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Assessment of Radiation Variations with Distance in the Vicinity of GSM Base Stations Antenna

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Abstract- Electromagnetic radiations from GSM (global system for mobile communications) base stations were measured at far fields at a distance above 50 meters away from the base station using hyper log antenna with Spectran 6080 (spectrum analyzer). The uncertainty of the measurement was taken into consideration during conversion from peak powers to peak power densities. In this paper, we analyzed the measured field values to see how the values differ and compared the field measurement with the simulation results. Also, the field result was compared with international safety level standard as given by ICNIRP, and was found to be about 0.06% lower. The result also showed that the peak power density decreases as we moved away from the base stations. The total obtained radiations level within the environment stood at 5.2284 mW/m2. This is even below the safety standard level as recommended. Finally, we looked at the implications of such variation within the environment.

Index Terms- Electromagnetic radiation; Spectrum analyzer; exposure variations; frequency selective; simulation.

1.0 INTRODUCTION

It has been observed that the GSM technology of wireless communication produces constant pulsed microwave radiation [1]. The cellular base stations are transmitting continuously even when nobody is using the phone. We know from a variety of scientific studies, including microwave engineering that significant biological effects result from non-thermal effects of extremely periodic pulsed HF radiation [1]. There are certain standard guidelines that are used to conduct HF public exposure measurements. These guidelines are based on International Commission on Non-Ionization Radiation Protection (ICNIRP) recommendations, which only take into account the risk of thermal effect of high energy [1]. And this high frequency radiation exposure measurement is conducted to observe the percentage of the current standard with only broadband (not frequency selective) measurements [1]. 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 therefore that exposure recommendations based on non-thermal effects are by far lower by many magnitudes. Frequency selective measurements are also necessary to observe the cellular base station downlink frequencies and differentiate them from other radiation sources as FM radio or TV transmitters [1]. Therefore very limited information is available on the exposure to cellular base station radiation around residential areas at different distances and directions to the antenna sites. This is what we have tried to investigate in the study.

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2.0 Related Work

In a related work, measurement of non-ionization radiation levels was carried out in an urban environment in Spain. In the work [2], the authors reported the results of such measurements performed in the city of Santander in Northern Spain. In this case, measurements were performed using four different types of instruments. The reason for using different equipment was to compare the measurements and know the possible errors in using different instruments. The highest observed value was 2.23 μW/cm². The measured values were statistically analyzed in order to determine the probability of not receiving radiated powers higher than 2.23 μW/cm². The mean value was found to be 0.27518 μW/ cm², with a standard deviation of 0.2973. Differences in the measurements performed were in the order of ±3 dB between instruments, which was however considered as satisfactory.

Some recent studies have also reported other several adverse effects on humans resulting from radiofrequency electromagnetic fields (RF-EMF) [3]. One of such studies investigated the effects on human sperm quality and fertilization potential [3]. In the work, highly motile human spermatozoa were exposed for an hour on 900-MHz mobile phone radiation at specific absorption rate of 2.0 W/Kg and examined at various times after exposure. The results showed that radiation has significant effect on sperm morphometric and sperm fertilization potential [3]; which could lead to infertility in humans.

Many other studies, including the recent publication by Dr. Fareeha Zafar [4]; an outcome of a survey work presented at a Science Technology Workshop & Exposition, University of Nigeria, Nsukka in June, 2013. The survey showed that radiation from GSM phones breaks DNA molecules in cultured cells within 24 hours. The presentation also supported the issue of fertility reduction in male sperm caused by radiation from GSM phones. The paper also revealed that health con-

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cerns are sometimes expressed by people who live or work closely to base station antennas located on towers or roof tops.

3.0 Materials and Methods

3.1 Modeling of Antenna Base Station

The power radiated by an antenna is a function of the number of radio channels per base station and also the number of mobile stations effectively connected to the base station. The effects of the number of traffic channels, the actual phone traffic and discontinuous transmission (DTX) on power radiated can be compensated for by using the following argument:

- The phone traffic can be described by introducing a multiplier ζ, where $0 \leq \zeta \leq 1$
- Allowance for discontinuous transmission is made by introducing a factor δ of value 0.5, in which it is assumed that the subscriber uses half of the connection time in talking as described above.

