ELF AND RF ELECTROMAGNETIC FIELD MEASUREMENT IN A SHOPPING MALL

S. SELIM SEKER, YUSUF BULUT, ONUR ERINC, A. YASIN CITKAYA

Boğaziçi University, Department of Electrical and Electronics Engineering
34342 Bebek-İstanbul, TURKEY
seker@boun.edu.tr, citkaya@boun.edu.tr

Abstract
The issue of health effects of electromagnetic fields has become popular in recent years. The aim of this study is to measure extremely low frequency (ELF) and radio frequency (RF) electromagnetic fields in a public place and also to compare these results with the current safety limits. A shopping mall is chosen for this research since a large number of visitors and employee is present during working hours.
Due to the existence of high voltage transmission lines, electrical distribution networks and wiring systems, ELF measurements are carried out. RF measurements are also important due to the wireless technologies including global system of mobile (GSM) base stations and antennas and wireless internet access points.
A group of data is collected around the main distribution room and transformer area which are considered to have largest electromagnetic field strengths for ELF. Additionally, measurements are made on the ground floor to examine the field created due to Taksim-Levent subway. RF measurements are carried out on several floors and points and they form another group of data. The results are plotted as 3-D figures. Finally, all collected data is compared with general public exposure safety limits of International Commission on Non-Ionizing Radiation Protection (ICNIRP) and several conclusions are proposed.

Introduction
With the developing technology, the demand of electromagnetic energy has been increasing. As a consequence, the issue of health effects of electromagnetic fields has become popular in recent years. In this project, the aim is to measure the electromagnetic field in a public building where a large number of people is present at a certain time.
Metrocity is chosen as the measurement area. The building is visited by many people during the day and the effect of electromagnetic fields would be bigger than many other public places. First group of data is collected from the floor above the ground level. Central distribution room and transformers area are considered to have the most powerful fields so field strengths are measured only at those areas. Second group of data is collected in the entrance hall and one of the corridors in the ground level. Ground level is chosen because it is the closest level to substations and transformers. Only the closest corridor to the transformers is examined since it has the biggest potential for high electromagnetic (EM) field strengths. Several fixed installed sources are operated in the specified environment. Obvious examples are high voltage transmission lines operating between 34.5kV and 380 kV at 50 Hz. It is important to notice that such exposure levels occur only directly below the lines; exposure decreases with the square of distance to the lines. Using underground buried cables is another approach to establish power supply. In this case, electric field strength exposure can be neglected; the distribution of the magnetic flux density differs compared to power lines. Substations and power plants are usually not accessible to the general public. The highest magnetic flux densities can be found close to several domestic appliances that include motors, transformers, and heaters. Such exposure levels are very local and decrease rapidly with the distance.
There are different opinions exist in the scientific community about biological effects of electromagnetic fields. Since it has a potential of threatening human body we should be more careful in our daily life when using household appliances or cell phones.
The trend about the interconnection of electronic devices has been moving to wireless for the last ten years. The antennas and receivers have been replacing the cables. Probably, the best example of this process is the cellular phones. Since the wireless technologies are becoming newly common, the biologic effects of the electromagnetic pollution are not clear yet. Even though many studies have been carried about the topic, there

are not sufficient data to evaluate the biologic effects of the electromagnetic fields appropriately. Further efforts are needed in order to reach any conclusion, especially for the long term effects.
Lots of research has been conducted by many scientists and engineers about the biological effects of RF EMF. The literature surveys are made about the biological effects of RF EMF on rats, microorganisms, brain, children, bone marrow tissue, enzymes, stem cells, fetuses, and voluntary human subjects. Also, there are papers about the penetration models of RF EMFs into biological bodies [1-2].

