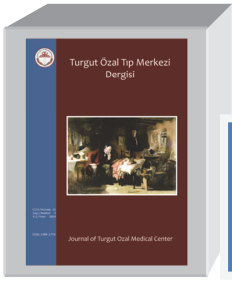

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Measuring, Evaluating, and Mapping the Electromagnetic Field Levels in Turgut Ozal Medical Center Building and Environment

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Abstract
Objectives: To take measurements for electromagnetic field levels in the range of 5Hz-8GHz frequency at Turgut Ozal Medical Center, Inonu University, a medical center visited by over 500.000 patients every year, and analysing the results.
Material and Methods: Two Wavecontrol MonitEM, continuous electromagnetic field measurement stations have been used to observe the values of electrical field levels at 100kHz-8GHz and GSM and 3G frequencies inside and outside the medical center in different times of the day. We used Narda EHP-50D device for continuous electromagnetic field measurements to observe the values of the electrical field levels around the medical center, from the building out towards the nearby switchyard, and high voltage power transmission lines in a range of 5HZ-100kHz frequency. We also employed a Wavecontrol SMP Meter electromagnetic field measurement device to observe the electrical field level values at 10Hz-3KHz, 100KHz-8GHz and GSM and 3G frequencies. The source frequencies were measured by Aaronia Spectran HF-60105.
Results: The high electromagnetic field levels within the medical center are caused by the systems operating at high frequencies used, again, within the medical center, and not by the external electromagnetic sources.
Conclusion: As a result of instant and continuous electromagnetic field measurements at 5Hz-8GHz frequencies in the interiors and exteriors of the medical center, none of the values we have measured was over national and international standards.
Key Words: Electric and Magnetic Fields; High Frequency Electromangnetic Field; Electromagnetic Field Monitoring in Hospitals; Electromagnetic Pollution Maps.

Turgut Özal Tıp Merkezi Binası ve Çevresinde Elektromanyetik Alan Seviyelerinin Ölçülmesi, Değerlendirilmesi ve Haritalanması

Özet
Amaç: Yılda 500.000'in üzerinde hastanın ziyaret ettiği İnönü Üniversitesi Turgut Özal Tıp Merkezinin, 5Hz-8GHz frekans aralığındaki elektromanyetik alan kaynaklarının hastane yerleşkesindeki seviyelerinin ölçülmesi ve değerlendirilmesi.
Yöntem ve Gereçler: Tıp Merkezine dış kaynaklardan etkiyen yüksek frekans elektromanyetik alanların etkilerinin belirlenmesi için 100kHz-8GHz ve GSM & 3G frekanslarında ölçüm alan iki adet Wavecontrol MonitEM sürekli elektromanyetik alanları izleme istasyonu kullanılmıştır. Tıp Merkezi yerleşkesine sınır olan şalt sahası ve yüksek gerilim enerji nakil hattının elektik alan etkilerinin belirlenmesi için 5Hz-100KHz frekanslarında ölçüm alan bir adet Narda EHP-50D alçak frekans sürekli elektromanyetik alanları ölçüm cihazı kullanılmıştır. Tıp Merkezi içerisinde anlık elektromanyetik alanların belirlenmesi için 10Hz-3KHz, 100KHz-8GHz, GSM & 3G frekanslarında ölçüm problarına sahip Wavecontrol SMP Meter cihazı kullanılmıştır. Bu etkiyi oluşturan kaynakların frekansları AAronia Spectran HF-60105 ile belirlenmiştir.
Bulgular: Tıp merkezi içerisindeki elektromanyetik alan seviyesi değerleri dış elektromanyetik kaynaklardan değil; hastane içerisindeki yüksek frekansta çalışan sistemlerden kaynaklanmaktadır.
Sonuç: Tıp merkezinin iç ve dış mekânlarını kapsayan, 5Hz-8GHz frekans aralığındaki, anlık ve sürekli elektromanyetik alan ölçüm sonuçlarına göre ulusal ve uluslararası standartların üzerinde herhangi bir değer ölçülmemiştir.
Anahtar Kelimeler: Elektrik ve Manyetik Alanlar; Yüksek Frekans Elektromanyetik Alan; Hastanelerde Elektromanyetik Alanların İzlenmesi, Elektromanyetik Kirlilik Haritaları.