For a base station with N channels, one of which is the base control channel (BCCH), the total power in the main lobe antenna will be:

$$P_{rad} = P_{max} + \delta\zeta(N-1)\, P_{max} \qquad (1)$$

Assume $\zeta = 1$ and $\delta = 0.5$, then

$$(P_{rad})_{max} = P_{max} + 0.5(N-1)\, P_{max} = 0.5(N+1)\, P_{max} \qquad (2)$$

This occurs when all the channels are occupied as say during the peak hours.

Therefore, for a typical base station with 4 channels and for maximum traffic ($\zeta = 1$), we obtain

$$(P_{rad})_{max} = P_{max}[1+0.5(4-1)] = 2.5P_{max} \qquad (3)$$

If nobody is using the base station, the traffic is minimal, that is, $\zeta = 0$,,,',,,,,,,,and minimum value o the power radiated is then given by:

$$(P_{rad})_{min} = P_{max}[1+(4-1)0.5x0 = P_{max} \qquad (4)$$

In this case, only the BCCH is transmitted (control channel)

From '' (3),'' and ''(4),'' the incident power to the ground surface originating from one base station with four (4) channels has the value between:

$$P_{max} \leq P_{rad} \leq 2.5\, P_{max}$$

For mast that is host to a number of base station antennas each with N_i channels, the maximum power radiated is a superposition of the power radiated from each radiator. Thus:

$$(P_{rad})_{max} = \sum_{i=0}^{n} 0.5(Ni+1)pi \qquad (5)$$

P_i is the power radiated per channel by antenna i with number of channels N_i

These predictions may be modified by incorporating the effects of power losses L. Hence, when losses are incorporated, the equation for power density now becomes:

$$\text{Power density (S)} = 0.08\, N/R^2 x\, 10^{(G(\phi,\Theta)-L)/10} \quad W/m^2 \qquad (6)$$

$$\text{Power density (S)} = 0.08\, N/R^2 x\, 10^{(G(\phi,\Theta)-L)/10} \quad W/m^2 \qquad (7)$$

This is a case of assumed real condition because the effects of losses are incorporated.

Equation (7) represents the mathematical models for the simulations of the power density (S), under a free space and assumed real conditions, respectively.

3.2 Simulations of the Power Density

Here MATLAB codes were developed for the simulation of the power density.. The simulation shows the variation of power density with distance at any assumed antenna gain. This was done for three different values of antenna gain using '' (7),''. The equation represents a plane wave approximation at a far field, where cos ϕ or sin Θ is unity; based on the assumption that $\phi = 0$ and $\Theta = 90^0$. Again, ''(7),'' represents free space and assumed real conditions, respectively.

In the mobile – radio environment, it is commonly assumed that the probability density function (pdf) of angular wave arrival P_r (Θ, ϕ) is uniformly distributed in both azimuth angle ϕ and the elevation angle Θ. But in practice, it is not true because the actual distribution of elevation angle Θ is not exactly uniform and thus causes slight differences in the measured data [5].

3.3 Field Measurement Method

In this study, the portable EMF measurement system, Spectran HF 6080 model, is used to measure the peak power from the mobile base stations. It is a professional piece of equipment which allows measurement of high frequency fields. It is also a frequency selective equipment which is calibrated between 0 to 1GHz (for GSM 900) and between 1 to 2 GHz (for GSM 1800). The Measurement error Eexpectancy (MEE) stood at ±3dBm, as was stated earlier in section 2, and this concerns the measurement uncertainty. This means that after measurements, the value 3dBm is to be added to compensate for the measurement inaccuracy. Example, if -45dBm is measured, adding 3dBm to it gives -42dBm. Two measurement procedures were implemented, one for determining the power density due to the base station of interest, and the other for evaluating the total exposure due to RF (radio frequency) sources transmitting across a wider spectrum.

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Fig.1. Research Team Setting up the Equipment.

3.3.1 Measurement of Power Density

To measure the power density from a mobile base station, the equipment was set-up in the vicinity of the base station. The equipment consists of three main components, which are Hyper Log 7025 Measurement Antenna, Spectran-HF 6080 and communication software installed in a laptop (Aaronia AG Software), as shown in fig.1. The Spectran-HF 6080 was connected to a Laptop for data logging. This is because the Spectran-HF 6080 has low memory capacity that will accommodate large data. When assessing simultaneous exposure to multiple radio signals with different frequencies, exposures due to individual frequencies should be combined since their effects are usually additive [6]. The 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:

$$\sum_{i=1}^{Ni} \frac{S_i}{S_{ref}}, i \qquad (8)$$

where Ni is the total number of signals producing the exposure, S_{ref} is the reference level as given by ICNIRP and S_i represents the power density measured from each base station.

