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Measurement and Evaluation of Electromagnetic Pollution in Ondokuz Mayıs University Kurupelit Campus in Samsun, Turkey

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***Abstract*—In line with technological developments and increasing demand in mobile communications, external electromagnetic radiation (EMR) sources and exposure levels are going up day by day. Therefore measuring and evaluating the exposed EMR levels have become more substantial for human health. It is especially important to determine the EMR levels in campuses where cellular systems used densely. Thus, in this study, EMR levels were measured in Samsun Ondokuz Mayıs University Kurupelit Campus between years 2013-2015 and evaluated. Approximately 400 measurements were performed using PMM 8053 and SRM 3006 at 23 different location in the Campus. The results show that the measured EMR levels (the max. is 2,68 V/m) are far below the limits which are determined by ICNIRP. Additional analyses demonstrate that 55% of total electromagnetic pollution is caused by UMTS2100, 32% is produced by GSM900, 7% by GSM1800 and 6% is aroused from the devices that use the remaining frequency bands.**

Keywords—electromagnetic radiation, electromagnetic pollution, field measurements, PMM 8053, SRM 3006.

I. Introduction

The growth of technological developments leads to an increase in the demand for wireless system. The equipment that use wireless systems emit electromagnetic waves like any other electronic device, and common use of them cause an increase in electromagnetic radiation (EMR). Demand for communicating from any place, for cellular system operators to install more base stations. Since each base station works within a limited geographical region and for limited number of users, new base stations requested to widen the coverage area [1, 2]. Beside this often use of multimedia services leads additional base station installation. Because each base station is an EMR source, the increases in number of them give rise to an increase in exposed EMR level.

Signals used in cellular systems are categorized as non-ionizing waves since their frequency is less than 300 GHz. Although these signals have not enough energy to snatch electrons from atoms, they may have detrimental effects on human health [3]. There are many independent organization that research the potential effects of EMR on human health. The most important of these organizations is International Commission on Non-Ionizing Radiation Protection (ICNIRP) and recommends the limits of exposure [4]. In Turkey, regulations on EMR limits are made by Information and Communication Technologies Authority (ICTA), and it is based on ICINRP guideline [5].

There are many reasons of variety in EMR levels such as geographical structure of area inside of base station's coverage area, number of users, distance from base station, line of sight (LOS). Measuring and evaluating the levels of EMR is at great importance for human health especially in regions where cellular systems are densely used. Therefore, there are many researches and studies in literature [6-14] that focused on measurement and assessment of EMR emitted from base stations.

Campuses are the places where the cellular systems are used densely. The demand for these systems increases significantly especially at certain times of a day. In order to determine the effects of electromagnetic pollution emitted by cellular system base stations on students and personnel health, it is essential to measure and evaluate levels of EMR during day time (e.g. rush hour). Therefore, in this study, EMR measurements were done at 23 different locations in Samsun Ondokuz Mayıs University Kurupelit Campus during over two years and at different times of a day. The obtained measurement levels were checked if these are compatible with the international standards. Beside this, main EMR sources in the Campus were determined and statistical analysis of recorded values was made.

II. Measurement of EM Pollution

There are international standards and limits on effects of EMR on human health. The limits are recommended by an international commission ICNIRP which is recognized by World Health Organization (WHO). The limits of electrical field are shown in Fig.1 based on ICNIRP guidelines on exposure limits [4].

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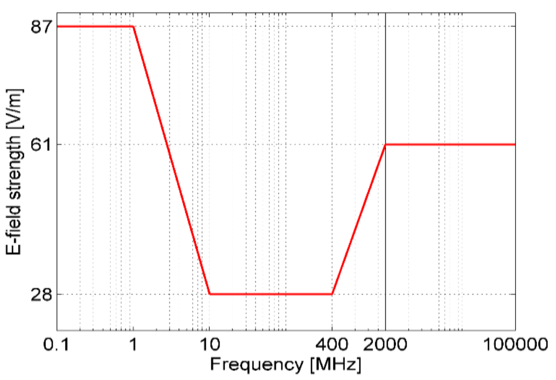