INTRODUCTION

In recent years, the widespread use of communication systems and the increase in next-generation wireless communication, the effect of electromagnetic field radiation is growing in a dramatic way. Simple to install and accessible with mobile benefits of wireless technologies, these systems are widely preferred. One of the places where such systems are used intensively is medical centers. Operating at high frequency, 3G and WLAN (Wireless Local Area Network) information and communication technologies are widely in hospitals for intermediate care, non-critical patient monitoring, information, and communication purposes. Both the electromagnetic waves that have been emitted by high-frequency wireless communication devices inside and outside hospitals and the power frequency electric transmission lines and distribution systems inside and around hospital premises may create serious impacts on medical devices, staff, and inpatients. Furthermore, it has been detected that electromagnetic field interference causes different types of faults in high-precision medical devices. Such defects may give rise to many irreparable issues in medical centers. To exemplify the point, we can recall the medical literature reports that give an account of the death of two patients due to the cessation of patient monitoring systems as a result of electromagnetic field interference (1). Since the 1970s, experts have shown serious concerns about electromagnetic interaction. By the year 1979, Food and Drug Administration (FDA) issued a set of rules entitled "electromagnetic compatibility standards for medical devices" (2). Since then, several studies have concentrated on electromagnetic interference due to electromagnetic fields and the compatibility of medical devices. One of the most important works on this subject was made by Silberg (3). Silberg's study presents hundreds of cases related to the effects of electromagnetic fields on interference in medical devices. All of these cases are based on FDA reports between 1979 and 1993. In addition to the influences of electromagnetic fields on medical equipments, studies have also focused on characterisation of the electromagnetic environment in hospitals (4-6). Today, there are also researches to evaluate the effects of electromagnetic pollution on biological system and their results are still being discussed. The majority of the discussion revolves around the question whether base stations and mobile phones cause cancer. Although some epidemiological studies have managed to establish a relationship between certain types of cancer and the growing number of base stations and mobile phones use, the number of studies arguing the opposite are also plenty (7-15). That's why the effects of electromagnetic pollution on human health is still an up-to-date issue that is still debated by scientists. Meanwhile, International Agency for Research on Cancer listed ELF (Extremely Low Frequency) magnetic fields and RF (Radio Frequency) radiation as 2B potential carcinogen factors in 2004 and 2011, respectively.

Many studies have been carried out to measure electromagnetic field levels of resources operating at high frequencies such as TV and radio broadcasting and mobile services outside hospitals and to determine their effects. Whereas some studies have focused on the characterisation of the electromagnetic field distributions in the power frequency of hospital environments (f=50-60Hz) (16, 17).

To put it very roughly, any wire with electric current produces a magnetic field around itself. Magnetic field magnitude is proportional to the magnitude of current flowing through the wire. The energy units in hospital buildings are internal sources of power frequency electromagnetic fields. These units are designed to supply energy for all the wiring and devices including medical equipments in hospitals. Considering the increasing need for more medical equipment in large scale hospitals, it is safe to say that the need for energy is proportional to such growth rates. This increase in electric current means an increase in the electromagnetic levels in the premises. In addition, high level of electric and magnetic fields, even in low frequencies, can also affect the operation of the medical devices (18).

Therefore, measuring high and low frequency electric and magnetic fields in and around hospitals and evaluating these results according to appropriate standards is a necessity. Still, it is not possible to claim that the number of studies that have been presented on this subject is sufficient. Through numerous measurement techniques, many studies have investigated the effects electromagnetic field resources on power frequency within hospital buildings. Moreover, many of these studies have conducted instantaneous or periodical electromagnetic field measurements (19). However, as it has been mentioned above, these effects may take place any time and can lead to irreversible consequences. Thus, unlike in other environments and institutions, the effects of electromagnetic fields should be monitored, measured, and assessed continuously in major medical centers and clinics. To this end, systems that can measure, control, and display the data about the levels and frequency spectrum of electromagnetic fields should be regarded as a requirement in medical centers. In this study, by setting MonitEM continuous electromagnetic field measuring and monitoring stations (20), we have aimed to perform continuous electromagnetic field measurements and evaluate the results both inside and outside a university hospital that has been selected as a pilot area.

Visited by half a million people each year, Turgut Ozal Medical Center (TOMC), where we conducted our research, is one of Turkey's largest university hospitals in terms of the number of incoming patients as well as staff. The electric field measurements between 2011 and 2013 have shown that the electric field intensity on Inonu University campus has been increasing (21). The initial purpose of this study is to conduct electromagnetic field measurements and to identify the amplitude and frequency distribution in the selected medical center. Apart from this, we also intend to determine the effects of electromagnetic fields especially operating at high frequencies on the personnel, devices, systems, and inpatients. For this, we have made measurements by using MonitEM continuous measurement systems and the collected data of this research has been presented throughout this study.