An exposure quotient not exceeding unity indicates compliance with the ICNIRP guidelines [6]. Our main concern here is to find the peak power density since the measured values are in peak power. To do this, equation (2) will be useful since the required parameters are known

$$Speak = (10^{(P-G)/10}/1000)*(4*\pi)/\lambda^2 \ [16] \qquad (9)$$

Where Speak represents the peak power density in (W/m^2), P is the measured peak power in (dBm), λ is the wavelengthh of the transmitter frequency (m), and G is the antenna gain (dBi) and the measurement uncertainty correction was assumed to be ±3dB.

4.0 Results and Discussion

This study sets out to determine the level of electromagnetic radiations by GSM Base Stations around their immediate environment. There are certain standard guidelines that are used to conduct high frequency public exposure measurements. These guidelines are based on International Commission on Non-Ionization Radiation Protection (ICNIRP) recommendations.

4.1 Simulation Results

In section 3.1, we were able to develop a mathematical model that could be used to estimate the level of electromagnetic radiations from GSM Base Stations, and to determine the level of compliance using international safety guidelines [ICNIRP]. In this section, we have presented the results obtained from both simulation and field measurements. The field measurement was conducted using frequency selective equipment instead of broadband equipment to enable us collect data within the range of frequencies specified for GSM base stations. This was done to eliminate unwanted interferences and helped to give a quantitative analysis and assessment of the impact of electromagnetic radiations from GSM Base Station antennas. Here, the effects of losses were incorporated unlike in the case of free space condition. The results are shown in fig.2. , fig.3. , and fig.4. , respectively.

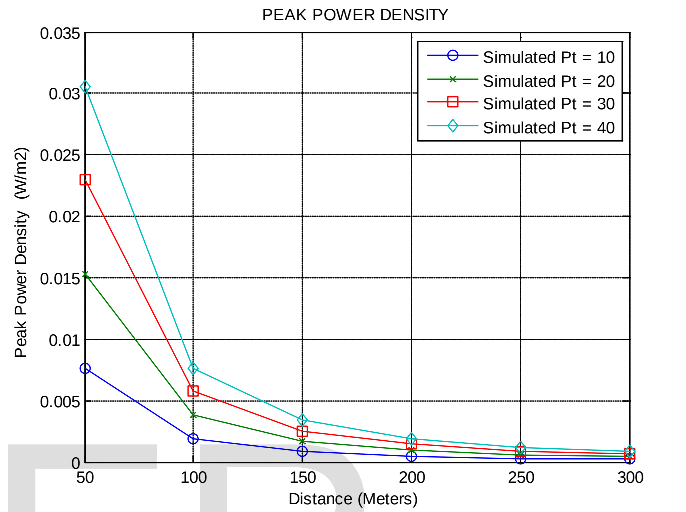

Fig.2. Graph of Power Density variations with Distance at Antenna Gain = 10dBi; Losses = 4dB.

The graph shown in fig.2. was generated by using antenna gain of 10dBi, and assumed losses of 4dB. The same assumed powers of 10W, 20W, 30W, and 40W were also used as shown in the legend.

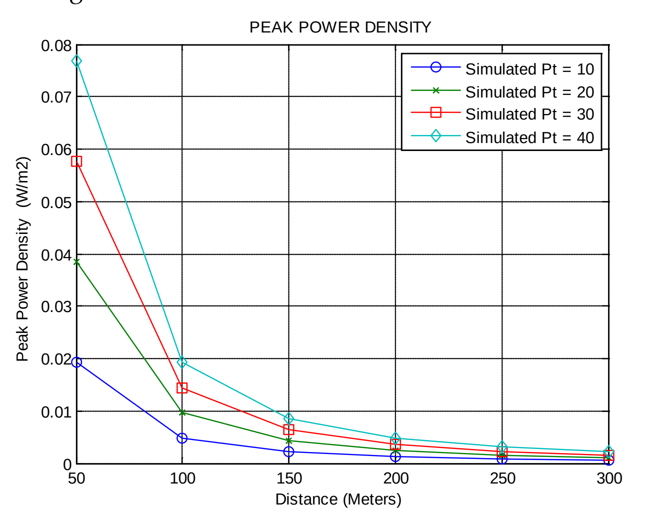

Fig.3. Graph of Power Density variations with Distance at Antenna Gain = 15dBi; Losses = 5dB.

In fig.3. above, antenna gain of 15dBi and 5dB losses were used during the simulation. Other assumptions were also made as above in terms of transmitted powers of 10W, 20W,

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30W, and 40W.

