GSM Base Station Radiation Level: A Case Study of University of Nigeria Environment

Mamilus . A. Ahaneku, Anthony . N. Nzeako

Abstract :- Electromagnetic radiations at high frequencies have varied effects on different biological media. Investigations are on going to ascertain the effects of electromagnetic radiations on human, especially with the proliferation of communication masts in the cities. In this paper, efforts are geared towards the assessment of the level of impact on the environment especially as it concerns the pulsed signal at microwave frequencies. This paper will also offer some perspectives on the potential implications for human health exposure on the radiation should the exposure limit exceed the recommended safety zone of about 300 metres away from the base stations. Two measurement procedures were implemented here; one for determining the power density due to the base station of interest, the other for evaluating the total exposure within the university environment. The maximum level recorded at the various sites was 1.3 mW/m^2 while the total sum of radiation level encountered was about 2 mW/m^2. The investigated level was compared with the international safety level and was found to be below the recommended safety level as provided by international agencies such as ICNIRP and ANSI as examples.

Keywords: GSM Base Station, Radiation Level, Microwave Frequencies, Environment.

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1 INTRODUCTION

Many things have been said about electromagnetic radiation and its likely dangerous consequence(s) on the lives of the people living around its emission sites. This study offers a perspective on the potential implications of the pulsed signal at microwave frequencies currently used in GSM (Global System for Mobile communications) on human health. This perspective differs to some extent from that currently espoused by mainstream science. This paper also provides a much more holistic insight into the essential elements of the problem. Electromagnetic Radiation may be defined as an emission from electrical equipment [1]. It has been observed that the GSM technology of wireless communication produces constant pulsed microwave radiation [1]. Cellular base stations are transmitting continuously even when nobody is using the phone. It is known from a variety of scientific studies, including microwave engineering that significant biological effects result from non-thermal effects of extremely periodic pulsed high frequency radiation [1]. It is a thing of great concern to observe that most of the official high frequency (HF) public exposure measurements are conducted to observe the percentage of the current standard (international and national standards). The safety guidelines based on ICNIRP (International Committee on Non-Ionizing Radio Protection) recommendations, only takes into account the risk of thermal effect of high energy HF – radiation [2]. Exposure measurement which only centers on broadband and not on frequency selective measurements is inadequate [3].

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Based on this, only in very few cases one or more percent of the (thermal) guideline value is reached or exceeded close to antenna sites. It should be noted that exposure recommendations based on non- thermal effects are by far lower by many magnitudes [3]. Frequency selective measurements are also necessary to observe the cellular base station downlink frequencies and differentiate them from other radiation sources such as FM radio or TV transmitters. Limited information is available on the exposure to cellular base station radiation around residential areas at different distances and directions. In the early history of life and time of man on earth, lightning bolts were the mankind's only electromagnetic hazard [1]. But with the electrical revolution of the last century many new ones have emerged involving power lines at frequencies of 50Hz and 60Hz and radio transmitters at kilohertz (KHz) to gigahertz (GHz) frequencies. The question of hazard also comes from the unintentional exposure to radiation from high-power radio, FM, TV, radar, and wireless transmitters [1]. Worst still is the advent of GSM Technology and the proliferation of communication masts in both rural areas and urban cities. The generality of the populace are still not yet convinced by the promises of telephone operators even government agencies that the emissions (radiations) from such sites are low hence free from any ugly consequences.

2 BASE STATION RADIATION ON THE ENVIRONMENT

Here, we are assessing the various ways radiation may affect the environment. The power assigned to a given base station is determined from its coverage and capacity requirements. However, the operator's desire to use the licensed spectrum as efficiently as possible will tend to maximize powers used in every cell if not properly checked. Otherwise, looking at the cost implications of building a base station, the tendency to increase the coverage area may force the operator to go contrary to the regulations establishing it in order to maximize profit.