MATERIAL AND METHODS

Throughout the process, we have taken continuous and instantaneous measurements of the following items and places in and around the TOMC buildings that are likely to cause electromagnetic pollution: WLAN systems operating at high frequencies, energy systems and distribution networks that operate on power frequencies, radio and TV stations located outside the hospital premises which also work at high frequencies, GSM and 3G base stations, and high voltage power transmission lines and distribution systems operating on power frequency. We have taken continuous measurements every minute of the day to determine the high frequency electric field intensity levels of the resources outside the Medical Center. For these measurements, we have used two Wavecontrol MonitEM (100kHz-8GHz) electromagnetic field monitoring stations that operate as GSM and 3G measuring probes with a capacity of three-directional (isotropic) measurement to monitor the aforementioned areas. To determine and measure the high frequency electric field strength level and distribution within the hospital, we used a Wavecontrol SMP Meter over three-directional wideband (100kHz-8GHz), and a GSM and 3G probe. To determine the electromagnetic field levels created by the high voltage transmission lines and distribution systems located in the vicinity, we employed a Narda EHP-50D (5Hz-100KHz) continuous electric field measuring and monitoring device. As for the electric field intensity of the power frequency within the hospital, we used a Wavecontrol SMP Meter and a low frequency probe (10Hz-3kHz). Following all the measurements, the spectrum analysis within the hospital was made by using an Aaronia Spectran HF-60105 (100MHz-9,4GHz).

The continuous electromagnetic field monitoring stations were positioned on the first floor balcony facing the façade of the hospital. The continuous measuring station that operates at 100kHz-8GHz frequency range was placed on the west façade of the hospital facing the radio and television transmitters. The station for continuous GSM and 3G frequency measurements was stationed on the northern front of the hospital building facing the base stations located around the hospital for three weeks. After three weeks, this station was relocated for continuous measurements by moving it close to the base stations on the roof of the hospital.

Parallel to the measurements taken by the Wavecontrol SMP Meter and probes measuring 100kHz-8GHz and GSM and 3G frequencies, we also took measurements 150cm above from the ground-level in periods of 1-second during the working hours when electric field strength levels reached their highest. In addition to the 24-hour continuous measurements, we covered all the units in the hospital (over 26km) for instantaneous measurements of electric field intensity. The coordinates and measured values of electromagnetic field distribution within the hospital have been provided with the maps. Wavecontrol SMP Meter takes measurements every second in 6-minute periods. With its built-in GPS, the coordinates of the measuring points have been recorded with the measured electric field strength values.

We used MapInfo 9.5 software to measure the broadband (100kHz-8GHz) and electric field intensity values (GSM and 3G) of the base stations within the vicinity and to create pollution maps. To create the grids we used the Vertical Mapper tab of the software. For the drawings, we employed Natural Neighbour Interpolation method. Blue tint on the map indicates lowest values while the red tint indicates maximum values.

RESULTS

TOMC premises where we conducted our research have been shown in Figure 1. The capital letter A indicates TOMC. The base stations in the northern part of the hospital are indicated by red and blue elliptical shapes (B and C). The measuring path from the switchyard located on the south-west façade of the hospital (D) towards TOMC is shown by a red line. The measurements and evaluations on this scheme are as follows.

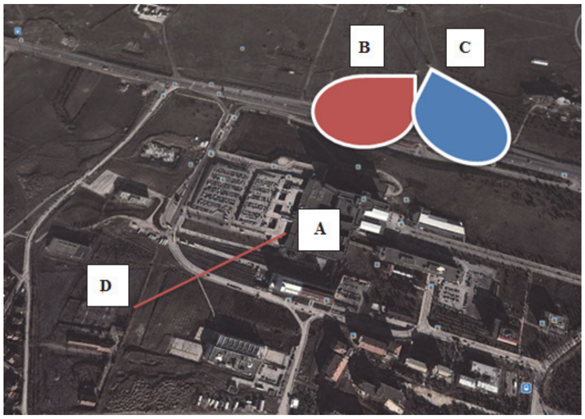

Figure 1. Turgut Ozal Medical Center premises as seen from the sky.

To the north of TOMC, close to the hospital building, there are two base stations. Therefore, to determine the electric field intensity effecting the hospital, we placed a continuous electromagnetic field monitoring station on the balcony of the first floor of the medical center. The locations of the base stations and the continuous GSM and 3G frequency monitoring station are shown in Figure 2. Through continuous electric field measurements, this station has provided us with electric field strength values that have come from the nearby base stations and effected the hospital building between 12.06.2013 and 08.07.2013.

Figure 2. The station located on the first floor of the medical Center facing the base stations in the north.

Located on the TOMC first floor balcony facing the western front of the hospital, the continuous electromagnetic field measurement station operating at 100kHz-8GHz frequency range is shown in Figure 3. In addition to GSM and 3G signals, electromagnetic fields from radio and television stations are also effective in this area. The continuous measurement station is located at this point to determine the impact of electric field intensity levels from the nearby radio and TV transmitters.

Figure 3. The station located on the first floor of the Turgut Ozal Medical center facing the radio and television transmitters in the west.

The graph revealing the electric field strength values from both of these continuous electromagnetic fields measuring stations during the same period of time is given in Figure 4. In the figure, the blue graph illustrates the values from the GSM & 3G frequency base station measurements while the red lines indicate the values from the station operating at 100kHz-8GHz frequency.