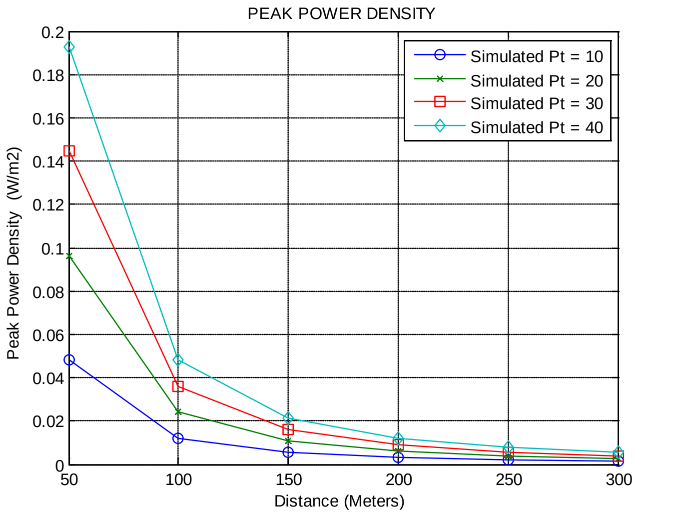

Fig.4. Graph of Power Density variations with Distance at Antenna Gain = 20dBi; Losses = 6dB

Fig.4. presents the result of the simulation when antenna gain of 20dBi and assumed losses of 6dB were used. Other assumptions as in the previous cases remain the same.

4.2 Field Results

Table 1, table 2; show measured data collected at four different locations for GSM 900 and GSM 1800, respectively; while Table 3, table 4; each represents the values calculated from table 1, table 2, respectively. The measured data were recorded in peak power values with units in dBm, while the calculated values were converted to peak power densities and expressed in mW/m². This is because radiation levels are expressed in terms of power density levels with units in W/m². Both tables 3 and 4 are also shown graphically in fig.5. and fig.6., respectively. Table 5 gives the summary of the pollution levels observed in all the locations.

Table 1
Measured Peak Power GSM 900 (dBm).

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

Table 2
Measured Peak Power of GSM 1800 (dBm).

POLARIZATION	ARTS	ODIM	CLUB	PG
1825 MHz	-41.69	-58.01	-43.80	-41.63
1837 MHz	-42.06	-51.88	-42.64	-50.07
1840 MHz	-43.87	-45.98	-47.48	-51.75
1843 MHz	-43.5	-43.87	-49.32	-51.26
1846 MHz	-43.18	-41.38	-50.74	-53.34
1849 MHz	-44.03	-42.13	-50.17	-53.42

Table 3

Calculated Peak Power Density of GSM 900 (mW/m²)

POLARIZATION	ARTS	ODIM	CLUB	PG
936 MHz	0.0865	0.0121	0.3360	0.1532
939 MHz	0.0029	0.0008	0.3172	0.0345
945 MHz	0.0105	0.0017	0.0022	0.0183
948 MHz	0.0209	0.0011	0.2094	0.0222
951 MHz	0.0400	0.3454	0.0822	0.0443
954 MHz	0.0333	2.5920	0.0697	0.0758

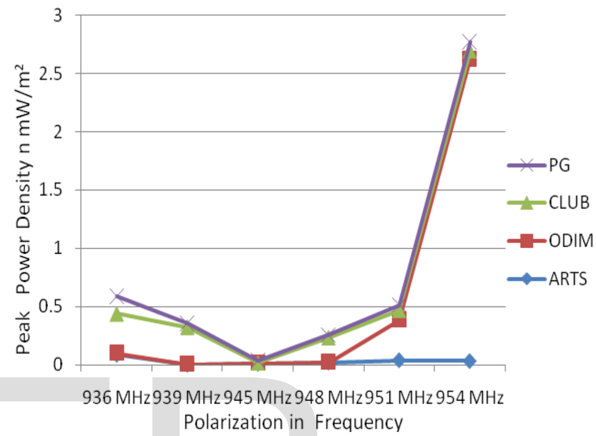

Fig.5. Peak Power Density of GSM 900 (mW/m²) showing Exposure variations

Table 4
Calculated Peak Power Density of GSM 1800 (mW/m²)