Measurements

Measurements are carried out at Metrocity which is a big shopping mall situated in 1.Levent Istanbul. It consists of 165 stores in 5 floors, restaurants and cafés, has 1200 vehicle capacity of parking and a direct connection to Metro 1.Levent subway stop [3]. The facility is built on 60.000 m^2. The main entrance is on the ground level, and other floors are located below the ground level. it has a direct connection to metro transportation in the -3rd floor. ELF fields at 50 Hz are mainly generated by the substations and transformers in the building. The complex is comprised of a shopping mall and 3 towers which rise above it: a 27-floors office tower on Büyükdere Avenue and two residential towers, each having 31 floors. Additionally, on the top of the shopping mall, there is another floor, where the transformer, circuit breakers, central air condition units are placed.
In order to enable the visitors to have nonstop mobile communication through their cellular phones, a private GSM system for Metrocity is established. There is one base station on the parking lot floor, and two base stations on the -4th floor. Moreover, there are several minor GSM antennas on every floor.
It is found that, the biggest ELF EM field levels are located at 1st floor above the ground level. The measurement data are collected from central distribution room where transformers and 34.5kV transmission lines are located. Moreover, the ground level, where much more people are exposed to ELF fields, is chosen for the next measurement area due to its proximity to the transformers and high potential transmission lines.
Electromagnetic field measurements of ELF are performed with Holiday Instrument HI-3604 Power Frequency Field Strength Measurement System [4].The HI-3604 can both measure electric and magnetic fields with its two switch selectable sensors. The instrument can be used for data logging, waveform output, full auto-ranging.
While measuring wave strengths, the probe of HI-3604 is held 2 meters above the ground to eliminate barriers of human body to waves. Since the direction of the fields is not known, maximum values of measurement are taken and recorded while rotating the probe. It is tried not to be in contact with the instrument's probe to ensure the correctness of the measurements. All the measurements are made in the afternoon between 16:00 and 20:00 o'clock, since electricity consumption is relatively higher at that time period.

ELF EMF measurement results

The highest value for electric field is measured near the cables attached on the wall with E field of 785 V/m. Those cables are carrying 34.5 kV high voltages. The highest magnetic field is measured also near to those cables with a value of 298 A/m. Measuring high field strengths is also possible where underground cables pass below. Standing over metal surface electric field strength is measured about 684 V/m near a plug and its cable around which is just near the entrance of the room. As moved away from the cables and devices, approximate field strengths of 2 V/m and 1 A/m are observed. Figure 1 shows the diagram of the central distribution room. Surface plot of electric and magnetic fields are shown in Figures 2 and 3, respectively.
Second measurement place is near the transformers which are approximately 5 meters away from the Central Distribution Room. Transformers are located in a room and it is not allowed to enter those rooms due to safety concerns, hence the closest measurements were taken just near the door of the rooms. Step down 1600kVA power rating Tr9, Tr10, Tr11 transformers are placed next to each other for mains of the mall. Tr9 and Tr10 is 0.5meter behind the door, Tr11 is 1meter behind the door. Measurements for the magnetic field strengths are given in Figure 4. It shows the relation between the fields and the distance. Figure 5 shows the surface plot of magnetic field near the transformers. Figure 6 shows the surface plot of magnetic field in the entrance hall. It is again verified with the measurements that, field level intensity is inversely proportional to the distance from the source.

