DETERMINING THE EFFECT OF ESTABLISHMENT OF 4G SYSTEMS ON ELECTROMAGNETIC RADIATION LEVELS IN A PILOT DISTRICT

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Abstract. The level of radiofrequency electromagnetic fields (RF-EMF) exposure increases day by day as a natural consequence of technological development. In recent years, the increasing use of cellular systems due to technological developments in wireless communication systems has made it necessary to measure and evaluate RF-EMF originating from base stations which are the basic structure of these systems. In Turkey, as in April 2016, fourth generation of wireless mobile communication technology (4G) has been introduced and additional base stations are continuing to be added to the system. In this study, RF-EMF measurements were taken at four different times in order to examine and evaluate the change of RF-EMF before and after 4G in Atakum district which is one of the most crowded districts of Samsun, Turkey. Two of the measurements were taken before 4G and the remaining measurements were taken after 4G. Each measurement was taken at different times of the day (morning, noon and evening). The measurements were collected from 46 different locations using PMM 8053 RF-EMF meter which measures RF-EMF in the broad band from 100 kHz to 3 GHz. In the measurements, the maximum electric field strength (E_{max}) and the average electric field strength (E_{avg}) were recorded. The highest values that have been noticed in these measurements were 9.45 V/m and 17.53 V/m for E_{avg} and E_{max} , respectively. According to the measurement results, a decrease of 45.95% was observed in the measurement values of the morning hours compared to the measurement values of the evening and noon hours. The average RF-EMF value after 4G was introduced has increased by 30.95% compared to before 4G. Apart from these measurements, 24-hour measurements were taken at a location where the highest value was observed and analyzed to observe the change of RF-EMFs during a day.

Key words: Electric field strength, electromagnetic (EM) radiation, EM measurement

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1. INTRODUCTION

Technological products/systems, such as high-voltage lines, FM and TV transmitters, cellular systems, Bluetooth, microwave ovens, Wi-Fi, etc., which facilitate human life and increase in usage intensity, act as electromagnetic fields (EMF) sources. In particular, the increasing use of wireless systems has led to a significant increase in man-made radiofrequency EMF (RF-EMF). Measuring and evaluating RF-EMF from base stations, which are the basic building blocks of cellular systems, is of great importance for human health. The increase in the number of users using cellular systems, the ability of each base station to serve a limited area, and the ability of users to access the system from everywhere and use more multimedia force the cellular system operators to build more base stations. In parallel with this increase in base stations, an increase in the level of RF-EMF is also observed. There were around 100,000 base stations in Turkey before 4G, but with the establishment of 4G systems on April 1, 2016, the estimated number of base stations is around 130,000. Because there is a growing number of base stations being placed into crowded places;

measuring, evaluating the levels of RF-EMF and controlling their compliance with standards/limit values has become more crucial than before. Therefore, detrimental effects of RF-EMF on human health have been the subject of many researches [1-10] in the last decade.

There are many organizations in the world that are examining the effects of RF-EMF on human health due to cellular systems and setting some standards in this regard. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is the most important of these organizations. The ICNIRP identifies the areas where the RF-EMF level is detrimental to the frequency range [11]. Each country has its own determined limits. The USA and some European countries use limits determined by the ICNIRP, while other European countries like Switzerland and Italy use 1/10 of the ICNIRP's values as a limit. Turkey applies limits that are 75% of ICNIRP reference levels as endorsed by Information Technologies and Communications Authority (ICTA) [12]. Reference levels for general public exposure to time-varying electric field strength (E) for ICNIRP and ICTA are shown in Table 1. The limits are given for exposure averaged over a six-minute interval. There are

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currently three mobile communication operators in Turkey and they use 2G (second generation), 3G (third generation) and 4G (fourth generation) systems. According to [12], the limits are 30.9 (V/m) for 900 MHz base station, 43.7 (V/m) for 1800 MHz base station, 45.75 (V/m) for 3G systems, which is 2100 MHz, and also 45.75 (V/m) for 2600 MHz base station.

Table 1. Reference levels for general public exposure to time-varying electric field strengths for ICNIRP and ICTA

Frequency range (MHz)	Electric field strength (V/m)	
	ICNIRP	ICTA
0.010-0.15	87	65.25
0.15-1	87	65.25
1-10	$87/f^{1/2}$	$65.25/f^{1/2}$
10-400	28	21
400-2000	$1.375/f^{1/2}$	$1.03/f^{1/2}$
2000-60000	61	45.75
f is frequency in MHz		

2. MEASUREMENT OF ELECTRIC FIELD STRENGTH

In order to determine the changes in E levels with the deployment of 4G, E measurements were conducted using PMM 8053 EMF meter [13] in Atakum district at 46 different locations, considering the number of users, line of sight, and distance from a base station. A picture of one of the measurements is shown in Figure 1. The measurements were done at a height of about 1.5 m above the ground. Each measurement location which is separated by a distance of app. 100 meters is shown with a red circle in Figure 2.