2.1 Base Stations Operating Frequency Of Interest

Published standards for base station transmitters provide specifications for manufacturers. Each GSM radio channel consists of paired uplink and downlink frequencies that are exactly 45MHz apart for GSM900 and 95MHz for

GSM1800[3]. Given the communication distances involved, 20W and 40W are the normal maximum powers for individual transmitters used with GSM900 macro cellular base stations [2]. It should be noted that these are the powers at the output of each transmitter and should not be confused with the power radiated by the antenna. Sometimes, powers radiated by antennas are referred to as averaged powers [1] From a GSM base station with more than one channel, there are thus a variety of reasons for variations in the transmitted power at any given time: how many channels are in use, how many of the time slots in the traffic channels are used, and whether DTX is used or not. (DTX is a function that inactivates the transmission if there is no voice detected – then only a sample of the background noise is transmitted. If DTX is used, it effectively reduces the average power by approximately a factor two.) Any attempt to characterise the exposure around a base station should take this traffic-dependent time-variation into account. Information from the operator of the base station on traffic statistics [3] could provide a basis on how this should be done. Options could include sampling (for average situation) and/or choosing a probable maximum traffic time (for worst case situation).

2.2 Exposure Variations With Distance From The Base Station

An antenna does generally have some directionality. Omni-directional antennas radiate in every direction (seen horizontally), while sector antennas effectively radiate in a (horizontal) sector. This will permit increased re-use of frequencies, as it will reduce interference – accordingly [4]; most base stations in high traffic density areas such as cities are of the sector type for this purpose. Sector antenna gain is between 10 and 20 dBi. This means that the emitted power may be between 10-100 times stronger in the intended directions compared to an Omni-directional antenna, while it will be correspondingly weaker in other directions. For example, the exposure behind a sector antenna could be 300 times weaker than in the main lobe [5]. In addition to this horizontal directionality, the antenna lobe will also have a strong vertical directionality, with a fairly narrow beam, which is often tilted slightly downward.

At a sufficient distance from the antenna (of at least 10-15 meters) the EMR exposure levels can be characterised by the power density in W/m^2. In the main lobe, and disregarding attenuation by other objects ("free space"), this power density will decrease with the square of the distance above 300m. On the ground, however, this distance variation will be more complex, as the highest level will be found at a distance from the antenna where the main lobe reaches the ground. Closer to the antenna, the ground level will be substantially lower than in the main lobe. Due to the existence of side lobes, the actual variation with distance could be rather complicated. Similarly complicated variations can also be found indoors, on terraces etc. At larger distances, where (often) buildings or hills will interfere, attenuation and/or reflections will cause an even faster overall decrease in the power density, but also cause substantial variation. A decrease of power density with distance as $1/r^2$ has been found to be useful for example, base station power calculation [6].

3 INTERNATIONAL EXPOSURE GUIDELINES

The most recent U.S. safety standard for human exposure to electromagnetic fields is given by [7]. In the RF-microwave frequency range of 100 MHz to 300 GHz, exposure limits are set on the power density (W/cm^2) as a function of frequency. The recommended safe power density limit is as low as $0.2mW/cm^2$ at the lower end of the frequency range, because fields penetrate the body more deeply at the lower frequencies. At frequencies above 15GHz, the power density limit is about $10mW/cm^2$, and most of the power absorption at such frequencies occurs near the skin surface [1].

3.1 IEEE Safety Standards

IEEE C95.1 – 2005 is the human exposure standard. The complete name is standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 KHz to 300 GHz. It is categorized as maximum permissible exposure (MPE) limits for controlled and uncontrolled environments as shown in tables A and B.

Table A: MPE Limits for Uncontrolled Environments

FREQUENCY (MHz)	POWER DENSITY(w/m^2)
0.1 – 1.34	1, 000
1.34 – 30	$1,8000/f^2$
30 – 400	2.0
400 -2,000	f/200
2,000 – 100,000	10
100, 000 – 300,000	Increases from 10 to 100

Table B: **MPE Limits for controlled Environments**

FREQUENCY (MHz)	POWER DENSITY(w/m^2)
0.1 – 1.0	9,000
1.0 – 30	$9000/f^2$
30 – 300	10
300 – 3,000	f/30
3,000 – 3,000,000	100