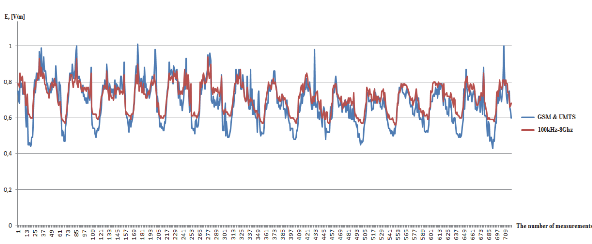

Figure 4. The continous electromagnetic field measurment results betwen 12 June 2013 and 27 June 2013 at wideband (100kHz-8GHz) and GSM and 3G frequencies.

In the last week of our measurements, the continuous electromagnetic field measurement station is placed next to the base stations on the roof of the medical Center to measure the exterior high-frequency electric fields. The time-varying electric field strength graph that is prepared according to the measurements is given in Figure 5.

Figure 5. The continuous electric field intensity values measured at GSM and 3G frequencies between 8 July 2013 and 12 July 2013.

While continuous measurements outside the hospital were going on, we measured the instantaneous electric field strength values at 100kHz-8GHz and GSM-3G frequencies in periods of 1 seconds in different areas within the hospital building by using Wavecontrol SMP meter device. These measurements were taken during the working hours, when the electric field intensity is in its peak. Besides, these measurements were made in the most crowded parts of the hospital like outpatient clinics, emergency services and relevant departments, social services department, intensive care units, pharmacy, and blood bank units. More to the point, we also measured electric field intensity levels from the ground floor up to the tower floors, where the inpatient floors are situated. We took over 8000 instantaneous 6-minute measurements at the specified frequency bands on the inpatient floors and in the hallways. In addition, we also took over 1000 measurements at a frequency of 50 Hz in and around the energy rooms within the hospital, power distribution boards, and the CCTV monitoring room which operates for 24 hours. In almost every part around these areas, albeit in certain degrees, one can talk about electromagnetic field pollution. According to these measurements, the highest electric field intensity value was measured around the RF-access entrance control systems, especially around the area where the card is held up for recognition. With 35V/m as the highest measured electromagnetic field strength value, the electromagnetic field around these devices influences a distance of about 30 cm. Because this local value also contains the general environment electromagnetic field intensity, it was excluded from the study. The electromagnetic pollution map showing the intensity values around the outpatient clinics is given in Figure 6. In this area, the highest electric field strength value was 10V/m.

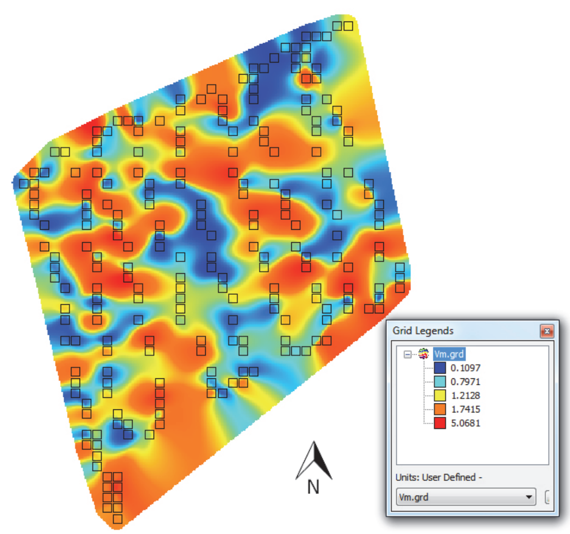

Figure 6. The instantaneous electromagnetic pollution map according to the measurements at 100kHz-8GHz within the hospital around the outpatient clinics.

The second highest electromagnetic field intensity value within the hospital was measured around the area where the administration offices are located. The electromagnetic pollutions map of this area is given in Figure 7.

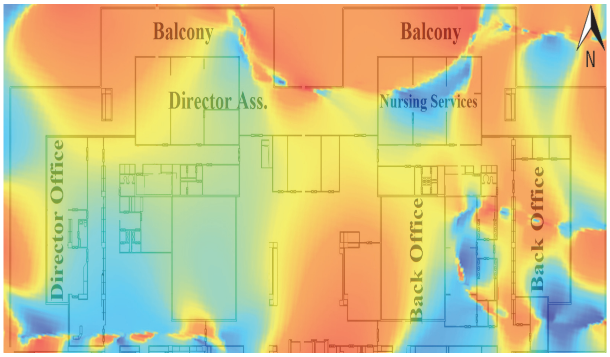

Figure 7. The instantaneous electromagnetic pollution map according to the measurements at 100kHz-8GHz within the hospital on the first floor around the administration offices.

As seen, the areas with intense electromagnetic pollution covers a large part of the study area. Therefore, it is required to assess the electromagnetic field strength values measured on the floors and areas in the regions of the are useful to assess the frequency spectrum. Accordingly, we conducted a sample spectrum analysis at 30MHz-9ghz frequency range in an area with a dense electric field intensity within the hospital using an Aaronia Spectran HF-60105 device. The results of this sample measurement is presented in Figure 8.

