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Electromagnetic Radiation Measurements of Selected Cellular Base Station in Sana'a: Long Term and Mapping Road Measurements

* Abdulsalam G. Alkholidi	Faculty of Engineering, Electrical Engineering Department, Sana'a University, Sana'a, Yemen. *Corresponding author
Fuad Hamamah	Faculty of Engineering, Electrical Engineering Department, Sana'a University, Sana'a, Yemen.

ABSTRACT

Radiofrequency radiation consists in radiating of waves of electric and magnetic energy moving together through space at the speed of the light. This paper illustrates the measurements of radiofrequency radiation of some mobile base stations in the capital of Yemen, Sana'a as long-term measurements. Yemeni towns in general are considered as non-urban cities. However, it is difficult for telecommunication engineers to find many options for the distribution of cellular base stations. The aims of this paper is to measure the radiofrequency radiation near of the schools, hospitals, universities, and crowded populated areas. The importance of this study is to focus on invisible pollution in Yemen because no one cares about this topic even ministry of telecommunication and information technology. Accordingly, there is a mandated radiofrequency radiation from cellular base stations unmatched worldwide. Experimental results of long term during specific points and 24 hours at fixed points, and mapping roads measurements are presented and discussed in this paper.

KEYWORDS invisible pollution, base stations, long-term measurements, environmental science, public health.

Introduction

Last decade wireless telecommunication technologies have developed significantly. The radio waves used in mobile telephony are, like visible light and X-rays, electromagnetic waves that consist of both an electric and a magnetic components which vary periodically with time. The frequency of variation determines the wave properties and their uses. Radio waves, which can be used for various types of communication, are found in the lower part of the spectrum and classified as non-ionizing radiation [1]. Many of the existing safety guidelines governing microwave/RF/ELF, controlled /uncontrolled exposure are based on intensity of exposure that produces heating of tissues due to energy absorption leading to temperature rise and manifested as thermal effects. On the other hand, though the human body could compensate for and handle the extra energy load through the thermoregulatory mechanisms without obvious increase in temperature, stress could still develop [2]. Indeed, we can utilize mobile phone in a way we desire, that is, we can turn it off in order to avoid its radiation when we do not want to use it. However, we cannot control base stations; moreover we do not know where they are mounted. So, radiation of base stations has more importance than that of mobile phones in this respect [3]. International Telecommunication Union (ITU-T) has issued several recommendation to regulate the nonionizing radiation emitted from mobile base stations, namely, K.52 [4-5].

This work concentrates on the long term measurements during specific time at specific points and 24 hours at a fixed point. Second type of this study is focus on mapping road measurements that show the power density in some roads in Sana'a on the map. The measurements for every point are registered but the maximum value is taken. The frequency and power density are registered for every band by the measurement device. Yet, then maximum readings with its frequencies that reveal which company they belong are taken. The readings are determined by several units (dBm, mW/m², μW/cm², and V/m). The measurements are carried out via using a spectrum analyzer device, manufactured by Aaronia Company in Germany [6]. It includes a spectrum analyzer (SPECTRAN®HF-2025E) at frequency range from 700 MHz to 2.5 GHz, with an antenna (HyperLOG®7025), and a new antenna (OmniLOG®9000). For more details about RFR in Yemen, readers merely can refer to reference [7].

Related Work

Although much work has been done toward measuring RFR, most techniques reported [8], such as for example the study developed by Leen Verloock et al. on temporal 24-hours assessment of radio frequency exposure in schools and homes. For the first time, temporal 24-hour measurements of all present RF signals, including LTE (Long Term Evolution), are performed with accurate spectral narrowband equipment in these environments where children are present. The largest maximal variations are obtained for the cordless telephone (DECT) signals (10.6 dB) and for the WiFi 2.4 GHz signals (12.7 dB), while variations of broadcasting signals and telecommunication signal were much lower namely, 2.9 dB and33 dB, respectively.

