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ORIGINAL ARTICLE

Investigating the Effect of Construction Type of BTS Antennas and the Type of Buildings around Them on the Microwave Radiation- A Case Study in Maragheh City

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ABSTRACT
Due to technology improvement particularly telecommunication technology, the use of mobile phones has increased in recent years. Service providers have increasingly installed more BTS antennas inside the cities and villages to meet the growing demand. However, there is a concern about the level of exposure to microwave waves from these antennas. It is due to this concern that the current study seeks to investigate the horizontal pattern of microwave radiation from BTS antennas considering the type of antennas and surrounding buildings in Maragheh city, East Azerbaijan Province, Iran. The required information was collected through the interview with the city telecommunications organization company and field observations. Then, measurements were performed based on the IEEE STD C95.1 standard method via SPECTRAN 4060 handheld RF spectrum analyzer device. Kolmogorov-Smirnov and Mann-Whitney tests were adopted to analyze data using SPSS software. The results of the study showed that the BTS antenna installation and the amount of wave propagation on surrounding buildings vary from service provider to service provider. It is recommended to pay more attention prior to installation process specifically in highly populated areas. However, all the measurements were within the acceptable range of the ICNIRP allowable limits.

KEYWORDS: *BTS antenna, Electromagnetic field, Power density, Microwave*

INTRODUCTION
Considering the improvement in telecommunication technology, an interest in the utilization of this technology also has increased [1-2]. However, the electromagnetic pollution inside the cities and urban areas has relatively increased [3]. In order to provide telecommunication service, a set of telecommunication stations, Base Transceiver Stations (BTS) antennas, and mobile terminals (mobile devices)

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should be installed inside the city areas [4]. The BTSs are often located in the vicinity of apartments and crowded districts [5]. Based on the latest reports, there are more than 6.9 billion mobile subscribers and 1.4 million mobile receiver stations worldwide to meet the growing demand for communications, and this number is growing significantly [6]. The BTS antennas facilitate wireless communication by receiving and sending waves. The frequency range of the BTS is limited between 900 MHz to 1800 MHz [7]. There are concerns among scholars about the impact of constant microwave radiation on human health where the majority of these antennas were installed nearby living areas [6-8]. This problem in urban areas even worse than in city areas, where these antennas were installed on roofs, facades, and indoors [9]. In addition, the results of a study showed that about 45% of mobile phone towers in metropolitan areas were illegally installed without following the norms [10]. The maximum exposure to BTS antennas wave was determined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the World Health Organization (WHO) to be 0.1 watts per square meter (100 MW per square meter) [2].

However, the results of a study showed that the exposure to microwave radiation in Nigeria was lower than the standard set by ICNIRP. It might be due to the reverse relationship between the power density with distance i.e., the more distance from the antennas, the less exposure to wave [6]. In a study conducted by Mortazavi et al., the distance criterion was identified as one of the most important factor determining the power density of antennas which should not be exceed the standard limit set for microwave radiation exposure [11]. Despite the very low power density around BTS antennas, a few number of research has focused on the impact of base station exposure on human health. Moreover, it is quite difficult to determine the impact of exposure those are below the identified threshold [12]. Shahbazi et al., in a study, showed that symptoms such as nausea, headache, dizziness, irritability, depression, sleep disturbance, and memory loss are statistically significant in residents who are living nearby the BTS antennas [8]. Various studies proved that children are more vulnerable than the other age groups to microwave exposure. Among people who are living in the vicinity of the BTS antenna, the prevalence of cancer, memory loss, problems in concentration, sleep disorders, mental disorders, and hyperactivity were reported more compared to those who are not living nearby these facilities. Hence, due to potential health risks such as learning disabilities and brain tumors, the New Zealand government prohibited the installation of BTS antennas in certain distances close to schools [6].

Considering all these issues, the purpose of this study is to investigate the amount of BTS antennas transverse radiation regarding the type of buildings around them and the type of installation of these antennas.