Figure 1. The ICNIRP guideline for public exposures as a function of carrier frequency

According to guideline [5] prepared by Information and Communication Technologies Authority of Turkey, based on ICNIRP, the limits are 41 (V/m) for 900 MHz base station, 57 (V/m) for 1800 MHz base station, 61 (V/m) for 3G systems which is 2100 MHz, and also 61 (V/m) for Wi-Fi (WLAN) equipment operating at 2,45 GHz. These values are the total limit values for a medium, the 1/4 of the limit values for a single device for injunctive relief taking environment and human health into account. The limits are given for exposure averaged over a 6 minute interval. Each country has its own limits determined. USA and some European countries use the limits determined by ICNIRP, while some European countries like Switzerland, Italy use 1/10 of ICNIRP values as a limit.

Fig. 2.a shows the city where Ondokuz Mayıs University (OMU) is located. OMU is a state university founded in 1975 in Samsun, Turkey. OMU is an extensive institution with 50.089 students and 1800 international students from 86 different countries, 1.294 academic personnel and 2.145 employees in total. Kurupelit Campus which consist of mainly academic and administrative units is established on 8.800 acre field.

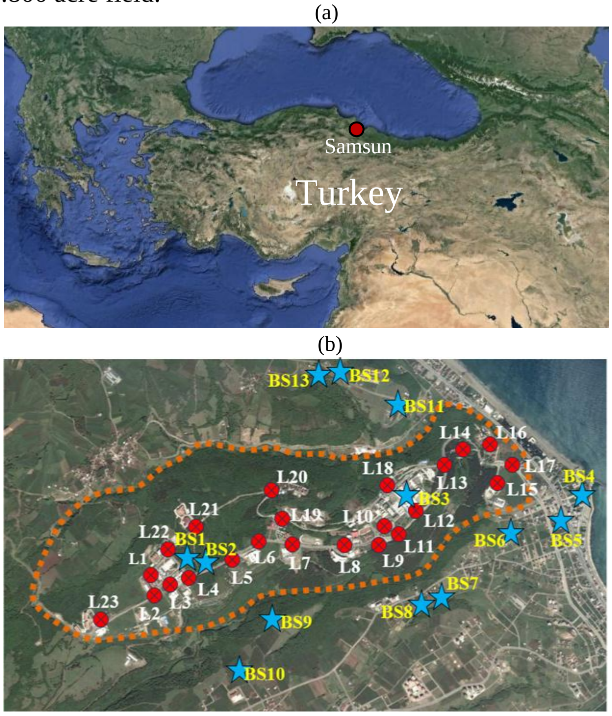

Figure 2. a) Location of Samsun, Turkey,
b) Kurupelit Campus, measurement locations and base stations

Fig. 2.b shows an aerial photo of the Kurupelit campus. In figure dashed line indicates Campus boundaries, each measurement location is marked with circle while base stations (BS) are marked with star. All base stations in and/or out of Campus are belong to three cellular system operators which operating in Turkey. Among these operators Turkcell and Vodafone use 900 MHz (GSM900) and 2100MHz (UMTS2100) frequency bands, while Avea uses 1800MHz (GSM1800) and 2100MHz. Measurements were conducted between years 2013-2015 on 23 different location using PMM 8053 and Narda SRM 3006 EMR meter. Figure 3 illustrates a picture of these devices. The devices can be set to display the instantaneous value, the maximum value, the minimum value, and the average value (averaging period can be set as required). The six-minute average specified by many of standards corresponds to the human thermal time-constant [4, 5]. Total EMR in the band between 100 kHz - 3GHz is measured with PMM–8053 while band selectives are done with SRM–3006. An example of a measurement in the band between 100 kHz-3 GHz is shown in Fig.4. In figure all services within the band are specified.