In the study presented by Agence Nationale des Fréquences [9], relating to electromagnetic field strength measurements in Yemen. This assignment will give the opportunity to make measurement between 100 kHz and 3 GHz, and to train some Yemeni engineers on the handling of measurement equipment's. The measurements took place in the 4 main industrial towns in Yemen. This choice is justified by the presence of the highest density of radio networks in these areas: Sanaa, Taiz, Eden, and Hodidah. The study reported at that time (xx) that all levels measured were compliant with ICNIRP reference levels for general public exposer. Finally, we quote the measurement presented by Lalrinthara Pachuau et al. [10]. RF radiation from mobile phone towers and their effects on human body. In this paper, power density of RF radiation have been measured in close proximity (less than 50 m) to mobile base station Global system for Mobile Communications 900 (GSM 900) at the selected locality in Aizawal and Mizoran, India. Absolute power densities have been measured at some selected houses. Frequency spectrum was analyzed at different sites. Different symptoms of RF exposure on human body are studied and results is analyzed in this paper.

Long Term Measurements at Specific Times

In this pattern of measurements, the antenna was mounted and connected to a spectrum analyzer. Then the device was fixed at a specific point at a constant distance from a mobile phone base station. This measurement was fulfilled at two different places.

Measurements Results and Discussion:

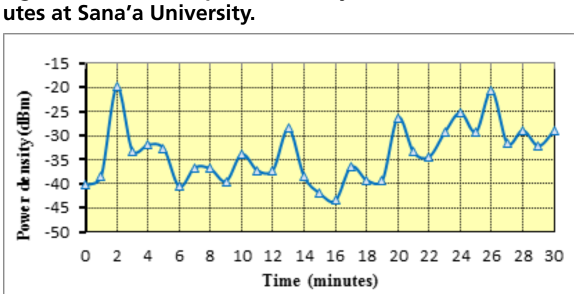
The first location is Sana'a University area. The number of readings was set in the device at 30 readings for half an hour (from 1:30 pm to 2:00 pm) at a distance of 180m from the mobile phone base station as demonstrated in Fig. 1. The device recorded and stored the data inside the memory every 60 second. After the operation measuring procedure, the device was connected to a computer and reading data by using (LSC) spectrum analyzer software. This program shows electromagnetic power density in dBm and frequency in MHz. The values were collected, analyzed, and drawn in function of the time. The distance and data are shown in Table 1 and the graph for this measurements is illustrated in Fig. 2.

Fig. 1. The measurement point is at distance of 180 m from base station in Sana'a University.

Table 1
Long term measurements at constant distance from base station in Sana'a University.

Readings at distance 180 m from base station in Sana'a university for 30 min. from 1:30-2:00 PM						
	P(dBm)	Freq(Mhz)	P(dBm)	Freq(Mhz)		
	-40.31	939	-43.49	945		
	-38.53	939	-36.47	945		
	-19.92	944	-39.25	954		
	-33.16	945	-39.35	948		
	-31.89	945	-26.27	948		
	-32.64	945	-33.44	948		
	-40.57	945	-34.41	944		
	-36.65	943	-29.35	944		
	-36.89	945	-25.21	943		
	-39.48	944	-29.24	945		
	-33.84	945	-20.64	945		
	-37.23	945	-31.58	945		
	-37.18	943	-28.92	945		
	-28.55	949	-32.15	944		
	-38.52	948	-20	945		
	-41.98	954				
Max	P (dBm)	-19.92	P (μw/m²)	1962.96	Freq (Mhz)	944

Fig. 2. Variation of power density with time for 30 minutes at Sana'a University.



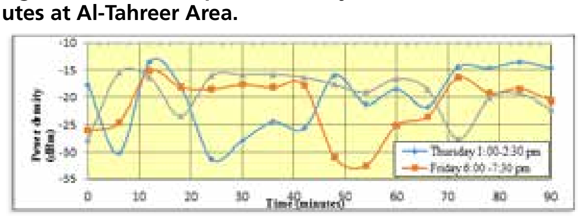
Based on the graph, the highest value the device recorded during this period was -19.92dBm at frequency 944MHz. Hence, the strongest electromagnetic power density at this value was 1962.96 μW/m² (0.86v/m), the minimum reading -43.49dBm at frequency 945MHz, that is, 8.628 μW/m² (0.057v/m). In the light of these measurements, it is concluded that there are variations in RF radiation level with time. The results showed that the variations have no systematic pattern during a specific time period which it varies randomly.

