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Investigation of EMF Radiation From GSM Base Stations and Mobile Antenna Towers in Different Locations–Libya

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***Abstract*— Cellular and wireless technology have high growing and demand worldwide. Some countries regulate the exposure and installation of radio frequency RF transmission stations. The purpose of this paper to assess the exposure of RF radiation from a selected cellular tower and mobile base stations antennas. Technology develops continuously, so the characteristics of radiation from electromagnetic field EMF sources expect to change in the power level and frequency of operation, which indicate of change of Human exposed level. This undertakes EMF surveys to investigate the levels of the power density of the global system for mobile communication GSM within some school buildings and compare the results with international standards for human exposure compliance.**

Keywords- *BTS, EMF Waves,* GSM, *Mobile Phones, Radiation.*

I. Introduction

Biological effect of EMF radiation depends on both the power level and frequency [1]. As the RF energy is directly proportional to the frequency, the shorter wavelengths of waves the more energy produces, that why level exposure varies depending frequency.

People are exposed every day to RF Radiation from both natural and man-made EMF sources. Exposure to RF radiation and its potential biological effects is becoming the subject of concern. The EMF levels continue to increase as technology growth. Libya has now fast growth in the telecommunication industry with no clear guidelines. Most of the providers are more concern about profits and deliver their service by increasing the coverage areas regardless of RF radiation concern. Accordingly, it becomes necessary to manage and monitor the levels of transmitted energy by such sources.

This study discusses measurements and survey of RF radiation that produced by GSM system in some locations in the city of Tripoli.

II. Biological Effects

The biological effects of RF radiation can be classified as *thermal* and *non-thermal* Effects. Thermal impact are generally associated with the heat produced by EMF sources in a specific area. The thermal effect has sufficient energy to make an increase in the temperature of the human body (e.g. exceeding 1 °C) in a level above 4w/kg "watts per kilogram". Non-thermal effects are associated with the amount of energy absorbed by a biological system that may cause changes in the system properties. Many studies and researches show that the maximum increase in temperature of the body exposed to GSM with 0.25 Watt power level antenna at 900 MHz and 1800 MHz were less than 0.1°.

III. International Standards

Various international guidelines and recommendations are implemented for protecting people from RF exposure. The safety limit is not an exact line between safe and risk; it provides a means of protection. The expected effect occur at levels of exposure results in significant heating of part or whole body.

The International Commission on Non-Ionizing Radiation Protection ICNIRP develops international guidelines and scientific advice on limiting exposure to non- ionizing radiation. ICNIRP limits are used in this study as a reference for comparison of the power measurements. Table I shows ICNIRP limits for potential exposure to EMF from high-frequency sources such as mobile phone System.

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TABLE I
ICNIRP REFERENCE LEVELS FOR GENERAL PUBLIC EXPOSURE FOR FREQUENCY UP TO 300 GHZ INCLUDING GSM BAND

Frequency Range MHz	Equivalent Plane Wave Density (W/m^{-2})
400-2000	*f*/200
2000-300000	50

Notes: *f* is frequency *of* the EMF signal

The equivalent power density is considered the maximum allowable power level that ICNIRP recommends not to be exceeded.

Table II shows Specific absorption rate SAR limitations given by ICNIRP. The limit values where established based on the increase of temperature by about 0.1 °C and the limit is depending on frequency of the RF source.

TABLE II
SAR LIMITS RECOMMENDED BY ICNIRP

Exposure Characteristics	Frequency Range	Whole-Body Average SAR (W/Kg)
400-2000	*f*/200	0.4
2000-300000	50	0.08

Note: All SAR limits are averaged over six minutes period.

Note that allowable maximum estimated SAR value in relation to power density is about 45 W/m^2 for GSM-1800. According to ICNIRP and most of the reliable researches "it is very unlikely that a person could be exposed to RF levels from mobile stations in excess of standards limits. The purpose of this paper to evaluate RF radiation from GSM system against the international standard.