Figure 3. A picture of a) PMM 8053, b) SRM 3006

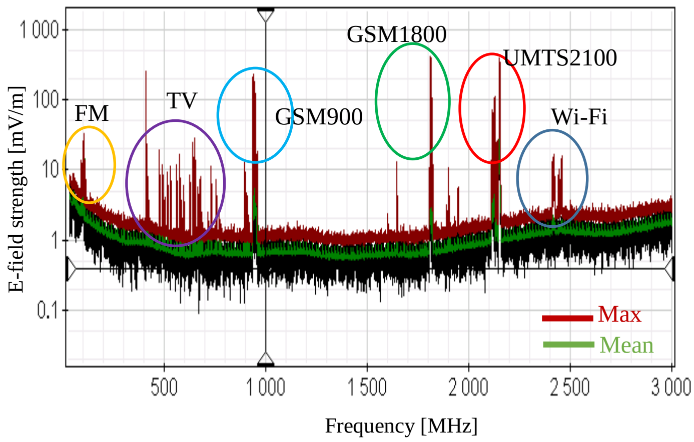

Figure 4. Detailed examination of the signal in the frequency domain between 100 kHz-3 GHz

III. Measurement Results

In this study, PMM 8053 and Narda SRM 3006 set to display the maximum value, and the average value (averaging period is 6 minutes) during measurements. Fig5.a illustrates the maximum E-field strength that obtained through the EMR measurements between years 2013-2015 for 23 different locations. Measurements were performed on different days and hours twice in 2013, three times in 2014 and 2015 using PMM 8053. During measurements PMM EP330 E-field probe was used. It is sensitivity is 0,3 V/m, and "low" sign appears on screen when E of medium below 0,3 V/m. In this case "0" is assigned to corresponding locations as shown in Fig. 5.a.

Measurements show that in case of LOS e.g. Location 1 (L1) and location 22 (L22) E value is relatively high. The maximum E strength is 2,68 V/m that was measured on L22 in year of 2015. E levels were relatively low in 2014, there is a general increase in E strength for 2015.

Fig.5.b depicts average E strength of six minutes measurement period in accordance with guideline established by ICTA. The highest average E strength is obtained as expected at locations where the maximum E strength was measured. The highest average E level is 1,36V/m at L22. In case of LOS and being close to base station (L1, L3, L5, L22) give rise to higher E levels as expected.