The second location in which measurements were fulfilled is Al-Tahreer area at a distance of 170m from the mobile phone base station during different times of day for consecutive three days. The measurements were taken on the following times: Thursday (from 1:00pm until 2:30pm), Friday (from 6:00pm until 7:30pm), and Saturday (from 3:30pm until 5:00pm). In all cases, a number of readings were set to measure15 values in device for 90 minutes period and between each reading 360 second. The values were analyzed and drawn in function of the time. All readings are shown in Table 2 and the graph for these measurements is illustrated in Fig. 3. The results as shown in graph illustrate that the strongest value on Thursday during recording period is -13.41 dBm at frequency 949MHz.Hence the strongest electromagnetic power density at this value is 8882μW/m² (1.83v/m) while, the minimum reading is -31.25dBm at frequency 949MHz, that is, 146 μW/m² (0.23v/m). On Friday the highest reading is -15.17 dBm or 5910 μW/m² (1.49v/m), whereas the lowest value is -32.51 dBm, that is, 109μW/m² (0.2v/m).

Table 2
Long term measurements at constant distance from base station in Al Tahreer Area.

Thursday 1:00pm-2:30pm 1 hour and 30 min.		Friday 6:00pm-7:30 pm 1 hour and 30 min.		Saturday 3:30pm-5:00 pm 1 hour and 30 min.	
Freq(Mhz)	P(dBm)	Freq(Mhz)	P(dBm)	Freq(Mhz)	P(dBm)
949	-17.71	949	-26.15	953	-27.87
949	-30.23	948	-24.61	949	-15.53
949	-13.41	948	-15.17	949	-16.38
948	-17.96	949	-18.15	948	-23.39
949	-31.25	949	-18.54	949	-16.05
948	-27.99	949	-17.69	949	-15.81
948	-24.49	949	-18.24	949	-15.75
949	-25.73	949	-17.84	949	-16.30
948	-15.94	946	-30.99	948	-17.66
948	-21.21	949	-32.51	949	-19.08
949	-18.54	949	-25.19	948	-16.59
949	-21.69	948	-23.51	947	-18.54
948	-14.40	948	-16.37	949	-27.74
948	-14.58	949	-19.25	949	-20.19
949	-14.95	949	-18.44	949	-19.38
949	-13.44	949	-20.60	949	-22.15

Fig. 3. Variation of power density with time for 90 minutes at Al-Tahreer Area.



On Saturday the strongest power density is -15.53dBm, that is, 5451μW/m² (1.43v/m); however, the minimum reading is -27.87dBm at frequency 953MHz, that is, 321 μW/m² (0.35v/m). The results are illustrated in Table 3.

Table 3
Result of measurements for 90 minutes at Al-Tahreer Area.

Day	Thursday	Friday	Saturday
Max	-13.41dBm at 949MHz	-15.17 dBm at 948MHz	-15.53 dBm at 949MHz
	8882 μw/m²	5910 μw/m²	5451 μw/m²
	1.83 v/m	1.49 v/m	1.43 v/m
Min	-31.25 dBm At 949MHz	-32.51 dBm At 949MHz	-27.87 dBm At 953MHz
	146 μw/m²	109 μw/m²	321 μw/m²
	0.23 v/m	0.2 v/m	0.35 v/m
Average	-20.1969 dBm	-21.4531 dBm	-19.2756 dBm
	1860 μw/m²	1395 μw/m²	2299 μw/m²
	0.84 v/m	0.73 v/m	0.93 v/m

These measurements show that there is variation in RF radiation level from mobile phone base stations during specific times. The results also show that the variations have no systematic pattern during stated time.

Long Term Measurements For 24 Hours
Measurements Results and Discussion:
The second experiment was to monitor closely a typical GSM tower. The measurements were carried out for 24 hours at a fixed distance from the mobile phone base station. The device was mounted with an antenna (HyberLog7025) and oriented to the tower of the base station at distance of 350m. The tower location was in Al-Bolyli Area. The equipment was fixed on the building rooftop of the researcher's residence. Then the number of readings were set at 240 readings in the function of the time between each reading 360 second that means the duration of measurements at 24 hours are 86400 second. Data was copied to spreadsheets to analyze it and draw it according to time. The 24 hour measurements of the power density was recorded in dBm and the frequency in MHz. The power density levels for 24 hours are illustrated in Fig. 4. The readings in the table indicate that most readings from the base station are at frequency of 951MHz.