IV. GLOBAL SYSTEM FOR MOBILE COMMUNICATION GSM OVERVIWE

Cellular systems usually use a number of low power transmitters to create mobile cells site, these cells sized in the area according to the power level, which based on the number of mobile subscribers and area to be covered. The most common mobile station MS systems use transmission power level range of about 5-20 W, while base transceiver station BTS systems have a power range of 20-320 W.

The most commonly used GSM systems operate in frequency ranges of 900 MHz and 1800 MHz bands. GSM-1800 provide more bandwidth and fewer power requirements than GSM-900 systems. Normally GSM antenna has gain about 15 dBi led to an increase in the total radiated power. The GSM 900 and GSM 1800 specification are shown in Table III [4].

TABLE III
GSM POWER AND FREQUENCY SPECIFICATIONS [4]

System	GSM 900	GSM 1800
Downlink Frequency	935-960 MHz	1710-1785 MHz
Uplink Frequency	890-915 MHz	1805-1880 MHz
Modulation	GMSK	GMSK
Typical Mobile Transmit Power	2 W	1 W
Maximum Base Station Transmit Power	320 W	20 W
Maximum Distance	35 Km	8 km

Note: GMSK IS Gaussian Minimum Shift Keying

GSM phones can emit more than twenty times more radiation compared to Code division multiplexing access CDMA phone systems and accordingly the use of CDMA of a better choice for reducing the average RF radiation [5].

V. RFI AND MIDICAL DEVICES

Using cellular communication near medical devices can increase the risks of electromagnetic interference EMI on the devices, which can become a potential problem. Many studies report that medical devices, such as pacemakers and other medical devices have failed to operate properly because of interference from other RF sources. The powered wheelchair is an example of sensitive equipment's to RF interfering. One study shows radiofrequency interference RFI from two-way police radios 'walkie talkies' or even mobile phones causing the electronic wheelchair to drive itself into traffic put the patient at high risk [6]. Another example of RFI happened in Patient Monitoring System PMS: In 1987, PMS failed to produce sound alarms notifications because of RF interference, patients are reported to have died because of late response [7].
IEEE Committee on Man Radiation COMAR recommends that medical devices be properly shielded and increasing electromagnetic capabilities in EMF environments.

VI. EMF RADIATION TYPES

EMF radiation is classified according to its energy into two types: Ionizing and non-ionizing, Ionizing radiation has sufficient energy to remove electrons from atoms resulting in tissue damage, includes X-rays and gamma rays where frequency above 10^{15} HZ. Non-ionizing radiation does not have sufficient energy to cause ionization. It includes radio waves, microwaves, infrared, ultraviolet, and visible radiation.

VII. EXPERIMENTAL PART

EMCO 3115 Ridged Waveguide Horn Antenna and spectrum analyzer were used to collect measurements of power emitted by RF sources. The EMCO 3115 Antenna is a linearly polarized broadband antenna with excellent characteristics within the frequency range of 1 GHz to 18 GHz. It is designed especially for RF measurements and in evaluating high-frequency RF sources. The 3115 has features

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low VSWR, high power handling 500 W and broadband operation spectrum. This antenna used with the spectrum analyzer for site survey and measurements. Frequency scanned through the BST electromagnetic frequency range 800-1800 MHZ at a different distance from BTS. The double-ridged waveguide horn antenna showed in figure 1 which typically used by the universal mobile telecommunications System and has antenna gain shown in figure 1 with the spectrum analyzer.