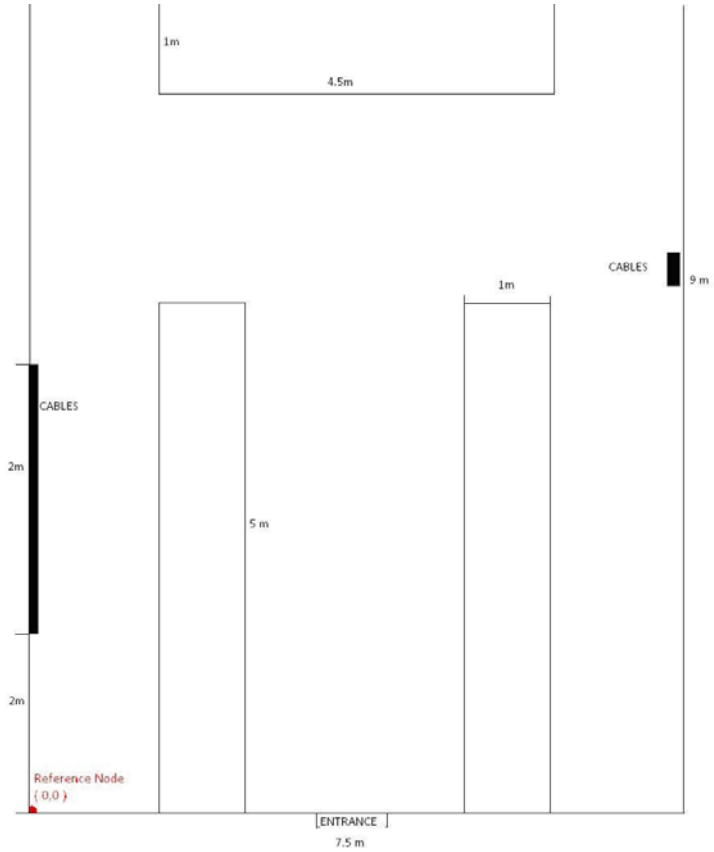

Figure 1. Diagram of Central Distribution Room

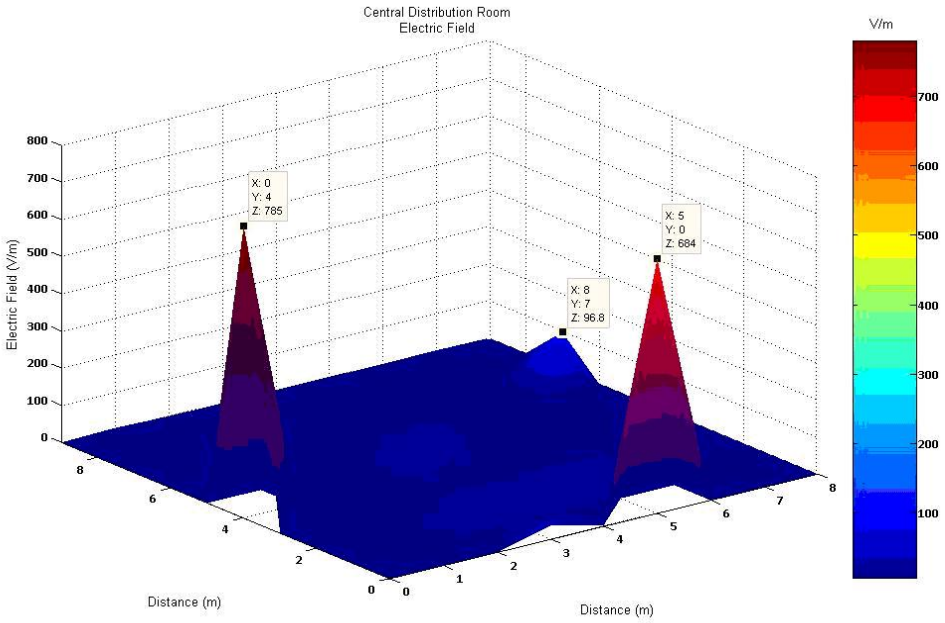

Figure 2. Surface Plot of EF in Central Distribution Room

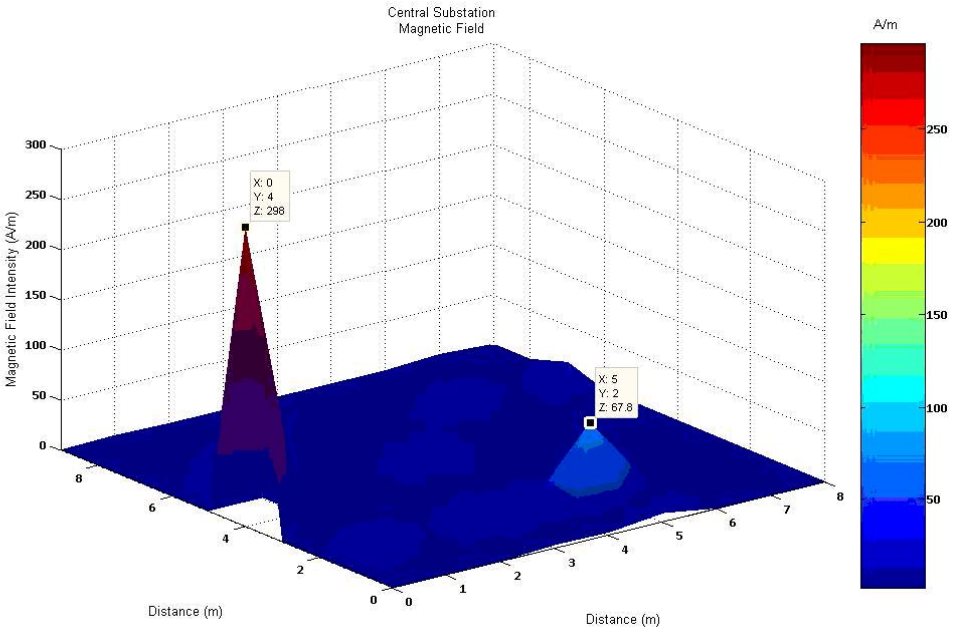

Figure 3. Surface Plot of MF in Central Distribution Room

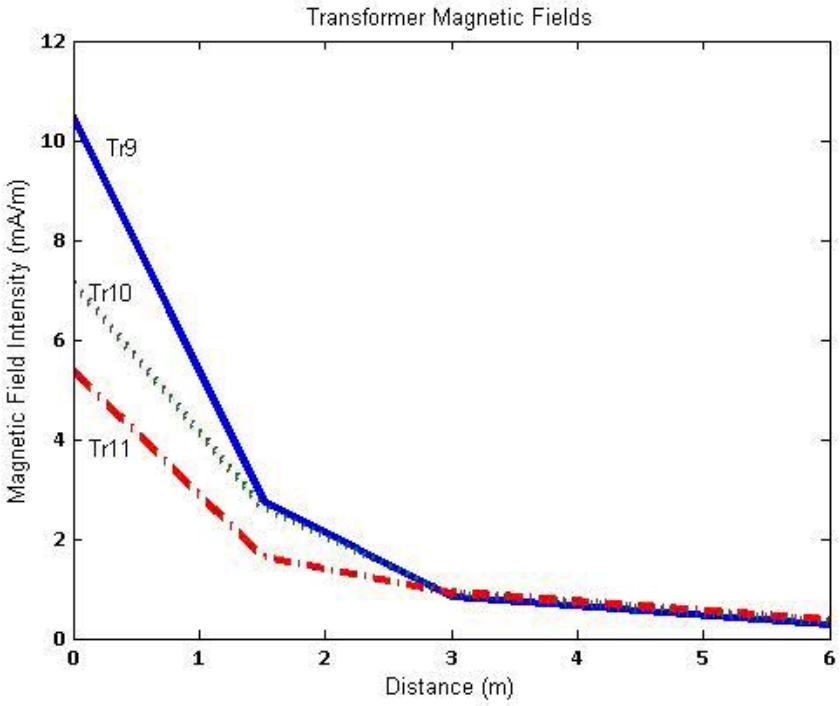

Figure 4. Relation between distance and transformer magnetic field strengths