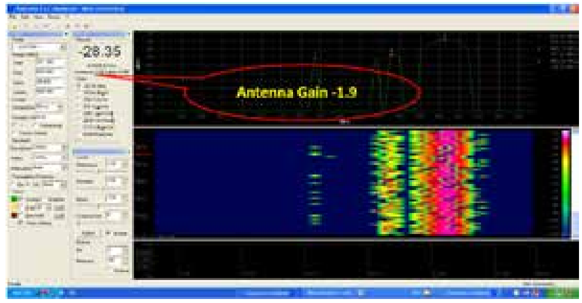
Fig. 4. Long-term (24 hours) measurement of RF radiation.

The results in the graph illustrate that the strongest value during recording period is -26.48 dBm at frequency of 951MHz. Accordingly, the strongest electromagnetic power density at this value is 553.77μW/m² (0.46v/m) at 11:48AM. The lowest reading, however, is -30.80 dBm at frequency of 951MHz, that is, 162.7 μw/m² (0.25v/m) at 9:18 PM. The average of readings is -28.47 dBm, that is, 277.3 μw/m² (0.32v/m). The antenna gain was displayed on the program which was -1.9 dBi as shown in Fig. 5. As a result, it was used to calculate the power density using the following equation:

$$S = \frac{10^{\left(\frac{P-G}{10}\right)}}{1000} * \frac{4\pi}{\lambda^2} \qquad (1),$$

$$\lambda = \frac{c}{f} \qquad (2)$$

Fig. 5. Spectrum analyzer software "LCS" illustrate all parameters of measurement.



The variation of the power density with time is due to the variation of the number of active time slots. With most sector antennas used in the mobile phone network, each one has two transmitters. Each transmitter has a bandwidth of 200 KHz generated from multiplexing 8 slots in the time domain. The minimum operation of a base station requires one transmitter to be in operation for each sector antenna. This transmitter operates at full power even when not handling any calls. This usually occurs after midnight on most sites. As more people use the network, the second transmitter is turned on allowing up to another eight simultaneous telephone calls. It may be observed from Fig. 4 that the peak hour of the network is, as expected, between 11 and 12 o'clock in the morning. As the power density at that interval is almost twice, its corresponding after midnight, it is concluded that the specific sector antenna operates at its full capacity at the peak hour. To reduce the call blocking probability the cell capacity may be enhanced by increasing the number of transmitters. If four transmitters are used to power the sector antenna instead of two, then it can handle up to 32 simultaneous calls allowing probable duplication of current RF levels. Based on the results, it could be concluded that there are variations in the RF radiation during the day. The variations have no systematic pattern during the day, and the levels of RF radiation on rooftop of buildings around the base station are more than the levels on the ground.

Mapping the Strength of Signals Along Some Major Roads in Sana'a
Electric field signals from mobile telephone base stations were measured along the major roads in Sana'a. The number of readings was set in the device at 306 readings for 157 minutes (from 11:50am until 2:27pm). The measurements were taken in several different roads around Sana'a university. Measurements were made in locations that maintain direct line-of-sight with known RF source. Practically, the measurement antenna was positioned in open area on a car, at height of approximately 1.7m above ground as shown in Fig. 6. The antenna was positioned and oriented so as to obtain maximum signal strength. The measurements were fulfilled and recorded in the device and it was downloaded to a computer, analyzed and drawn by using Google map.

Fig. 6. Antenna location on the car for mapping RF measurements on roads.

Measurements Results and Discussion:
Obtained measured values along the streets were carried out at more than 300 values. The power density levels are recorded in dBm in function of frequencies. The measurements in several roads included all bands for all mobile operators in

Yemen, Sana'a. It contains power density levels at 946MHz that belong to Sabafon Company, some locations give readings at 955MHz that belong to MTN, readings at 937MHz that belong to Y Company and also some readings for YemenMobile company at 877MHz.