MATERIALS AND METHODS

In the present descriptive-analytical study, we seek to investigate the impact of BTS antennas electromagnetic waves with a frequency range of 900-1800 MHz on the surrounding environment in the City of Maragheh, East Azerbaijan Province, Iran. In this study, the required data including the number of operators, service providers, and location of BTS antennas were derived from publicly available data in the telecommunications companies. Then, all other necessary information with respect to the surrounding building, and installation type i.e., roof or ground-mounted were collected via field observation. All measurements were collected based on the IEEE StdC95.1 standard method using the Spectran-4060 handheld RF spectrum analyzer device (made in Germany) at different distances e.g., distant and close to the antenna.

These antennas designed to provide coverage in various diameters considering the installed equipment. The BTS antenna could provide coverage of about 20 km, however, it is even less inside the cities due to the existing physical obstacles and limited to a coverage range of 2 to 5 km. In order to obtain necessary information, all horizontal measurements were collected at different distances of 0, 5, 10, 15, 20, 30, and 50 meters away from the antenna in three directions. We then repeated the measurement to ensure the data validity.

Moreover, traffic load during peak data traffic between 10 to 12 and 19 to 22 pm was also taken into account for measurement.

In order to minimize the negative impact of weather conditions on measurement, we tried to collect the required data when there were no interrupting factors. In this study, 10 to 12 noon was considered as a peak traffic time and 14 to 15 pm as low traffic load hours.

The sample size of 217 was determined at a confidence level of 95% based on the value of standard deviation and the maximum amount of error. In total, 1804 measurements were collected in different angles, distance, time period, and traffic load i.e., peak and off-peak data traffic. The primary obtained data were put into Excel then were analyzed using SPSS.

RESULTS

The two main service providers of Hamrah-e-Aval and Irancell possess 15 and 13 BTS antennas in the city of Maragheh. The characteristic of these antenna has been presented in Table 1.

Table 1. Characteristic of BTS antennas in Maragheh city

Variable	Hamrah-e-Aval	Irancell
Number of antennas in Maragheh	15	13
Stone buildings around the antenna	6	8
Non-stone buildings around the antenna	9	5
Roof mounted antenna	2	3
Ground antennas	13	10

The related data for each operator was collected considering peak and off-peak data traffic, then, average, standard deviation, minimum and maximum were calculated based on the different distances (see Table 2, 3, 4, and 5). The Kruskal-Wallis nonparametric test was applied for distances comparison and the Mann-Whitney test was developed to determine the relationship between microwave radiation with the type of surrounding buildings and the type of antennas.

Table 2. Hamrah-e-Aval antennas microwave radiation exposure during off-peak data traffic [13]

Distance	Antenna base	5 meters	10 meters	15 meters	20 meters	30 meters	50 meters
N	74	71	70	70	77	75	77
Average power density (mW / m2)	0.42974	0.38683	0.22363	0.23451	0.60070	0.26431	0.31709
Standard deviation	0.51679	0.30469	0.14167	0.14314	0.50609	0.12698	0.13786
Minimum (mW/m2)	0.01024	0.08734	0.07086	0.10644	0.06947	0.09556	0.10124
Maximum (mW/m2)	2.43000	1.28000	0.70940	0.68857	2.52000	0.69742	0.68949

Table 3. Hamrah-e-Aval antennas microwave radiation exposure during peak data traffic [13]

Distance	Antenna base	5 meters	10 meters	15 meters	20 meters	30 meters	50 meters
N	72	68	67	71	72	75	71
Average power density (mW / m2)	0.42801	0.31484	0.26512	0.26022	1.02104	0.40873	0.28799
Standard deviation	0.59513	0.21890	0.26664	0.19321	0.87811	0.19446	0.17798
Minimum (mW /m2)	0.01350	0.05614	0.09918	0.08519	0.22672	0.12502	0.02902
Maximum (mW/m2)	3.21000	0.94475	1.19000	0.98445	4.16000	1.0500	0.73050

Table 4. Irancell antennas microwave radiation exposure during off-peak data traffic [13]

Distance	Antenna base	5 meters	10 meters	15 meters	20 meters	30 meters	50 meters
N	49	59	58	60	58	60	63
Average power density (mW / m2)	0.25201	0.29162	0.24024	0.17191	0.47937	0.21444	0.15244
Standard deviation	0.27845	0.33865	0.22328	0.09980	0.23734	0.19090	0.11523
Minimum (mW/m2)	0.01614	0.02023	0.01503	0.03435	0.14336	0.03901	0.02445
Maximum (mW/m^2)	1.25000	1.04000	0.85717	0.38107	0.87231	0.79143	0.51805