Figure 8. The spectrum analysis conducted to determine the electric power resources and frquency levels within the hospital.

The highest and lowest VHF, VHF-TV, UHF-TV, ISM-433, ISM-868, GSM900Mhz, GMS1800Mhz, UMTS2100Mhz, and Wi-Fi 5.8 GHz frequencies acquired at wide band frequency and the spectrum analysis results are provided in Table 1.

Table 1. The highest and lowest electric field intensity values at VHF, VHF-TV, UHF-TV, ISM-433, ISM-868, GSM900MHz, GSM1800MHz, UMTS2100MHz and Wi-Fi 5,8GHz frequencies.

SPECTRUM	E,(V/m)	
	MAX	MIN
VHF (Very low frequency) 3-30KHz	1,4mV/m	0,3mV/m
VHF-TV (Very high frequency) 30-300MHz	0,8mV/m	0,15mV/m
UHF-TV (Ultra high frequency) 300-3000MHz	1,8mV/m	0,4mV/m
ISM-433 (Industrial Scientific Medical band)	525µV/m	200µV/m
ISM-868 (Industrial Scientific Medical band)	1300µV/m	830µV/m
GSM900 UPLINK	3mV/m	1,15mV/m
GSM900 DOWNLINK	3,25mV/m	1,3mV/m
GSM1800 UPLINK	1,8mV/m	0,4mV/m
GSM1800 DOWNLINK	1,5mV/m	0,3mV/m
UMTS2100 UPLINK	9mV/m	1mV/m
UMTS2100 DOWNLINK	1mV/m	1,3mV/m
WI-FI 5.8GHz	400mV/m	300mV/m

Today, the electromagnetic field measurements are conducted according to the regulations published in the Turkish Official Gazette on 21 April 2011, issue number: 27912. According to these provisions, electric field strength value of electronic communication devices set in health care facilities cannot exceed E=3 V/m to minimise the effect of electromagnetic fields on medical devices (Information Technologies and Communication Association of Turkey, 2011, Article number: 6-3).

The national electromagnetic field limit values set for Turkey for specific frequencies that are widely used are given in Table 2.

Table 2. The limit electric field values at different frequencies issues by ITCA of Turkey.

Frequency Band (MHz)	Single Device (V/m)	Total intensity in the environment (V/m)
Radio 87.5 - 108	7	28
Television VHF 174 - 230	7	28
Television UHF 470 - 854	7,39	29,81
GSM 900	10,23	41,25
GSM 1800	14,47	58,33
UMTS 2100	15	61

We have made measurements on every one of the thirteen floors on the tower part of the hospital at 100kHz-8GHz and GSM and 3G frequencies. The values in Figure 9 provide the general electric field intensity of every floor.

Inpatients are usually on the tower floors. We have determined the electromagnetic field distribution on these floors through measurements at 100kHz-8GHz and GSM and 3G frequencies and have provided the electromagnetic pollution maps of the 12th floor as a sample of these measurements (Figure 10).

After finalising the research within the hospital building, we continued our measurements around the switchyard to the south-west of the hospital. To determine power frequency electromagnetic fields around the switchyard area, we made measurements following the red line indicated in Figure 1 in periods of 5 minutes and, approaching to the hospital building 5m after each measurement. The details of all these measurements are as follows.

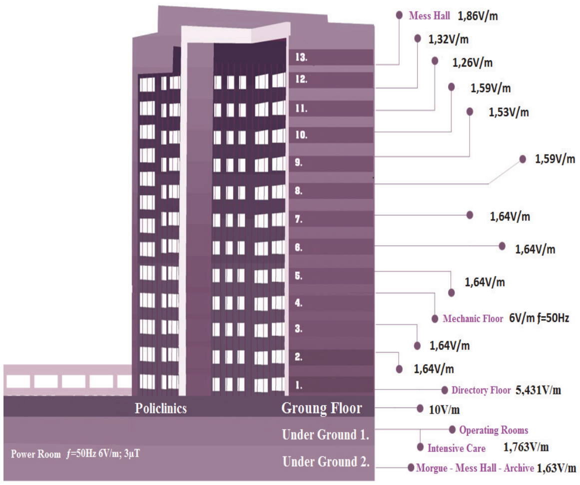

Figure 9. The highest electric field intensity values at 100kHz-8GHz frequency and power frequency measured on each floor.