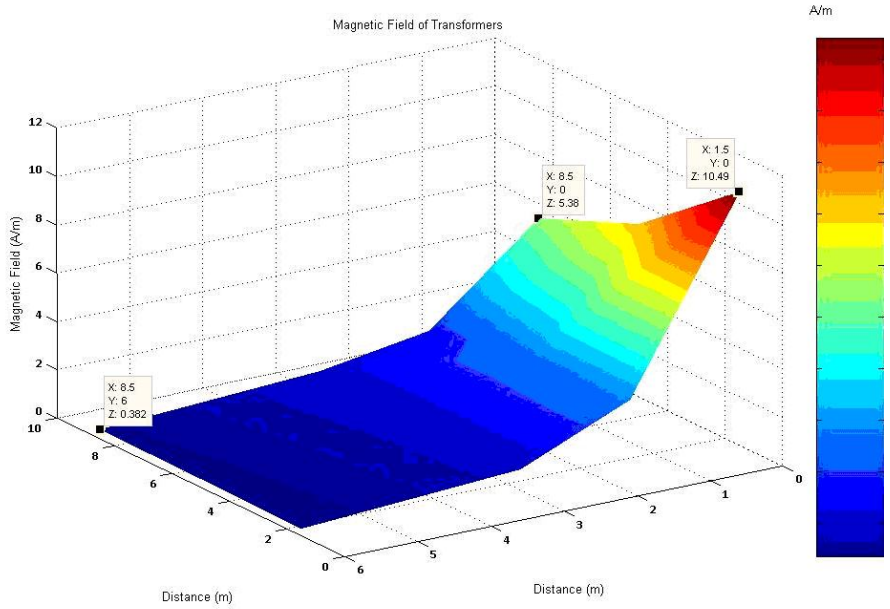

Figure 5. Surface plot of MF near the transformers

Measurements at the ground level are made in the entrance hall where it is the most crowded section of the mall. Second measurement place is the corridor where the stores are located. Due to the certain restrictions and the lack of permissions, the measurements of the