Figure 7 shows the electromagnetic power density levels on a color-coded map. The larger colored circles indicate higher signal levels, while progressively smaller circles indicate decreasing levels. There are some comments on the results of this experiment: First, it is found out that the strongest measured values were in Sana'a University and around Mathbah Bridge. Secondly, at rare places, the measured values were found low (less than 100µw/m²) wherever the beam of antenna was shielded by the buildings. Therefore, the RF radiation levels were low in the street, which indicates that this radiation was shielded and dissipated. Finally, it is noticed that the measurements of radiation levels according to this study in main roads around Sana'a University due to mobile phone base stations are below the reference levels established by the international health organizations but close to some national limits and some measurements exceeded Salzburg standard. The results show that the high readings are -11.67dBm, -15.8dBm, -16.08 dBm, -17.36dBm at 877MHz and -14.44dBm, -16.44dBm, -19dBm at 946MHz as shown in Fig. (8). For MTN the highest value is -19.28dBm at 955MHz. The maximum power density for Y Company are -21.61dBm at 934MHz. For Sabafon operator the highest value is -14.44dBm at 946MHz. The maximum power density for Yemen Mobile Company are -11.67dBm at 977MHz.

Fig. 7. Mapping RF radiation levels along main roads around Sana'a University.

Fig. 8. The highest values with its frequency for street mapping measurements.

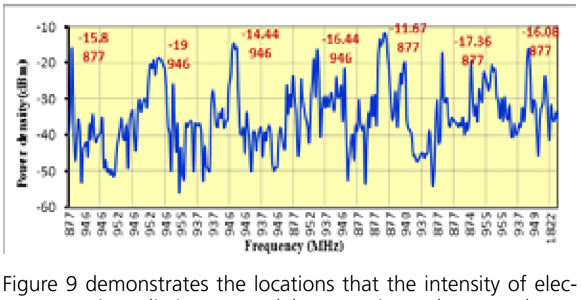


Figure 9 demonstrates the locations that the intensity of electromagnetic radiation around base stations along roads are the highest. The strongest measured values were at Sana'a university and around Mathbah Bridge. They were -11.67dBm at 877 MHz, that is, 6982µw/m² (1.623v/m) and -14.44dBm at 946 MHz, that is, 6962 µw/m² (1.62 v/m) consecutively. The maximum value was illustrated by LCS as shown in Fig. 10.

Fig. 9. Maximum values and its locations for street mapping measurements.

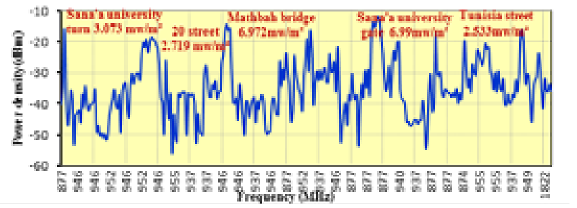
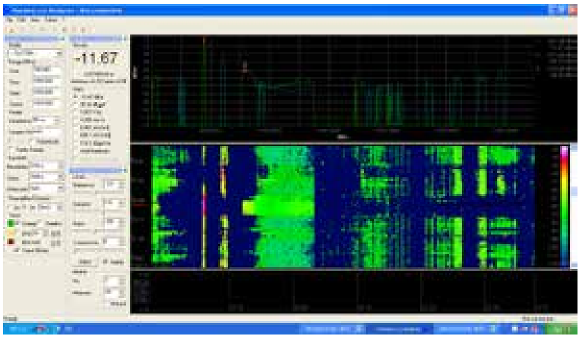


Fig. 10. LCS program illustrate the highest value at street mapping measurements.



Conclusion

This study found that the power densities were lower than ICNIRP reference level and FCC limit for general public, and close to some national standards like Italian, Bahraini, Kuwaiti standards and it had exceeded Salzburg limit. However, the obtained data is still not enough to conclude firmly that people may not have adverse health effects from EMR transmission from mobile phone networks. The intensity of the electromagnetic radiation was measured and 240 readings taken for 1440 minutes. The results showed that the variations have no systematic pattern during a specific time which it varies from time to another. For mapping measurements. The results further showed that the power densities of streets level in roads were significantly different. The intensity of electromagnetic radiation was higher in the locations wherever the buildings didn't shield the beam of antenna. We found that the highest measured values were in Sana'a University gate and around Mathbah Bridge. We would like to point out that the majority of readings in this study match ICNIRP standards. However, there are many irregularities in the installation of the BTS towers at a height for example of three meters or 6 meters above the ground in the middle of crowded populated areas. During the coming period, we will inform the mobile operating companies to respect ITU-T recommendation. In addition, we will participate in awareness the Yemeni community on non-ionizing radiation.

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