4 ESTIMATION OF POWER DENSITY

To estimate the power density within a GSM base station environment, we adopted a scenario where the antenna emits 5 watts of power per channel in a given location operating with four channels. It should also be recalled that the typical power radiated from outdoor antenna is between 5 watts and 10 watts per channel, which means that the total power from a base station could amount to some 40 watts depending on the number of channels and this also varies with time [5]. One channel (control channel) from each base station is always transmitting with essentially a constant power, regardless of the traffic intensity. Other channels (traffic channel) do only send when traffic requires. Table 1 shows the estimated values for transmit power of 20 W at antenna gain of 20 dB. Assuming a worst –case side lobe level of -5dB, the multiples of 50m up to 300m of the distance away from the base station is being considered. This is on the basis that power density decreases with the square of the distance away from the main beam [6]. This should be at a distance of above 300 meters [8]. The general expression for the power density represented by letter S, radiated by an arbitrary transmit antenna is:

$$S_{avg} = G_t P_t / 4\pi d^2 \quad W/m^2 \qquad (1)$$

where G_t is transmitter antenna gain in dB, P_t = power transmitted in watts d is distance in meters We assume free space condition in equation (1). But when actual measurement is carried out, equation (1) is no longer valid. Hence, another expression is adopted as shown in equation (2).

Peak power density,

$$S^{peak} = P_r G_r / 4\pi d2 = P_i (G-L)/A_e \qquad (2)$$

Or

$$S^{peak} = P_i (G-L)/A_e \qquad (3)$$

$$A_e = 0.13\lambda 2 \qquad (4)$$

P_i is the peak power measured in a specified direction in dBm; G is the antenna gain in dB,

A_e is the effective area of antenna, and L is the cable loss in dB.

Calculations

Assumed Power, P_t = 20W; Gain for main beam = 20dB; worst case side lobe level = -5dB (or 15dB). The cable loss also assumed as L =1.7 dB.

The coverage distance is limited at 300m, while multiples of 50m are used.

Recall from equation (1); power density, $S = S_{avg} = G_t P_t / 4\pi d^2 \quad W/m^2$.

When we convert the above equation into w/m^2, we obtain the values given in table 1.

The main beam is the region around the direction of maximum radiation. Thus, power density in the main beam is higher than that in the side lobes.

Table 1: Calculated power density values

Distance(d) in metres	Main beam, $S_{avg}(w/m^2)$	Side lobe, $S_{avg}(w/m^2)$
D1 = 50	0.043	0.013
D2 = 100	0.010	0.003
D3= 150	0.004	0.001
D4 = 200	0.002	0.0008
D5 = 250	0.001	0.0005
D6 = 300	0.001	0.0003

The calculated results in table 1 above, should be regarded as an over estimation of the power density experienced in real life situations. This can be regarded as free space values in the absence of attenuation, reflection and absorption in the real environment situations. Here, the maximum peak power density calculated is about $43mW/m^2$, in the main beam and 13 mW/m^2 in side lobe respectively. Let us now look at a case involving field measurement.

5 FIELD MEASUREMENTS

Two measurements procedures are implemented, one for determining the power density due to the base station of interest; while the other was for evaluating the total exposure in the university environment. When assessing simultaneous exposure to multiple radio signals with different frequencies, their effects are additive [9]. Total exposure can be expressed in terms of a quotient based on the measured power density, S of each detected signal and the ICNIRP reference level corresponding to the frequency of the signal, thus exposure quotient is equal to:

$$\sum_{i=1}^{Ni} \frac{Si}{Sref,i} \qquad (4.1)$$

where N_i is the total number of signals producing the exposure. An exposure quotient not exceeding unity indicates compliance with the ICNIRP guidelines [10]. Here, some selected base stations were visited and measurements taken in real life situation. The actual values measured were in peak power values as shown in table 2. It was converted to peak power density values as shown in table 3, using equation (3). The sites measured are four in number in different locations namely: Faculty of Arts (ARTS), Odim-Gate (ODIM), PG School (PG) and Staff Club (CLUB). The values were compared with the estimated values (free space values). This complied with the earlier statement that the free space values represent an over estimation of the power density in real life situation.

5.1 Peak Power Measured Values

Table 2: Peak Power measured at four different sites in dBm.

POLARIZATION	ARTS	ODIM	PG	CLUB
F1 = 936 MHz	-34.53	-43.06	-32.05	-28.63
F2 = 937 MHz	-49.16	-54.40	-38.52	-28.89
F3 = 945 MHz	-40.77	-51.44	-41.36	-50.50
F4 = 948 MHz	-53.53	-53.41	-40.51	-30.78
F5 = 951 MHz	-38.01	-28.65	-37.56	-34.88
F6 = 954 MHz	-38.85	-19.94	-35.28	-35.64

5.2 Peak Power Density Measured Values

Table 3: Peak Power Density obtained using equation (3) in mW/m2

POLARIZATION	ARTS	ODIM	PG	CLUB
F1= 936 MHz	0.040	0.005	0.070	0.155
F2 = 939 MHz	0.0038	0.0004	0.015	0.146
F3 = 945 MHz	0.009	0.0008	0.008	0.003
F4 = 948 MHz	0.0005	0.0005	0.010	0.095
F5 = 951 MHz	0.017	0.155	0.019	0.036
F6 = 954 MHz	0.014	1.153	0.033	0.031

See appendix B for the graphs on table 3.