POLARIZATION	ARTS	ODIM	CLUB	PG
1825 MHz	0.0628	0.0014	0.0386	0.0637
1837 MHz	0.0599	0.0062	0.0524	0.0094
1840 MH..	0.0395	0.0243	0.0172	0.0064
1843 MHz	0.0430	0.0395	0.0112	0.0072
1846 MHz	0.0463	0.0701	0.0081	0.0044
1849 MH	0.0381	0.0590	0.0092	0.0043

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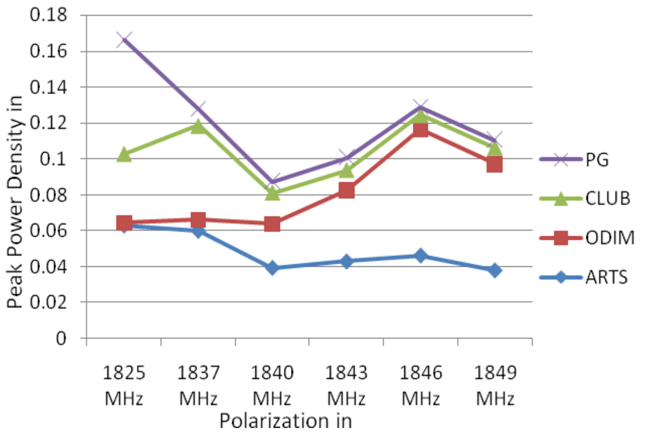

Fig.6. Peak Power Density of GSM 1800 (mW/m^2) showing Exposure Variations.

Table 5
Summary of Pollution Levels (mW/m^2)

LOCATIONS	GSM900	GSM1800
ARTS	0.1941	0.2896
ODIM	2.9531	0.1945
CLUB	1.0167	0.1367
PG	0.3483	0.0954

4.3 Analysis of Results

This section presents an analysis of the above results according to the stated aims and objectives of this work. In this study, we used technical data on antenna parameters from the literature for our simulations. Such parameters include: antenna gain, losses, etc. [7],[8],[9]. The ICNIRP recommends power density safety level of about 4.5W/m^2 for general public exposure [10],[11]. This covers the frequency range between (400 MHz to 2,000 MHz) in the far field. Far field here refers to distances greater than 10 metres away from the base station antenna [5]. The implication is that, any radiation level (in terms of power density), found greater than the safety level standard (ICNIRP) may have serious health problems if it is in contact with humans. This might be the reason(s) why Nigerian Communications Commission (NCC) forbids the erection of GSM Base Stations near residential areas as found in [12]. In compliance to this, a GSM base station situated very close to one of the buildings in one of the faculties in the University of Nigeria, Nsukka campus was not energised because of this prohibition law. It should be recalled that Federal Government allayed fears over GSM Base Stations Emissions as found in [13]. Again, a newspaper in Nigeria also reported about Cancer clusters at phone masts not quite long ago as found in [14]. All these are sources of worry to the citizenry and hence the situation needs to be addressed through a proper study. The outcome of this finding is geared towards drawing some useful conclusions on the matter.

Table 6
Measured Values from Locations per Distance (m)

DISTANCE (Meters)	ODIM (mW/m^2)	ARTS (mW/m^2)	PG (mW/m^2)	STAFF CLUB (mW/m^2)
50	0.0038	0.0272	0.0541	0.1060
100	0.0003	0.0009	0.0008	0.0079
150	0.0005	0.0065	0.0057	0.0007
200	0.0003	0.0003	0.0070	0.0614
250	0.1088	0.0126	0.0139	0.0326
300	0.8128	0.0105	0.0238	0.0219