Table 5. Irancell antennas microwave radiation exposure during peak data traffic [13]

Distance	Antenna base	5 meters	10 meters	15 meters	20 meters	30 meters	50 meters
N	48	58	54	53	59	59	56
Average power density (mW / m^2)	0.32974	0.51842	0.35607	0.24851	1.01101	0.34828	0.21048
Standard deviation	0.47176	0.77986	0.35492	0.13845	0.98754	0.21656	0.13239
Minimum (mW /m^2)	0.03294	0.00845	0.01732	0.06446	0.25173	0.10915	0.01635
Maximum (mW/m^2)	1.75000	3.51000	1.05000	0.65214	4.51000	0.98850	0.57926

The propagation rate of waves from BTS antennas around stone and non-stone buildings:

In this study, statistical analyses of power density were performed for both types of operators, taking into account the type of surrounding buildings, and the normality of the data was assessed using the Kolmogorov-Smirnov test. Since this variable does not follow the normal distribution to use parametric tests and the variable did not become normal with statistical techniques, so to answer the research hypotheses, the non-parametric test of Mann-Whitney was inevitably used (Tables 6 and 7). The results of the Mann-Whitney test showed that there was no significant difference in mean microwave radiation of Hamrah-e-Aval and the type of surrounding buildings (p-value $\geq$ 0.05), however, there was statistically significant differences between the microwave radiation mean of the Irancell operator and types of surrounding building (P-value <0.05)(refer to Table 8 and 9).

Table 6. Kolmogorov-Smirnov test for antenna waves- One-Sample Kolmogorov-Smirnov Test

		Hamrah-e-Aval	Irancell
	N	1010	793
Normal Parameters	Mean	0.39110	0.34596
	Std.Deviation	0.43074	0.46302
Most Extreme Differences	Absolute	0.204	0.233
	Positive	0.192	0.217
	Negative	-0.204	-0.233
Kolmogorov-Smirnov Z		6.479	6.573
Asymp. Sig. (2-tailed)		0.000	0.000

Table 7. Statistical analyses of power density measured according to the type of surrounding buildings

Group Statistics					
	Surrounding building structure	Number of measurements	Mean	Standard deviation	Mean Standard Error (SE)
Microwave radiation of Hamrah-e-Aval	Stone	412	0.46323	0.58019	0.02858
	Non-stone	598	0.34140	0.27525	0.01125
Microwave radiation of Irancell	Stone	547	0.41396	0.52838	0.02259
	Non-stone	246	0.19476	0.19383	0.01235

Table 8. Mann-Whitney test to compare the microwave radiation from antennas considering surrounding buildings

	Type of surrounding buildings	N	Mean of ranks	Sum of ranks
Microwave radiation of Hamrah-e-Aval	Stone	412	522.96	215461.50
	Non-stone	598	493.47	295093.50
	Total	1010		
Microwave radiation of Irancell	Stone	547	438.73	239987.00
	Non-stone	246	304.20	74834.00
	Total	793		

Table 9. Results of Mann-Whitney test considering surrounding buildings

	Microwave radiation of Hamrah-e-aval	Microwave radiation of Irancel antenna
Mann-Whitney U	115992.500	44453.000
Wilcoxon W	295093.500	74834.000
Z	-1.579	-7.650
Asymp. Sig. (2-tailed)	0.114	0.000