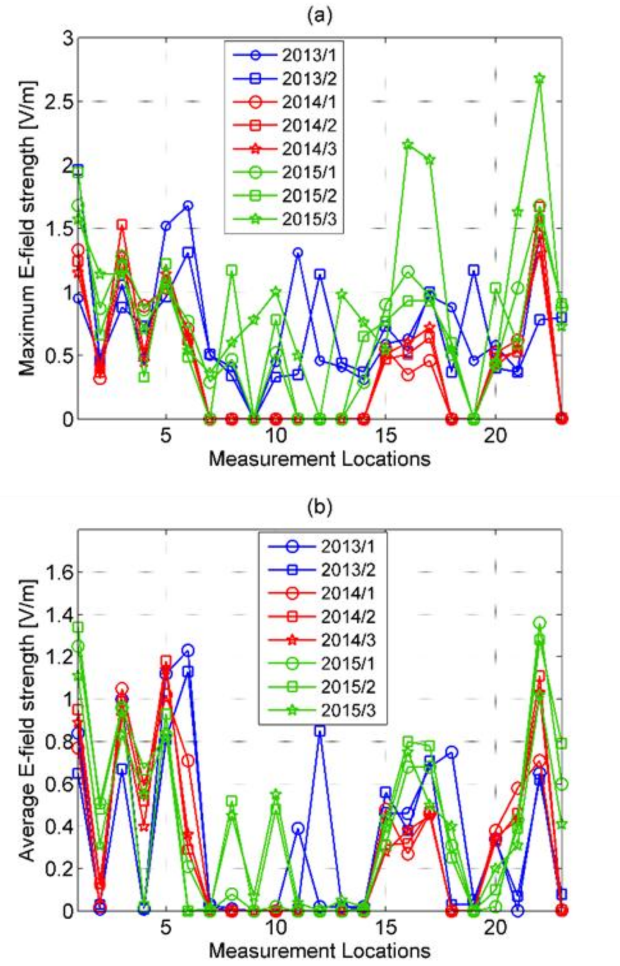

Figure 5. a) Maximum, b) Average E-field strength versus Locations

Table I indicates the maximum E (for maximum E-field strength, and average E-field strength) and mean E (for maximum E-field strength, and average E-field strength) for measurements of two years. As seen from Table I, the maximum E-field strength is 1,96 V/m in 2013, it becomes to 2,68 V/m with significant increase in 2015. The mean of the maximum E-field strengths is 1,23 V/m and 1,36 V/m for the years of 2013 and 2015 respectively. Mean values of the maximum E-field is 0,69 V/m in 2013 and 0,77 V/m in 2015. Mean of the average E-field values is 0,32 V/m in 2013 and 0,39 V/m with slight increase in 2015.

TABLE I. The change in E-field strength by year

PMM 8053 Measurements	Years	*Maximum E-field [V/m] (Fig 5.a)*	*Average E-field [V/m] (Fig 5.b)*
Maximum value of E-field strengths	2013	1,96	1,23
	2014	1,67	1,18
	2015	2,68	1,36
	Overall	2,68	1,36
Mean value of E-field strengths	2013	0,69	0,32
	2014	0,42	0,30
	2015	0,77	0,39
	Overall	0,62	0,34

SRM 3006 Measurements	
Maximum value of E-field strengths	1,249
Mean value of E-field strengths	0,45

Considering two years of measurements collected using PMM 8053 in 8 different periods, identifying the main source of E-field strength is the must. Therefore, to determine which transmitter that use different frequency band cause E field, band selective measurements were performed in 2015 by using Narda SRM 3006.

Fig. 6 shows spectrum of E-field at L22 that has the maximum E strength due to line of sight and closeness to the base stations. A picture of the base stations at L22 is given in Fig.7, and detailed information for BS1, BS2 are indicated in Table II.

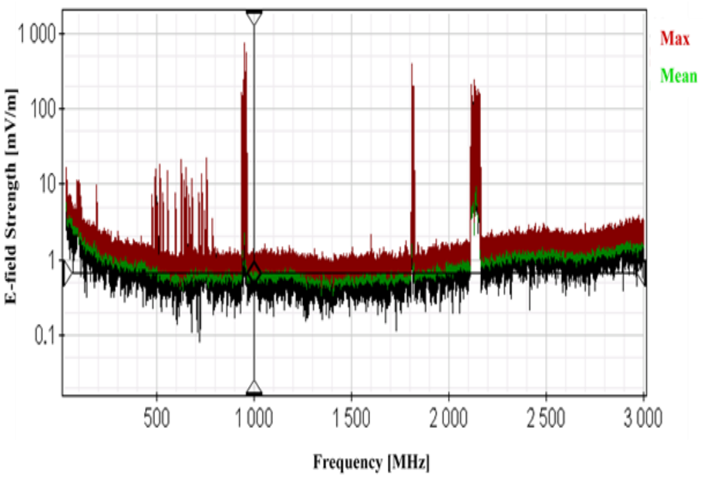

Figure 6. Frequency spectrum of L22

Figure 7. A picture of Base Stations at L22

TABLE II. Technical information for BS1, BS2

Operator	Frequency [MHz]	Antenna Height [m]	Antenna Gain [dB]	Max. Power [W]
Turkcell	900	58,7	15	8,32
	2100	55	18	25,24
Vodafone	900	48,5	14,4	20
	2100	48,5	17,5	20
Avea	1800	46	17,5	40