field strengths are made in the middle of a corridor with 8 meters intervals. Figure 7 shows the magnetic field against distance on ground floor corridor.

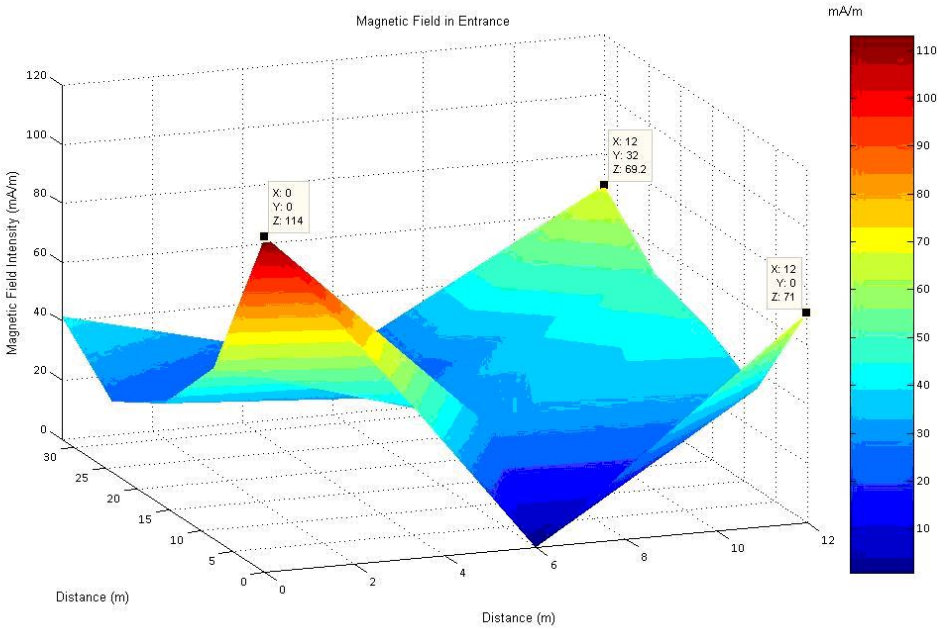

Figure 6. Surface plot of MF in the entrance hall

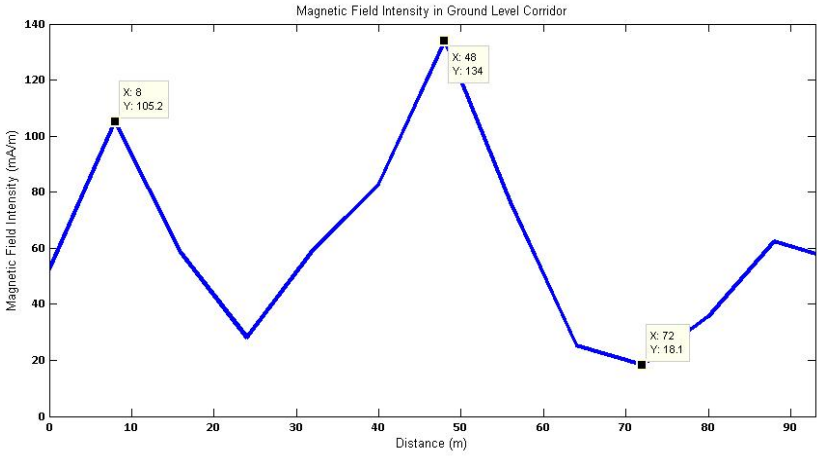

Figure 7. Relation between the distance and the magnetic field strength in ground floor corridor