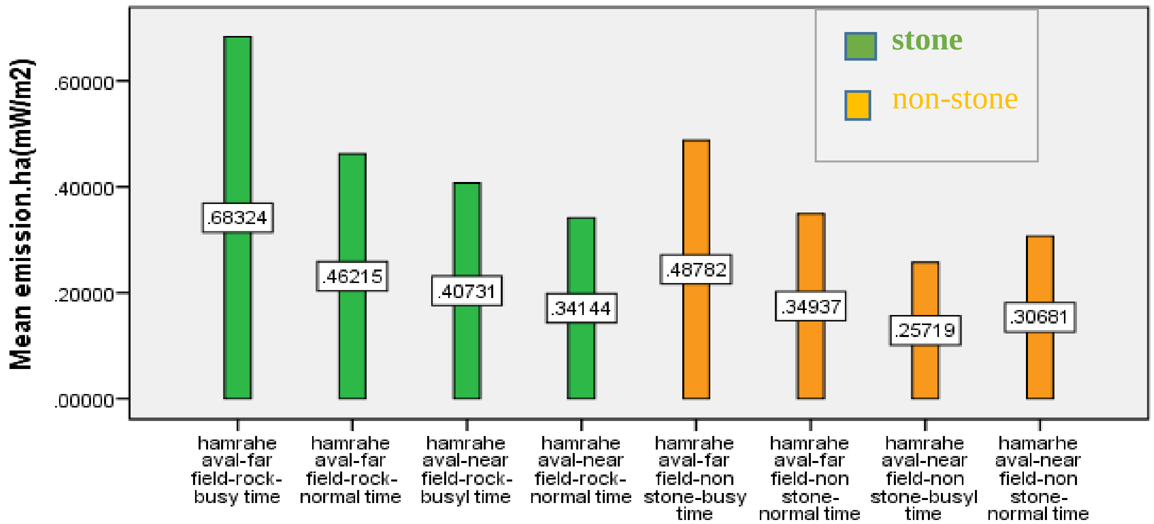

Fig1.Linear comparison of the Hamrah-e-Aval installed antennas' microwave radiation considering surrounding buildings and the traffic load

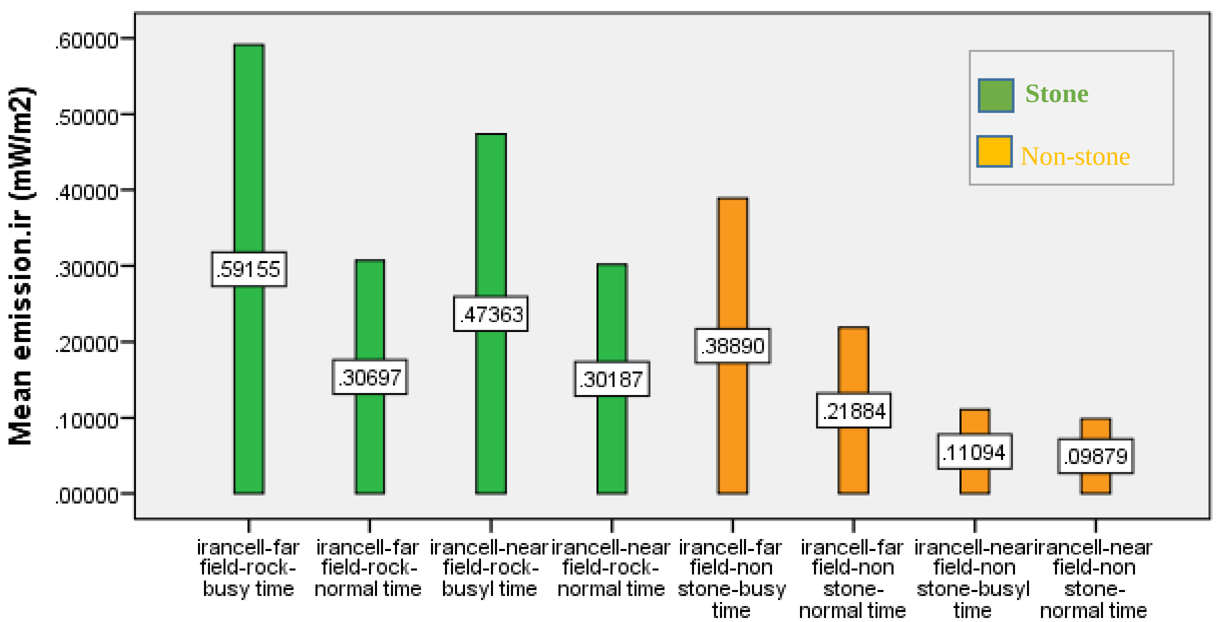

Fig2. Linear comparison of Irancell installed antennas' microwave radiation considering surrounding buildings and the traffic load

Figures 1 and 2 show the mean power density of the antennas in different situations, including peak and off-peak data traffic, distant, close, and the type of buildings in the vicinity of antenna. Figure 1 demonstrate the average power density of the Hamrah-e-Aval antennas during peak and off-peak data traffic. Hence, the average power density was higher when these were close to the stone buildings compare to the vicinity of non-stone building. In addition, the highest mean value of power density (0.68324) was determined during peak time and distant.