TABLE III. Frequency selective EMR field values for L22

Index	Service	f_{min}	f_{max}	Average (mV/m)
1	Low Band	30 MHz	87,4 MHz	61,63
2	FM Band	87,5 MHz	108 MHz	40,34
3	Air Band	108,1 MHz	136 MHz	18,66
4	Land Band-I	136,1 MHz	173 MHz	18,61
5	TV VHF Band	173,1 MHz	230 MHz	20,01
6	Land Band-II	230,1 MHz	400 MHz	24,22
7	Land Band-III	400,1 MHz	470 MHz	13,40
8	TV UHF Band	470,1 MHz	861 MHz	54,46
9	ETC1	861,1 MHz	889,9 MHz	6,393
10	GSM 900	890 MHz	960 MHz	860,2
11	ETC2	960,1 MHz	1,7 GHz	32,17
12	GSM 1800	1,701 GHZ	1,88 GHz	480,1
13	DECT	1,881 GHz	1,899 GHz	5,690
14	UMTS 2100	1,9 GHz	2,17 GHz	757,2
15	ETC4	2,171 GHz	2,399 GHz	32,70
16	WLAN	2,400 GHz	2,483 GHz	22,55
17	ETC5	2,484 GHz	3,000 GHz	59,57
18		Others		5,163
		Total		1249

Table III illustrates the change in E strength by frequency. It is seen from Table III that main sources of E are GSM900, GSM1800 and UMTS2100 bands. When total E is 1,249 V/m, 860,2 mV/m of this value is arise from GSM900 while 480,1 mV/m and 757,2 mV/m are from GSM1800 and UMTS2100 respectively. The total E strength of medium is calculated as follows:

$$E_{total} = \sqrt{\sum_{i=1}^{18} (E_i)^2} \qquad (1)$$

where E_i is the electric field for $i.^{th}$ band. E_{18} is the electric field caused by the other transmitters excluding 17 bands.

Fig. 8 depicts the change in average E strength by locations. In figure blue line represents the E-strength caused by GSM900, red and green lines show E-strength produced by GSM1800 and UMTS2100 respectively. It is seen from the figure that UMTS2100 has the highest share in total EMR. Considering all measurement locations, 55% of total EMR in Kurupelit Campus is emitted from UMTS2100. This percentage is 32% for GSM900 and 7% for GSM1800. The share of the rest of all sources is only 6% (Fig. 9).

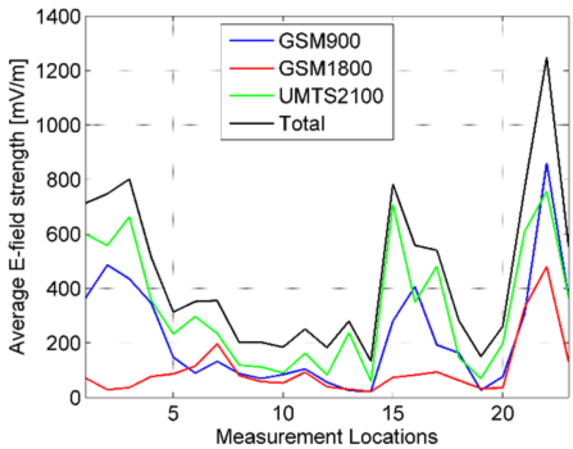

Figure 8. Band selective EMR measurements in the Campus

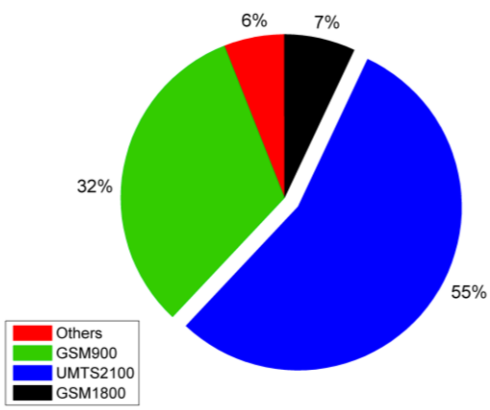

Figure 9. The pie chart of EMR for Kurupelit Campus

IV. Conclusion

In this study, EMR levels in Samsun Ondokuz Mayıs University Kurupelit Campus were measured between years 2013 and 2015, and the values were compared with limits determined by ICTA and ICNIRP. The maximum measured E value was 2,68 V/m for all medium. Comparing this value with the limit shows that there is not a significant electromagnetic pollution in Kurupelit Campus. The results also shows that the main reason of EM pollution in Kurupelit Campus is UMTS2100 base stations.

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