In the entrance hall, the high electric field level is the result of illumination system used in a store. Relatively high levels of magnetic fields are also probably generated by the illumination and wiring system used in the stores.
In the corridor, high electric field level is observed near the escalators, and high level at 90m is observed near a high-power speaker system. Highest level of magnetic field is observed at the nearest place to the transformers at the upper level.

RF EMF measurement results
For the on-site measurements, Narda NBM-520 Broadband Field Meter with Narda EF 0391 (NBM) E-Field Probe was used for RF measurement at the mall. The selected probe is suitable for monitoring human safety (general public safety), health and safety at work (occupational safety) levels. The specifications of the equipment are given in the reference [5].
The measurements on the ground floor were conducted between 16.00 and 19.00 o'clock. The time period of the measurements is the busiest time of the day, therefore measurements reflect the worst case, where the field intensities are at their maximums throughout a day. During the measurements, the probe of the measurement device was hold approximately 1,5m above the ground, and 2m below the ceiling.
Indoor DECT Station: The electric and magnetic fields in the vicinity of a DECT Station are measured from various distances and the following figures were obtained: The measurement results can be illustrated in Figure 8 and 9 as follows:

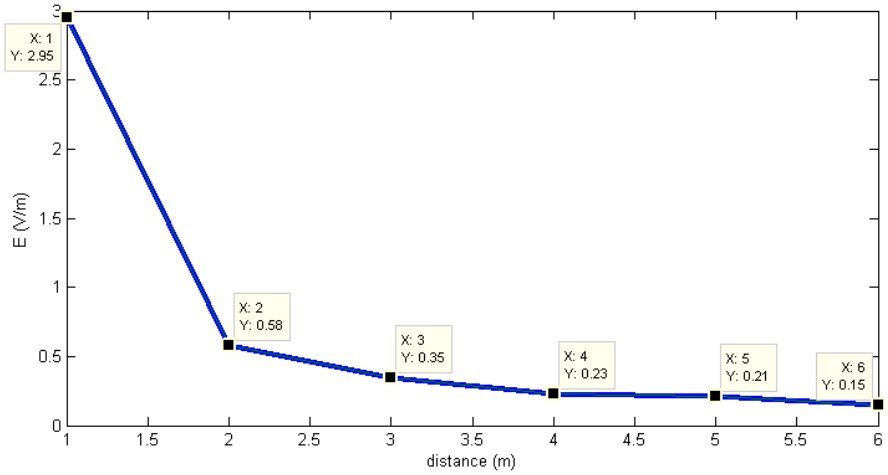

Figure 8. Electric field intensity around an indoor DECT station

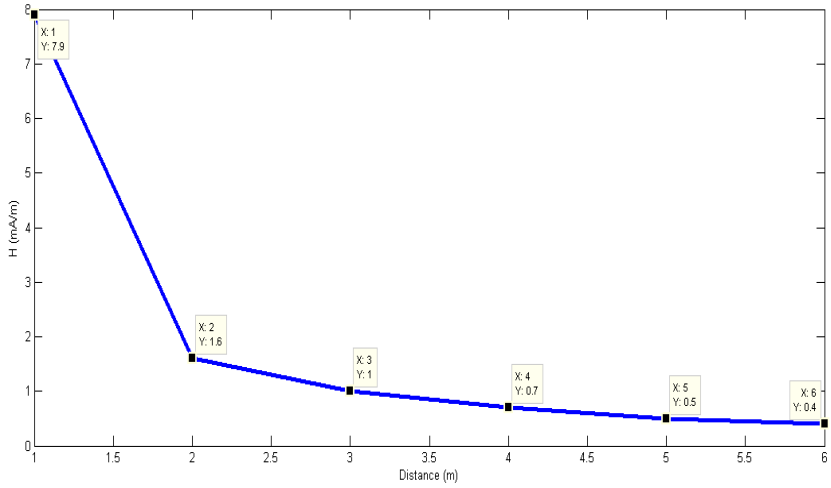

Figure 9: Magnetic field intensity around an indoor DECT station

It can be observed that the electric and magnetic field intensities decrease exponentially as going away from the source.

Corridor on the Ground Floor: The electric and magnetic field intensities through the corridor on the ground floor were measured at 24 equally spaced points. The measurement results are shown in Figure 10.

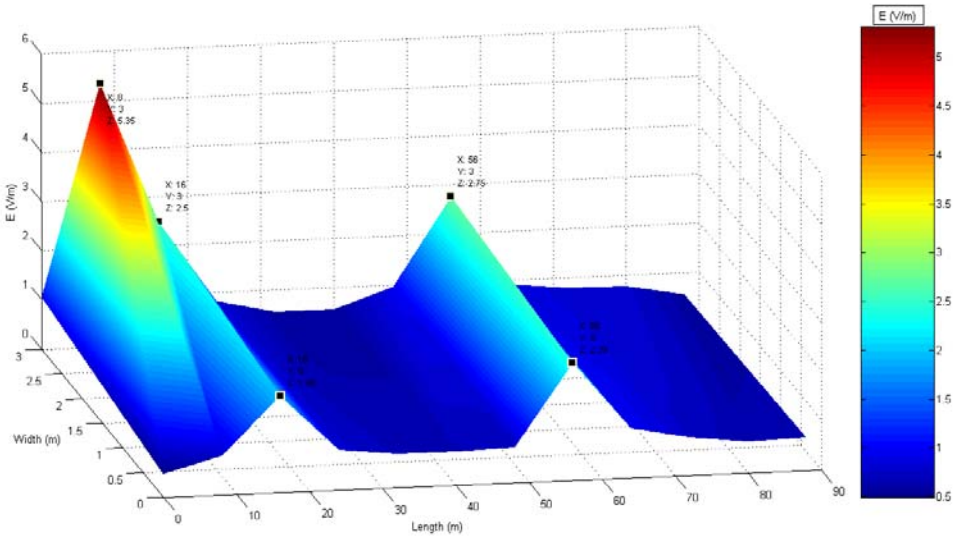

Figure 10. 3-D Electric field intensity plot through the corridor on the ground floor

At the first peak point, the electric and magnetic field intensities are illustrated in the figures as 5.35V/m and 13.4mA/m respectively. The reason for these peak values is the placement of GSM antennas. The stated values are measured under these antennas. At the second point, the electric and magnetic field intensities are recorded as 2.75V/m and 8.9mA/m respectively. The reason for these peak values is the placement of another GSM antenna. The values are once again measured under the antenna.

Entrance Hall on the Ground Floor: The electric and magnetic field intensities in the entrance hall on the ground floor were measured at 20 equally spaced points. The following Figure 11 was obtained:

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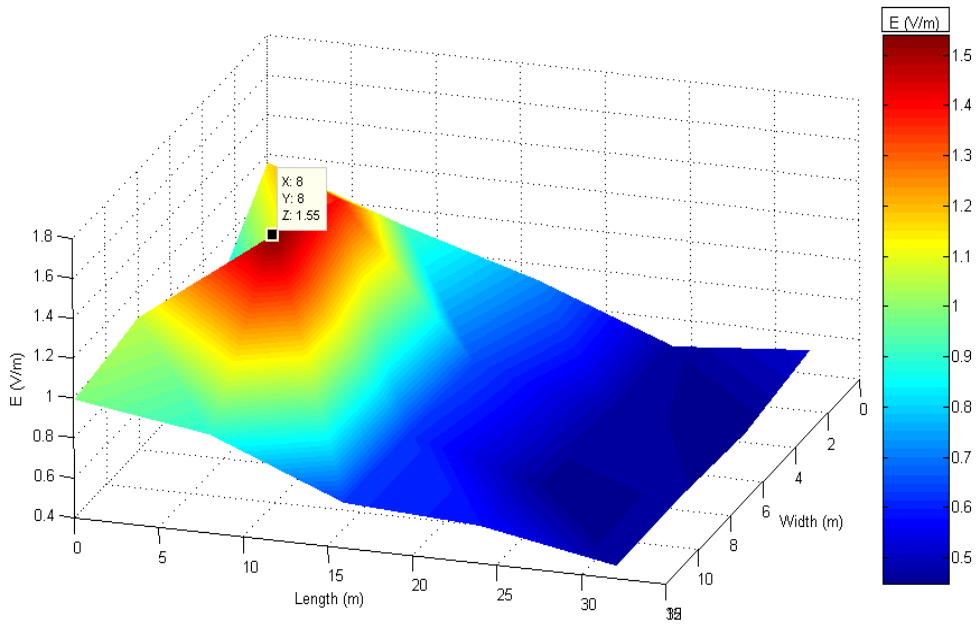

Figure 11. 3-D Electric field intensity plot of the entrance hall on the ground floor

At the point (8,8), the electric and magnetic field intensities reach their peak values compared to their vicinities, as shown in Figure 11. The electric and magnetic field intensities are recorded as 1.55 V/m and 4.4mA/m respectively. There is no obvious reason for these peak values like a DECT station or GSM antenna. The most possible reasons for these peak values can be the fluorescent lights and LCD TVs. The peak values are measured under the LCD TV.

Comparison with the ELF Standards and RF Standards

During the study, approximately 100 measurements are made at different regions and different floors of the mall. These regions include the corridors, the entrance hall, the central electricity distribution plants, the base stations, etc.

For the levels in the entrance hall and the ground level corridor, the general exposure limits are considered. It can be seen that, field strengths at those places are lower than the limits given by the ICNIRP guideline [6].

For the levels in the Central Distribution Room and near the transformers, the occupational exposure limits are considered due to the fact that level is limited to technical staff. It is found that field strengths are lower than the limits everywhere except magnetic field level in the Central Distribution Room is higher than the general exposure level. Technical staff should be very careful when working in that place to avoid adverse effects of ELF fields such as leukemia or other cancer types.

After measurements, it is clear that both electric and magnetic field levels in the ground level's entrance and one corridor are within the range of the ICNIRP standards. On the other hand, magnetic field level in Central Distribution Room is more than the general exposure limits. Technical management should be aware of this fact, and hence should provide necessary precautions for the staff. Table 1 summarizes the collected data and standard limits.

Table 1. Maximum field strength values in examined places and the limiting values

	E (V/m)	H(A/m)
Central Distribution Room	785	298
Transformers	4.4	10.49
Entrance Hall	15.4	0.114
Corridor	12.2	0.134
General Exposure Limits	5000	80
Occupational Exposure Limits	10000	400

The highest values of electric and magnetic field levels of RF are measured as 5.35 V/m and 13.4mA/m respectively. These values are recorded on the corridor on the ground floor. The reason for these peak values is the placement of GSM antennas, since the values are measured under these antennas. The measured values of electric and magnetic field levels are less than the safety limits for both occupational and general public exposure guidelines.

Summary
In this study, the highest values of electric and magnetic field levels of ELF and RF in a shopping mall are compared with the occupational and general public exposure safety limits in a shopping mall. Researches on the biological effects of RF electromagnetic fields are still on progress. Up-to-now, from the experiments on animals, plants, and humans, there exist reasonable data set to conclude that the RF electromagnetic fields with high intensity result in health problems, such as many cancer types. Also, it would be wise to be careful about the RF radiation exposure levels; because the future studies may reveal that the low levels of RF radiation are also dangerous in terms of health issues. The long duration of exposure to the RF electromagnetic fields also increases the risk of having health problems stemming from the exposure.

Acknowledgments
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