The relationship between the Microwave radiations from Roof mounted and ground antennas:

In this section, statistical analyses of power density were performed by considering the type of antenna installation. Kolmogorov-Smirnov test for the variable of "antenna type" showed that this variable does not follow the normal distribution and does not become normal using statistical methods. Therefore, nonparametric test of Mann-Whitney was used to answer the research hypotheses (Tables 10 and 11). According to Mann-Whitney test, it was found that the mean microwave radiation in the Hamrah-e-Aval operator at different heights (Roof mounted and ground) are not significantly different (p-value -0.05) but the mean microwave radiation in Irancell in the roof-mounted and ground antennas are significantly different (P-value <0.05). (Table 12, 13)

Table 10. Results of Kolmogorov-Smirnov test for both Hamrah-e-Aval and Irancell roof-mounted and ground antennas

		Microwave radiation of Hamrah-e-Aval	Microwave radiation of Irancell
N		1008	848
Normal Parameters	Mean	0.39071	0.34595
	Std.Deviation	0.43111	0.44962
Most Extreme Differences	Absolute	0.204	0.227
	Positive	0.192	0.215
	Negative	-0.204	-0.227
Kolmogorov-Smirnov Z		6.486	6.609
Asymp. Sig. (2-tailed)		0.000	0.000

Table 11. Statistical analyses of power density measured according to the type of antenna installation

Group Statistics					
	Location	N	Mean power density (mW / m^2)	Standard deviation	Mean standard error
Microwave radiation of Hamrah-e-Aval	Ground	852	0.39801	0.44987	0.01541
	Roof mounted	156	0.35080	0.30724	0.02459
Microwave radiation of Irancell	Ground	389	0.34568	0.58774	0.02979
	Roof mounted	305	0.42299	0.25707	0.01472

Table 12 Results of Mann-Whitney test on the Roof-mounted or ground antenna measures

	Location	N	Mean of ranks	Sum of ranks
Microwave radiation of Hamrah-e-Aval	Ground	852	507.94	432768.00
	Roof mounted	156	485.69	75768.00
	Total	1008		
Microwave radiation of Irancell	Ground	389	277.28	107861.00
	Roof mounted	305	437.06	133304.00
	Total	694		

Table 13. Results of Mann-Whitney test for both Hamrah-e-Aval and Irancell roof-mounted and ground antennas

	Microwave radiation of Hamrah-e-aval antennas	Microwave radiation of Irancell antennas
Mann-Whitney U	63522.000	32006.00
Wilcoxon W	75768.000	107861.00
Z	-0.878	-10.421
Asymp. Sig. (2-tailed)	0.380	0.000