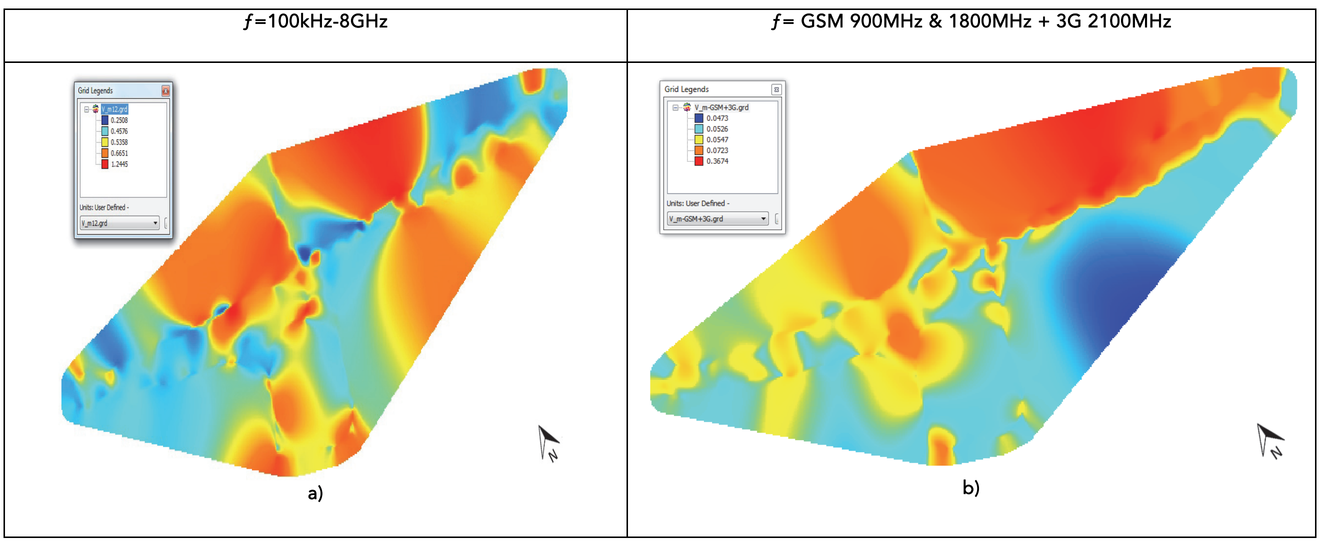

Figure 10. The electric field intensity distribution map measured at 100kHz-8GHz and GSM and 3G frequencies on the 12th floor, the inpatients' floor.

At the end of 2300 measurements in the switchyard at 50Hz electric field power frequency for 20 hours, we obtained the average electric field value as 95 V/m. The electric field shift graph in the area from the switchyard toward the hospital is given in Figure 11.

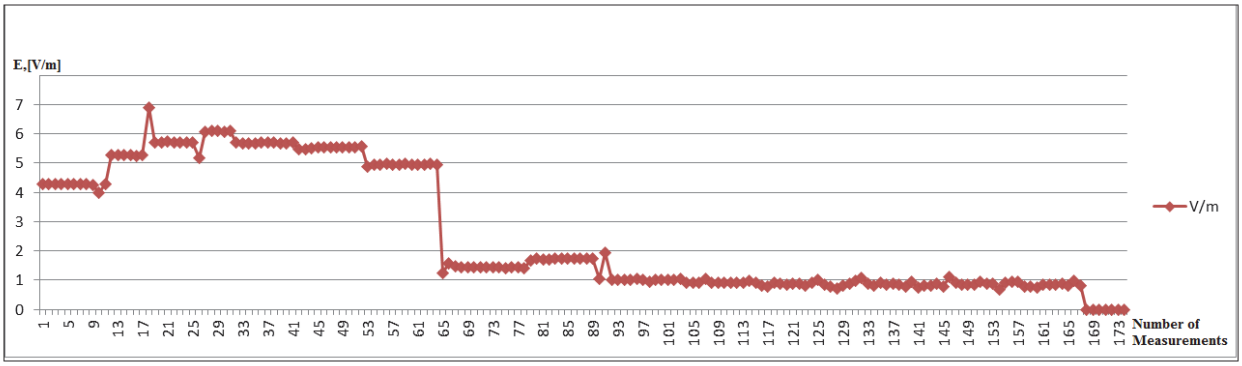

Figure 11. The electric field change at 50Hz graph from the swithyard towards the medical center.

Studying these results, it can be clearly seen that the effects of low frequency electromagnetic pollution in the medical center are actually very low. In likewise manner, the high electromagnetic field values in the premises in fact result from systems operating at high frequencies such as hospital pagers, WLAN systems, and radio communication systems, and not from external electromagnetic sources. However, the electromagnetic field intensity in some locations reach such levels that should not be neglected. High frequency signals coming from within the hospital may influence electronic systems, devices, and, particularly, living organisms. Thus, lowering the electromagnetic pollution levels in these areas is of great importance.