6.0 RESULTS AND DISCUSSIONS

It was observed from the calculated values that the power density at the main beam is much greater than at the side lobes as shown in table1. It can be deduced that as the distance away from the base station increases, the power density decreases. But the power density variation is some how complicated looking at the measured values in table 3. It increases up to the point the main beam touches the ground and then decreases as it moves away from the main beam. There are factors responsible for these variations. Such factors include: Side lobe effects, attenuation and obstacles like buildings, trees, ground reflections etc. The measured values from the frequency selective equipment (spectran 6080 model) did not differ much from the estimated values. See the equipment set up in appendix C.

7 CONCLUSIONS

Frequency Selective equipment used was able to capture the range of frequencies required in this measurement. The power density variation is complex. The highest level of radiation was found at a distance where the main beam reaches the ground while the value obtained closer to the antenna is lower. Again, the presence of the side lobes makes the variations more complicated. The measured values showed a little contrast from the calculated values. We are not surprise because of some environmental factors such as attenuation caused by buildings, trees around the sites and reflections. The result of our study shows that it is not possible to exceed the maximum safety level standard given the present antenna gain and transmit power currently been used in cities across Nigeria. The outcome of the investigation shows a high level of compliance of the ICNIRP guidelines by some of the communication operators in the Nigerian environment. The maximum level recorded was 1.3 mW/m^2 while the total sum of radiation was about 2 mW/m^2 within the university environment.