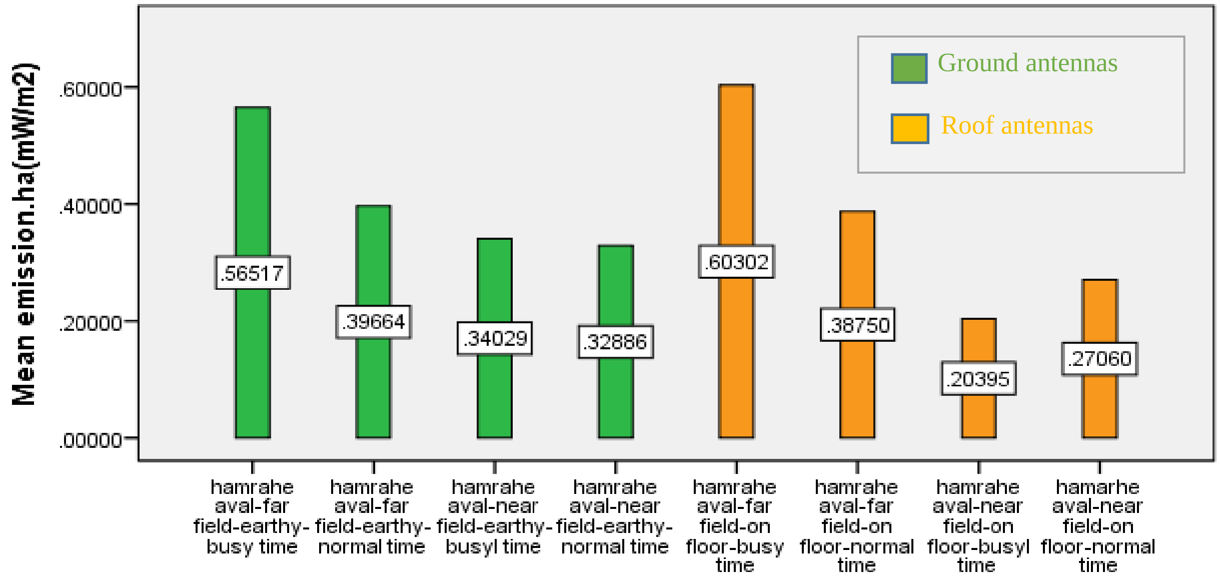

Fig 3. Linear comparison of Hamrah-e-Aval installed antennas' microwave radiation during peak and off-peak data traffic

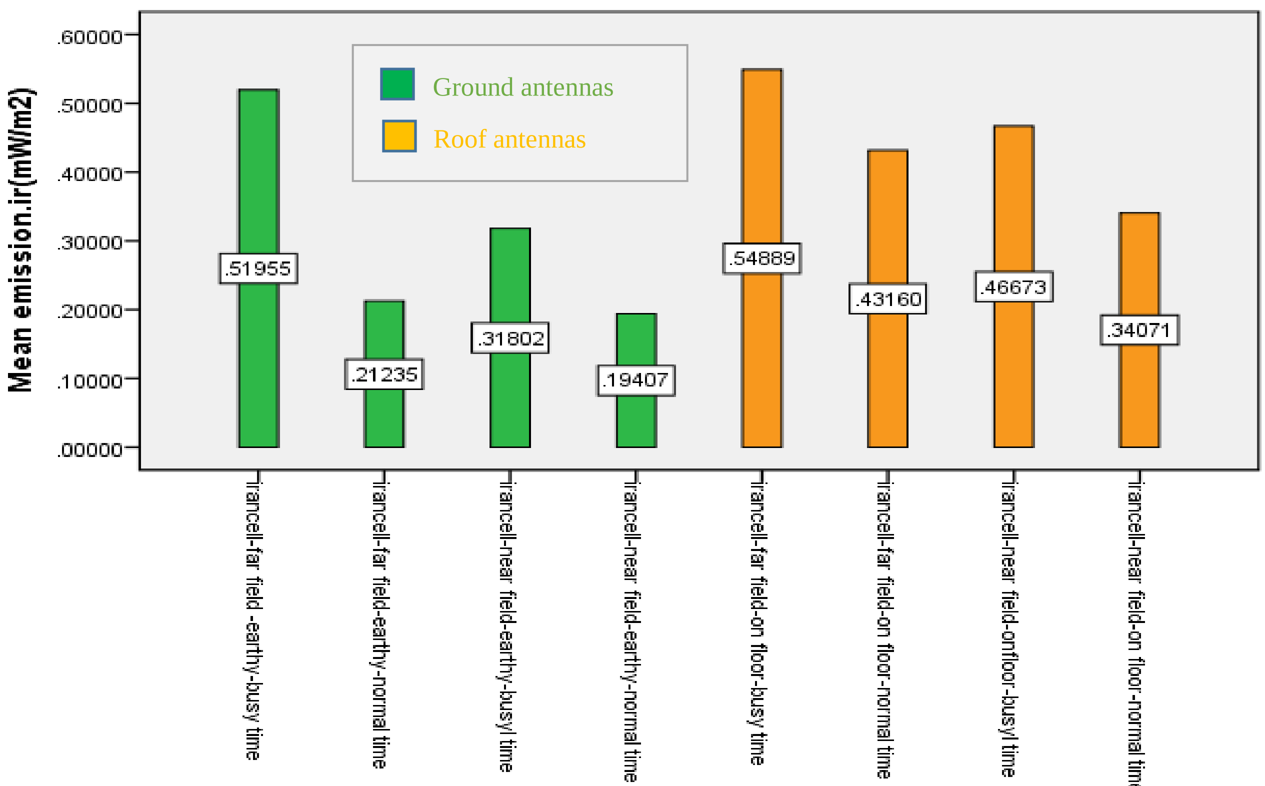

Fig4. Linear comparison of Irancell installed antennas' microwave radiation during peak and off-peak data traffic