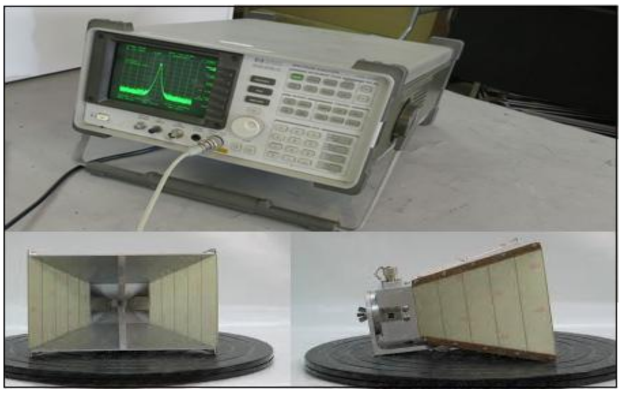

Figure 1. Double- ridged waveguide horn antenna with spectrum analyzer

The antennae are connected to the spectrum analyzer through a 10-meter length RG 213 cable which has attenuation is evaluated from 0.5to 1 dB according to operating frequency. The spectrum analyzer allows displaying a graphic of the measurement results. The frequency range covered during measurements was from 800 MHz to 2.2 GHz. The amplitude displayed by the analyzer in *Root Mean Square* RMS value.

A. *Calculation of Power Density:*

The spectrum analyzer measure amplitude in millivolts (mV). The following equation used to convert the received voltages into electric field strengths.

$$E = VrxAf\,10^{L/20} \tag{1}$$

Where E is the received electrical field, V_{rx} is the voltage received by the antenna, *Af* is the antenna factor which is defined as the ratio of the electric field at the antenna to the voltage generated by the antenna, and L is the cable loss in dB.

$$Af = \frac{\text{field strength at antenna} \quad (\text{V/m})}{\text{Voltage produced by antenna} \quad (\text{V})} \tag{2}$$

Figure 2 shows the EMCO 3115 the antenna factor over the operating frequency range, while the antenna gain is in figure 3.

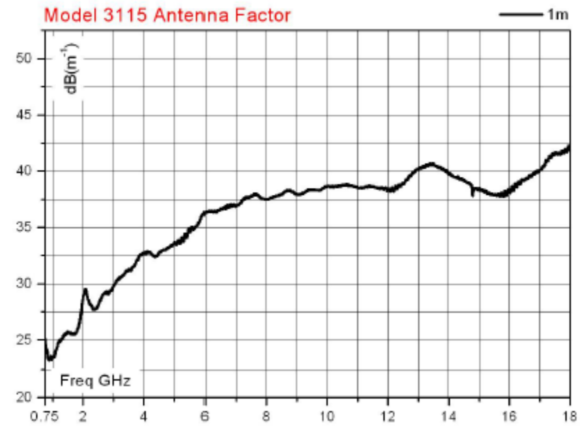

Figure 2. Model 3115 Typical Antenna Factor

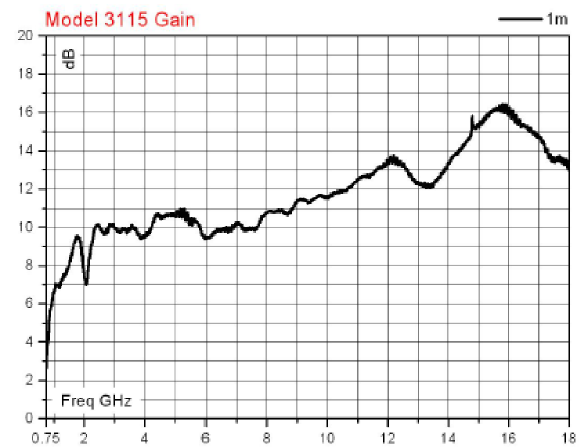

Figure 3. Model 3115 Typical Antenna Gain

For the power density, it is simply calculated using the following equation

$$Pd = \frac{E^2}{\eta} \tag{3}$$

Where η is the intrinsic impedance of free space equal to about 377 ohms and P*d* is the received power density.

Many factors to be considered while measuring the power emitted from the antenna including time average, polarization , and frequency of the transmitted power. This study aims to measure the maximum power at a different distance from BTS antenna.

B. *Exposure Assessment:*

For exposure to radio waves, *exposure quotient* needs to be calculated it is the ration of power density measured Pd_{ms} to the power density of standard limit P_{dst}.

$$\text{Exposure quotient} = \frac{Pdms}{Pdst} \tag{4}$$

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Where P_{dms} is measured power density and P_{dst} is the maximum allowable power density defined by the international standard.

