees in the workplaces in Malatya Street of Elbistan district of Kahramanmaraş. Since the radiation dose index was found to be smaller than one (RDI<1), it was determined that the radiation dose and radiation dose index were also below the allowed values.

It should not be forgotten that the factors that affect radiation exposure are time, distance and radiation intensity. The difference of radiation pollution from other environmental pollution is that it cannot be detected by sense organs, and this makes it more dangerous than other environmental pollutions. As a result, it is recommended to carry out awareness studies by authorized institutions for both cases, whether it is exposure to ionizing radiation such as X-rays and gamma rays, or exposure to non-ionizing radiation of radiofrequency origin such as microwave and radio waves.

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