The results of average power density of Hamrah-e-Aval and Irancell antennas in different situations i.e., peak and off-peak data traffic, distant and close, and roof-mounted or ground has been demonstrated in Figures 3 and 4. The mean power density of Hamrah-e-Aval antennas close to exposure source, during both peak and off-peak data traffic, was higher than those roof-mounted antennas, but after 20 meters, the roof-mounted type had more wave propagation (Figure 3). The highest value (0.60302) was related to peak data traffic hours, distant, and roof-mounted antennas.

However, the average power density of Irancell's roof-mounted antennas, was higher than ground antennas at all times. The highest value (0.58899) was related to peak data traffic hours, distant, and roof-mounted antennas (see Figure 4).

DISCUSSION

Due to the reflection, absorption, and interference in complex environments, it is quite challenging to precisely determine the power density of BTS antennas [14-16]. The reason for this can be attributed to natural and human barriers [11]. BTSs are usually surrounded by buildings, vegetation, or other barriers which is cause power density decreases, scatter, or electromagnetic energy reflection [5].

The results of study about the effect of modern building materials on radio signal propagation showed that metal-based coatings decrease energy loss, also prevent RF radiation. The attenuation of the exterior wall and the windows are those impacting factors on reducing and the radiation of the RF signal. In addition, in older buildings, the presence of seams between different elements of the building (especially around the windows) leads to easier passage of RF signals. However, in modern buildings, due to the use of materials such as aluminum, some of these waves are reflected, which results in decreasing the penetration. The convergence of several reflected waves around such buildings adds to the propagation problems. [17].

In this study, among 1804 cases, the highest power density was equal to 4.51 mW/m^2 in 900 MHz band in distant and close distances. It was in line with 0.1% of the maximum exposure to environmental standards [13].

Hans-Peter Hutter et al. (2006) measured the power density of electromagnetic waves of BTS antennas in Austria. They found that the power density of electromagnetic waves vary from 0.0002 to 4.1 mW/m^2, while the obtained values were less than the recommended values [18]. The results of this study were consistent with Hutter et al., findings [12].

In the current study, the lowest microwave radiation frequency was measured from Irancell antennas (0.152 mW/m2) in off-peak data traffic at a distance of 50 meters, while the highest frequency (1.021 mW/m2) was recorded from Hamrah-e-Aval antennas during peak data traffic in a distance of 20 meters. Nasseri et al., (2013) examined the radiation frequency of BTS antennas in city of Hashtgerd, Iran. According to the results of their studies, the lowest power density (0.02 mw/m^2) was measured from Irancell roof-mounted antennas. It could be due to the impact of building structure on preventing microwaves exposure [19].

Given the increasing trend in the telecommunication service coverage, therefore, more BTS will be installed to meet the demand where it would be increase microwaves exposure in city of Maragheh. On the other hand, due to the direct and indirect effects of these stations on urban environments, these are the subject of urban planning in most countries. However, it is of particular importance to take into account the effect of BTS in urban planning [20], it is also recommended to set up safety protocols on radiation parameters to minimize negative effects of BTS human health [1].

Service providers in some cases did not follow the minimum distance role (10 meters) from residential areas for the installation of BTS which should be controlled by observatory organizations [21].

From measurement point of view, it is recommended for other scholar to record horizontal and vertical measurement in a different population density, peak, and off-peak data traffic.

CONCLUSION

In the current study, the microwave radiation frequency affect was different considering operators, surrounding buildings structures, and the type of installation but in both operators i.e., Hamrah-e-Aval and Irancell, the maximum power density was recorded at a distance of 20 meters. Although all measurements in both types of operators were much lower than the ICNIRP allowable limits. However, new telecommunication technologies with a higher frequency and power density are now coming to market, so, to minimize the negative impact of these BTS on human health, different studies should be conducted.

The limitations of this study were the determination of the amount of iron in buildings around antennas and taking into account the number of users of each operator. Therefore, to achieve accurate and comprehensive answers, more extensive studies are needed.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest in this study.

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