If exposure quotient is less than unity, compliance with ICNIRP guidelines is demonstrated and power level to be considered acceptable.

C. Site Selection

In this study, we choose the Site of measurement based on the following conditions.

- Direct and long-term exposure.
- Antenna mounted on top of School, hospitals, and buildings.
- Densely populated areas near to BTS.

We selected the school building because of some studies consider children absorb energy differently than adults because of differences in their anatomies and tissue composition, and because their bodies are still developing, children may be more susceptible to EMF radiations [8].

D. Devices Calibration and Measurement Accuracy

The accuracy constitutes the biggest problem in EMF measurements. Accordingly, the calibration of equipment's is the most important part before any measurement procedure.

Power density measurements performed with an Advantest spectrum analyzer and calibrated with the directional antenna as a reference. EMCO 3115 Antenna shows great performance and accuracy and has been used because of it is superior specification over a wide frequency band.

E. Sites Measurement

Sites location details: 1- Alfateh University.2- Elfernaj Secondary school, 3- Alittihad school for basics education 4- Tripoli clinic airport road: all sites located in Tripoli the capital city of Libya.

Note: In some locations, different sources of RF radiation observed including TV broadcast station and telecommunication towers, also some of the microwave transmitter which will be included in the receiving signal in the frequency range of 700 MHz to 2 GHz.

The power density measurements were conducted under daylight in real-life. The antenna was directed in various positions in order to receive maximum power densities. For interest (GSM900, GSM1800) frequency band measurements conducted for 6 min scanning time. The power density levels are given in $\mu W/m^2$ (microwatt per square meter). In addition, results were calculated in consideration of antenna factor and gain as well as cable and connector losses.

Final measurements were compared with other international measurements of same RF sources shows that all measurements were satisfied the comparison.

In these selected sites a large number of students are living and stays for a long time near to BTS mainly GSM antennas and it is expected to have long time exposure to EMF Radiated from Antenna cellular towers.

Distance from the RF source was taken for selected locations at different antenna heights and orientations from RF source.

F. Measurement Results

The results of power measurements were processed and maximum value in each frequency range has been selected to compare against the international standard limitations.

The results translated to charts of power against frequency which is showed in figure 4 indicates to the final result in comparing the standard power limit.

The power density levels are given in $\mu W/m^2$, values are displayed in table III with respect to the *line of sight* in the proximity of the antenna (<100 m).

The measured power density ranged between 400 $\mu W/m^2$ to 1200 $\mu W/m^2$ "maximum obtained value at each measured frequency".

The highest power density levels were found is about 12900 $\mu W/m^2$ were recorded very close to the antenna on the upper floors of the building. Although these maximum recorded value considered the special case where not common to have people at this location.

The maximum power level in the area of interest was found to be ranged of 2500 $\mu W/m^2$ to 5000 $\mu W/m^2$ which is more considered for concern as people exposed to RFR for a long time daily.

The power density was noticed to be increased with height from ground level in the main beam of antenna radiation and reached its maximum value approximately 1300 $\mu W/m^2$ at the window (about 9 m height) of the building with the line of sight from the antenna.

This measurement confirms that the exposure level is not only depending on the distance from RF source but it should depend on the location of the exposed person compared with antenna properties including the main beam of the radiation, and the characterizations of EMF waves like frequency and polarization. Some samples of power density are listed in Table IV.

TABLE IV
SAMPLES OF MAXIMUM MEASUREMENT

Frequency *f* (MHz)	Measured Power Density $\mu W/m^2$	ICNIRP Power Density Level (*f*/200) $\mu W/m^2$	Exposure Quotient
850	1550	4250000	3.65E-09
900	8450	4500000	1.88E-08
910	12950	4550000	3.41E-10
920	8400	4600000	1.84E-09
930	8500	4650000	2.78E-09
1750	1350	8750000	9.71E-11
1800	9680	9000000	1.44E-10
1820	7680	9100000	1.48E-10
1830	2410	9150000	5.11E-10

Note: The Exposure quotient values shows that the measured power level is found to be Orders of magnitude lower compared with the maximum exposure levels established by ICNIRP.