DISCUSSION

The station that was set to analyse the effects of external high-frequency resources on the medical center (Figure 2) that operated at GSM and 3G frequencies has given us 1241 measurements to study. Analysing these values, we have observed serious fluctuations in electric field intensity throughout the day. The main reason behind these surges and falls is the mobile communication traffic in the base stations at different times of the day. The values tell us that the electric field strength values increase starting from the morning hours, reaching their peak at noon time, and show a downward trend towards the evening. During this period, the mean electric field intensity level was 0.7 V/m, while the highest value was 0.94 V/m. These values were measured on June 18, 2013 at 14:00.

The continuous electromagnetic field station working at 100kHz-8GHz frequency range was positioned on the west side of the medical center (Figure 3). Analysing the 722 average electric field strength values measured by this device between June 12 and 27, 2013, it can be seen that the mean electric field intensity was 0.69 V/m and the highest value was 1.01 V/m (measured on June 16, 2013, at 11:00). Figure 4 presents the graphs of the measurements taken at 100kHz-8GHz and GSM and 3G frequencies during the same time period. The analysis of the measurements together with the values obtained from these two stations show evident similarity though the amplitude of the electric field strength in these areas were not the same. The highest and lowest electric field strength values correspond to the electric field strength values at GSM and 3G frequencies. In other words, because the electromagnetic fields created by radio and TV broadcasting does not constantly change as it is the case in GSM and 3G base stations, which is dependent on the number of users, the electromagnetic pollution caused by the radio and TV transmitters is ever present in the environment. Because, independent of the user at the receiving end, the output power of these devices and systems that transmit these signals varies in very low levels. But the signal level of GSM and 3G systems change during the day depending on the number of mobile phone users and duration of use. Correspondingly, electromagnetic fields waves emitted from the base station tend to increase or decrease depending on the data and call traffic. As can be seen, the main source of high-frequency electric field values outside the hospital are the base stations. It can easily be predicted that an increase in the number of base station and user traffic in the region will rise these values to higher levels. Nonetheless, increasing capacity of the hospital, the new institutes that are under construction around the hospital, the rapidly rising number of students on campus, the construction of a 25,000-seater city stadium across the medical center, and the growing public housing around the area will undoubtedly be the new resources of electromagnetic pollution in the region.

Finally, one of our devices was placed on the roof of the medical center, where some of the base stations are located. The 209 electric field intensity levels measured between 8 July 2013 and 12 July 2013 in periods of 30 minutes have been assessed and the mean values of the time-varying electric field curves have been presented in Figure 5. Examining these values, we have concluded that the electric field strength values around the base stations were at high levels and, in line with the instant measurements at these frequencies, the highest values were measured on the 13th floor within the hospital. During this period, the average value of received electric field level was 2.46 V/m; measured on the 11 July 2013 at 13:30, the highest electric field strength was 3.15 V/m.

As a result, we have observed that high-frequency electric field intensity on TOMC campus environment is constantly present at a minimum level of 0.5 V/m.

Comparing the continuous measurements made outside and inside the hospital, we have seen that the electromagnetic pollution levels within the hospital are higher than the values in the external environment. The measurements taken per 1 millisecond within the hospital and their spectrum analysis clearly show the influence of many electromagnetic field sources such as radio and TV broadcasting frequencies, ISM (Industrial Scientific Medical Band), wireless communications, GSM 900MHz, 1800MHz, UMTS 2100MHz, and WLAN frequencies.

The measurements made in the interiors of the medical center show that the most intense electromagnetic pollution is found around the ground floor, where the outpatient clinics are located, and the first floor, where the administrative units are based. The measurements on the B1 and B2 floors have revealed that the GSM and 3G frequency values on these floors are already too low for phone calls. In this case, one should consider the effect of the local electromagnetic fields emitted by the mobile phones to capture the signals from the base stations rather than the influence of electromagnetic fields from the base stations themselves. At times when the signal level from the base station is low, mobile phones consume more power to capture the base station signals.

Mobile phones have different electric field intensity according to their qualifications. We have seen that mobile phones create electric field strength between 0.41 V/m and 14V/m on standby. The average electric field strength was measured as 3.72 V/m on call and the instantaneous electric field strength values ranged between 5v/m and 25v/m. On voice call, however, the average electric field strength value was 4.35 V/m while the instantaneous field strength values were determined between the range of 10v/m and 27v/m. At instances of having incoming calls, the average electric field strength value was 3.38 V/m while the instantaneous electric field strength values ranged between 5v/m and 15v/m. The average electric field strength was 1.02 V/m while sending text messages and the instantaneous electric field strength values were between 6v/m and 10v/m. The average electric field strength value was 1.71 V/m while sending MMS messages and the instantaneous electric field strength values were reported to be between 2v/m and 8v/m (22). These values tend to increase in mobile phones when the signals are very low or there are no signals at all. In such cases, depending on the region, the effects of mobile phones stand out. In these areas where mobile devices try to capture signals, patient monitoring systems and devices around operating rooms and intensive care units may malfunction due to the electromagnetic interference from the mobile phones (1).