Figure 1. Taking measurement with PMM 8053 EMF meter

Figure 2. a) Location of Samsun, Turkey, b) Measurement locations in Atakum district

In this study, E measurements were taken at four different times in order to examine and evaluate the change of E before and after 4G in Atakum district, which is one of the most crowded districts of Samsun, Turkey. Total E in the band between 100 kHz – 3 GHz was measured with PMM–8053 with EP-330 isotropic electric field probe [13] twice in August 2015, named M1 and M2, and in December 2016, named M3 and M4, respectively. Two of the measurements were taken before 4G (August 2015) and the remaining measurements were taken after 4G (December 2016). Each measurement was taken at three different times of the day (morning, noon and evening). In each measurement, the maximum electric field strength (E_{max}) and the average electric field strength (E_{avg}) were recorded. Based on the international standards and ordinances released by ICNIRP and ICTA, the duration of each measurement was six minutes.

3. MEASUREMENT RESULTS

In the first stage of the study, the maximum E (E_{max}) and the average E (E_{avg}) were measured at 46 different locations and are given in Figure 3.a. and Figure 3.b respectively. In Figure 3, the x axis indicates the total of 12 measurement times (four different days, each day at three different times). The first measurement time (M1) represents the morning of the

first measurement day, while the second (M2) and third (M3) measurement time represent the noon and evening of the first measurement day. Similarly, M4, M5, M6; M7, M8, M9; M10, M11, M12 are measurement times of morning, noon and evening for the second day, third day and fourth day, respectively. M1, M2, M3, M4, M5, M6 indicate E measurement times for before 4G, while others indicate the same after 4G. The reasons of various E levels may be: the number of base stations in the measurement area, output powers of base stations, distances from the base stations, whether there is line of sight between the units or not, and the number of users. As seen from Figure 3.a, the $E_{\max}$ is 4.77 V/m which is measured at the 26th location (measurement time 5). The maximum E_{avg} is also obtained at the 26th location (measurement time 8) as 3.20 V/m accordingly (Figure 3.b).

Figure 3. a) Maximum ($E_{\max}$) b) Average (E_{avg}) Es versus locations

The changes in the means of the E_{avg} s and $E_{\max}$ s for all of the measurements by locations are shown in Figure 4. It is seen from the figure that the maximum mean values of the $E_{\max}$ and E_{avg} are reached at the 26th location. The mean $E_{\max}$ is 3.53 V/m, and mean E_{avg} is 2.32 V/m for this location.

Figure 5.a shows the maximum E values measured at the positions for all of the measurements at three different times of day (morning, noon and evening), while Figure 5.b shows the average E values. The mean

$E_{\max}$ value is 1.26 V/m for the noon, while it is 0.70 V/m for the morning measurements. The mean E_{avg} values are 0.54 V/m for the noon and 0.37 V/m for the morning measurements.

Figure 4. The mean values of $E_{\max}$ and E_{avg} for twelve different measurement times

Figure 5. a) The $E_{\max}$ b) the E_{avg} values for morning, noon, and evening

Figure 6.a shows the maximum E values obtained as a result of E measurements taken before and after 4G. When the figure is examined, the E values obtained after 4G are generally higher than the E values obtained after 4G. Figure 6.b shows the average E

values obtained as a result of E measurements made before and after 4G. Before 4G, the mean of the $E_{\max}$ was 1.03 V/m, and it decreased to 0.92 V/m after 4G. For the case of E_{avg} , the corresponding values were 0.42 V/m and 0.55 V/m. The average E value after 4G was introduced has increased by 30.95% compared to before 4G.

Figure 6. a) The maximum E values before and after 4G
b) the average E values before and after 4G

In order to have a better visualization of the changes in E levels, they are transferred on a map using MapInfo and the means of the E_{avg} s and $E_{\max}$ s for all of the measurements are shown in Figure 7.a. and Figure 7.b.

Measurements were taken to determine how the E values measured at location 26 change during a day and the results are given in Figure 8. A picture from the measurement location is given in Figure 9. This measurement is a 24-hour measurement after 4G. The measurement started at 6 pm and continued until the next day. Figure 8 shows a great variation depending on the measurement hours. It is seen here that the number of users actively using the base station is the main factor influencing the E. Low E values were measured between the hours of 05:00 – 07:00 at night, especially when using very high E values between 12:00 and 18:00. The highest measured E value was 17.53 V/m, while the 24-hour average was 9.4495 V/m. The standard deviation value is 2.0227 V/m for this 24-hour measurement.

Figure 7. MapInfo picture of a) $E_{\max}$ b) E_{avg} after 4G

Figure 8. E levels during a day for location 26

Figure 9. A picture of location 26

4. CONCLUSIONS

In this study, RF-EMF measurements were taken at four different times in order to examine and evaluate the change of RF-EMF before and after 4G in Atakum district, which is one of the most crowded districts of Samsun, Turkey. Two of the measurements were taken before 4G and the remaining measurements were taken after 4G. Each measurement was taken at three different times of the day. When the results are examined, the measured RF-EMF values may vary depending on the measurement location and the measurement time. The highest measured electric field value is 17.53 V/m and the highest average electric field value is 9.44 V/m. Even though the measured E levels are below the limits that are determined by ICNIRP and ICTA; they may be considered as high in some countries (e.g. Switzerland and Italy) where lower limits are applied. According to the measurement results, a decrease of 45.95% was observed in the measurement values of the morning hours compared to the measurement values of the evening and noon hours. The average RF-EMF value after 4G was introduced has increased by 30.95% compared to before 4G. Apart from these measurements, a 24-hour measurement was taken at a location where the highest value was observed and it was analyzed to observe the change of RF-EMFs during a day.

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