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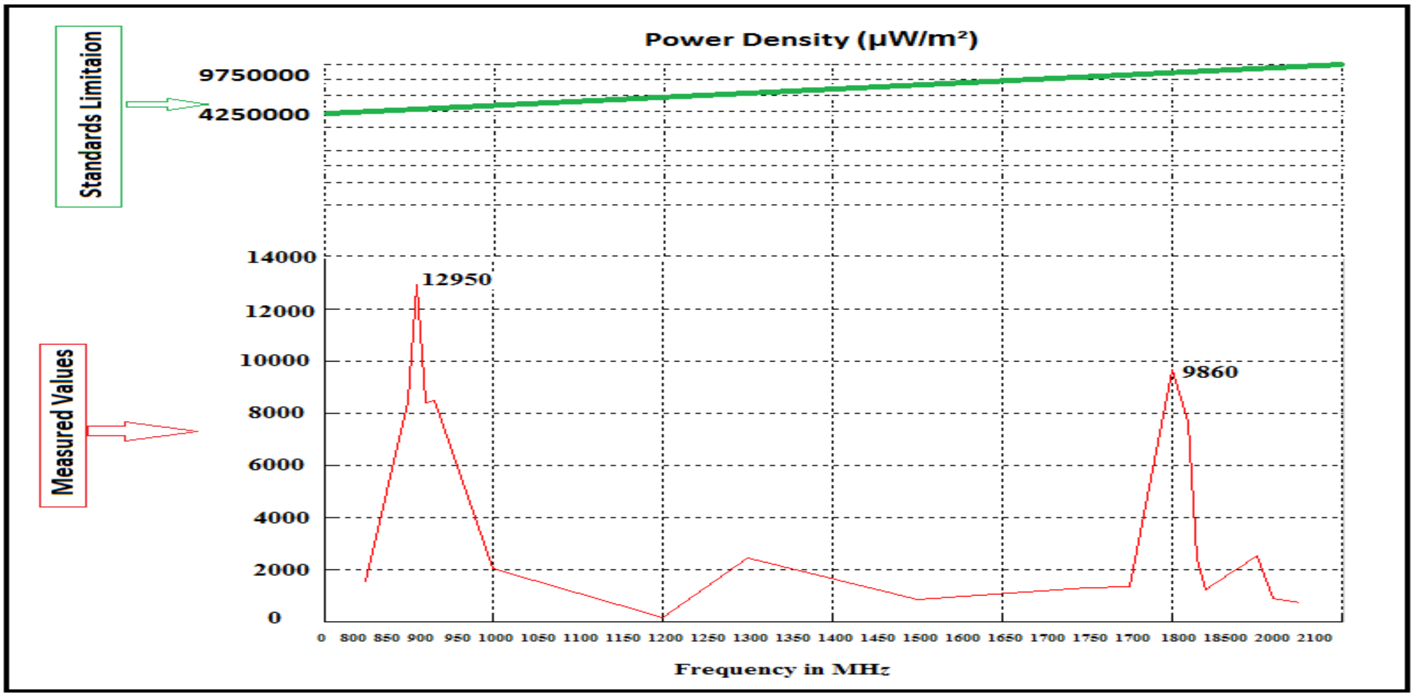

Figure 4. Measures results of all sites VS standard level

VIII. CONCLUSION

The highest RF power levels in all locations were found the line of sight and according to antenna setup where main radiation beam concentrated. The power reduced as the meet of obstacles indoor measurements. Figure 4 Shows the final measurements compared to the allowable standard level.
The measured RF power density was much below the international standard recommended limit values. Accordingly, the cellular phone tower and BTS station under this investigation is to be considered safe in compliance with protection standards.

The results were compared with ICNIRP standards and show that the value of power density at general people exposure areas is about a thousand times smaller than the ICNIRP guidelines and hence the average values of the SAR estimated to be much lower than the Standards limitation.

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