We have mapped the electric field pollution distribution in accordance with electric field intensity values and coordinates that we have measured on the tower floors of the medical center at 100khz-8GHz and GSM and 3G frequencies in periods of 6 minutes. A sample electric field pollution map of the 12th floor has been presented in Figure 10. According to the results, the highest electric field intensity at 100kHz-8GHz and GSM and 3G frequencies were 1.32 V/m and 0.37 V/m, respectively.

In the light of these results, suggesting that a large portion of the electric field pollution within TOMC vicinity result from systems like pagers, WLAN connections, and radio signals operating at high frequencies rather than GSM and 3G frequencies would be a sound remark.

Our measurements to determine the effect of the switchyard located on the south west side of the medical center on the hospital have shown that the impact of the switchyard ceases towards the hospital building and ends at the border of the hospital. We have also conducted our research on the 2nd basement floor where the power unit is located. The constant electric field measurements taken during the working hours when the energy consumption is higher than normal reveal that the highest electric field strength value was 6V/m while the average electric field strength value was 0.526 V/m. On this floor, the instantaneous magnetic field measurements have shown the highest and average magnetic field intensity values to be 3μt and 2.285 μt, respectively.

The magnetic field intensity in front of the power distribution panels of the medical center was measured as 0T, which shows that the panels are sufficiently insulated and are not likely to cause any problems. The measurements taken at the security monitoring room, a location occupied by the staff for 24 hours, have told that the highest and average magnetic field intensity values were 9μt and 3.84μt, respectively. These measurements were taken right in front of the CRT (Cathode Ray Tube) monitoring devices. The measurements taken around the uninterrupted power supply located in this room, however, show 29μt as the highest magnetic field intensity value and 20.05 μt as the average value of the magnetic field intensity. We can summarise the results of the continuous and instantaneous electromagnetic field measurements taken at TOMC premises and our examination and evaluation of these results as follows.

The highest electromagnetic field strength outside the medical center at 100kHz-8GHz frequency range was E=1.01 V/m. Despite the fact that the area is surrounded by base stations and other sources of electromagnetic fields (radio and TV transmitters etc.), the electric field strength remained below E=1.01 V/m.

On the roof of the hospital, next to 6 sectorial antennas, the measurements taken at GSM and 3G frequencies have given us the value of E= 3.15 V/m. After a one-week of continuous electromagnetic field strength measurement in the area, the intensity has remained below this value.

The continuous measurement of electromagnetic fields outside the hospital has given us the highest values during the daytime hours. This is because the intense mobile phone use of the hospital staff, visitors, and people on the nearby main campus of Inonu University.

The measurements within the different areas of the medical center show that electromagnetic field intensity is especially high around the joint corners of the corridors where the wi-fi systems are located. Besides, the measured electric field intensity level is around 10 V/m in the corridors where the doctors' offices and examination rooms are located.

All the measurements made show that high-frequency electromagnetic field strength values inside the medical center are 3 to 3.5 times higher than those measured outside the hospital. The main reason for this are devices and systems operating at high frequencies like pagers, WLAN, and radio signals. In order to reduce the level of pollution, and considering the number of users, communication systems with lower levels of electromagnetic field intensity may be preferred.

Within the medical center, on the basement floors and in areas away from the base stations, it has been observed that mobile phones are unable to capture the necessary electricity field level to make and receive calls. Base station require to send higher levels of signal for mobile phones to capture signals. However, in this case, mobile phone related exposure of electromagnetic field will also increase. Therefore, we recommend continuous measurement of GSM and 3G signals in this area.

On B1 and B2 floors and in the areas around the southern façade of the hospital, where mobile phone signals are weak, it is a better idea to set mobile phones to flight modes rather than keeping them on standby to reduce the risk of mobile phone related malfunctioning of medical devices.

Another point to keep in mind is to hold out the cards as closely as possible to the electronic card recognising systems at the automatic doors within the medical center, which will reduce the instantaneous electromagnetic effects.

We have also observed low frequency electromagnetic field sources around the medical center than may cause some impact on systems. However, we have seen that the average electromagnetic field value resulting from the nearby electrical switchyard and the high voltage power transmission line is 0.87 V/m and well below the limit values.

The continuous and instantaneous electromagnetic field measurements at 5Hz-8GHz frequency in some of the areas within the medical center show that these values are very close to some national and international limit levels. Therefore, these areas should be kept under control through regular measurements.

The expansion of such medical centers and other major medical institutions and equipping these centers with new generation wireless communication systems (WiFi, access point, and bluetooth patient monitoring systems) are inevitable facts. However, adding the increasing number of devices that emit electromagnetic fields in these environments to the picture above, it is easy to predict that electromagnetic pollution will eventually increase rapidly. In these cases, performing continuous and periodical measurements and evaluating the results with mathematical models would be very useful. For this purpose, MonitEM, constant electromagnetic measurement and monitoring systems, can be effectively employed in mission-critical areas (intensive care units, operating rooms).

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