APPENDIX A

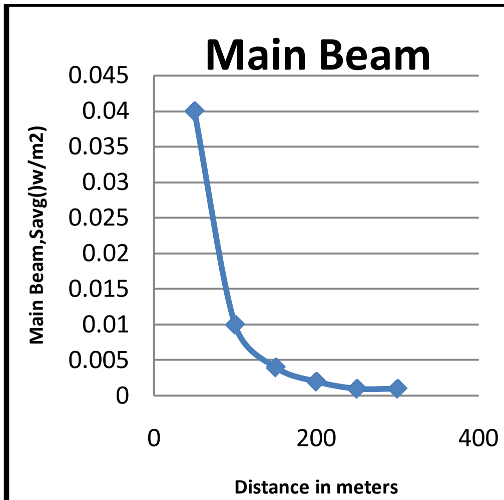

Fig. A1 Graph of power density versus distance

APPENDIX B

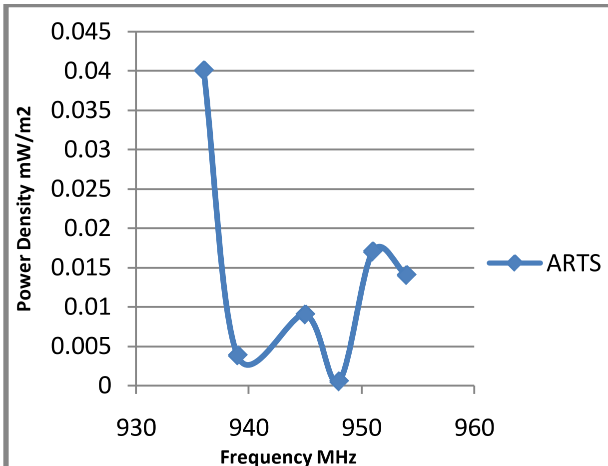

Fig. B1 Graph of Power Density versus Frequency

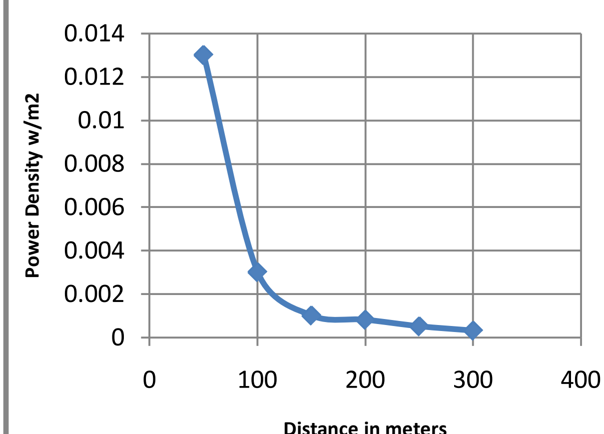

Fig. A2 Graph of Power Density versus distance in Side Lobe

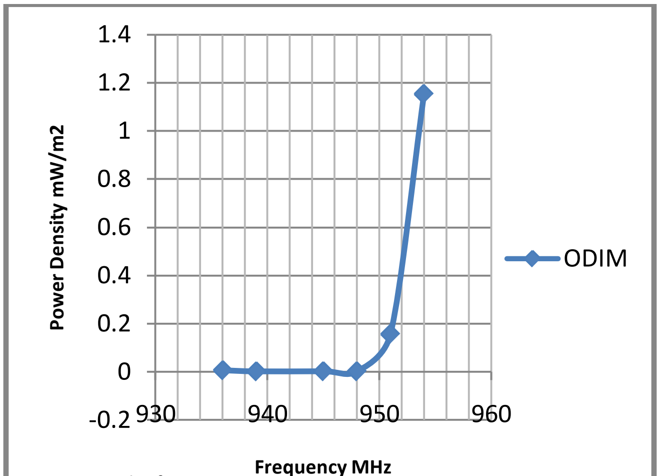

Fig. B2 Graph of Power Density versus Frequency

APPENDIX B Continued

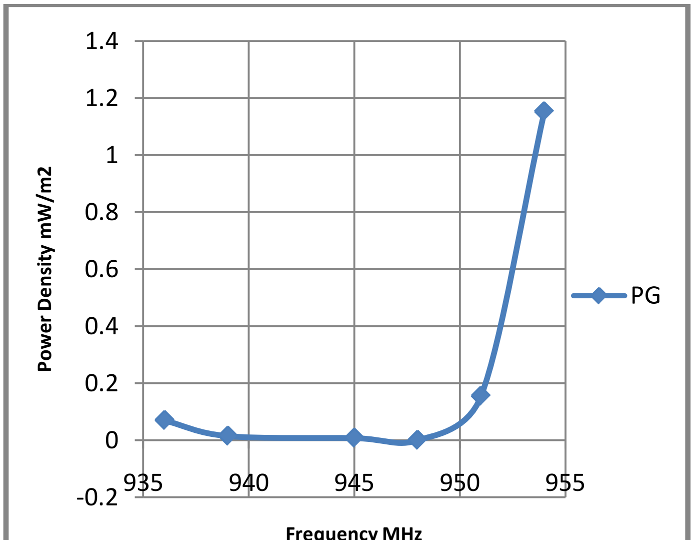

Fig. B3 Graph of Power Density versus Frequency

APPENDIX C

Fig. C1: Showing a typical base station in one of the sites.

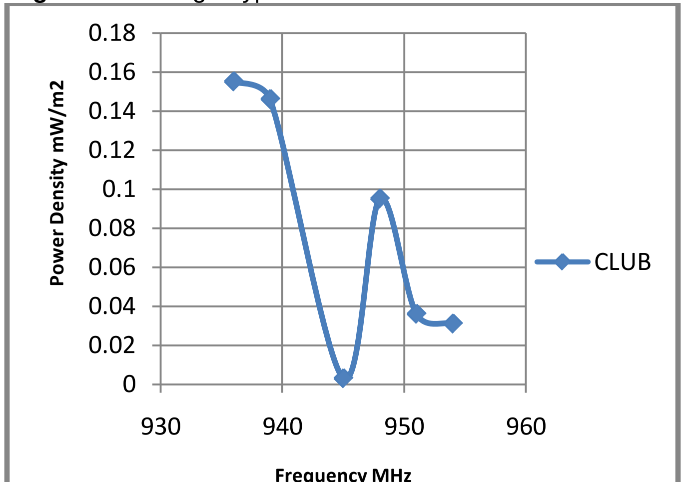

Fig. B4 Graph of Power density versus Frequency

Fig. C2: Showing the equipment set-up and members of the team.

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