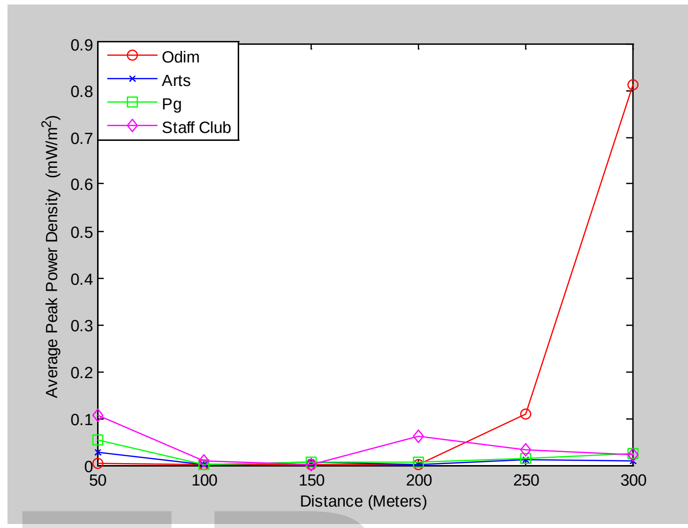

Fig.7. Graph showing distance variations with averaged peak power density

4.4 Observations

There was a noticeable rise and fall of peak power densities as recorded in the above tables, and illustrated by graphs in fig5., fig6., and fig7., respectively. This may be attributed to the rate at which the base stations were being accessed by the subscribers at the point of measurement, or, other factors such as attenuation, shadowing effects, etc. as earlier mentioned in the previous sections [8],[9],[15],[16],[17]. The power density also might drops due to congestion or over loading. But the very low measured values may have been distorted by ambient noise [2]. The measured field values were compared with the estimated values, and our experimental results have shown that simulation is an over estimation of values. This is because measurement of RF fields is a complex issue and requires complex equipment. Any simple method of assessment will produce over estimates of values [18].

The effects of antenna gain on the values obtained were such that high antenna gain resulted in high peak power density values. This can be seen from the simulated results. Moving away from the antenna showed a decrease in the peak power density. But, by our predictions, the peak power density was expected to increase as one moves away from the antenna. The increase will continue until it reaches a point of maximum radiation where the antenna beam reaches the ground, after which it starts to decrease by a factor (1/r^2)[7]. Again, looking at the simulated results, we noticed that the

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highest peak power density was about 800mW/ m^2, which occurred at a maximum transmitted power of 40 Watts. And from the measurement results, we noticed that at ODIM location, 2.9531 mW/m^2 was observed as the maximum for GSM 900, whereas, at ARTS location, we also observed 0.2896 mW/m^2 maximum for GSM 1800. This also agrees that the simulation results over estimated the peak power density values. Even though simulation presented over estimation, but, there were other factors that may have influenced the measured results. Such factors include: the number of channels, presence of trees, buildings, around the locations and the antenna height etc. [2],[17]. All these are the contributory factors which affected our readings and they could be found around the locations we visited. We noticed more trees at PG, and Club, than in other locations. Also, the numbers of channels observed were six (6) in each case, except for Club, which has 3 channels. These also affected the readings. Table 4.5 gives the sum total of the peak power densities measured in each of the locations for both GSM900 and GSM1800, respectively.

It has earlier been stated in section 2, that the presence of obstacles like trees, building etc around base stations cause attenuation of signals. These affected our reading adversely. Notwithstanding, within the limits of experimental errors, our measurement was still within our predictions. That is, the farther away one is from the base station, the lesser the radiation doses he/she takes. In all, the total power density level measured was more at Odim with a value of 3.1476 mW/ m^2, followed by the Club with a value of 1.1534 mW/ m^2. Others were the faculty of Arts, with a value of 0.4837 mW/ m^2, and the PG School, with a value of 0.4437 mW/ m^2. The total radiation level in the environment under discussion stood at 5.2284 mW/m^2.

5.0 Discussion

From the data collected, one would expect a decrease in power density but it seems there is no significant decrease in that direction but in reality it is not so. It appears to be because of the distance we limited our measurement (50 – 300) metres and other factors as stated earlier [8], [19]. Measurements were conducted at different distances and locations using frequency selective spectrum analyzer to obtain peak power values. The results showed that the radiation level was dominant at Odim when compared with other locations. Amplitude fluctuations were detected during measurements and this may be attributed to the rate at which the particular base station was being accessed by subscribers. This might cause the peak power either to increase or decrease, vice versa. The effects of phone traffic, and discontinuous transmission (which is inextricably linked to the number of channels) on the power radiated which are incorporated in the R. Cicchetti et al analytical model for assessing EM radiation in the vicinity of a base station antenna [9].

There are different Network Operators providing GSM services at the University of Nigeria, Nsukka campus. Measurements were made in the most sensitive areas around the campus, tracking the peak values over 6-minute intervals. The results are as presented in table 5, table 6, respectively. Readings were collected in the following locations: Faculty of Arts, represented by 'Arts', Odim-gate, represented by 'Odim', Staff Club, represented by 'Club', and Postgraduate School, represented by 'PG'. The sites were selected based on the anticipated number of traffic around them because of the high population density noticed around. Again, our target is to capture the influence of traffic channels around those areas. This is because the broadcast channels (BCCH) transmit continuously even if no subscribe is accessing the base stations [9]. But the traffic channel fluctuates whenever subscribers are accessing the base station.

The existence of a large number of scatterers and absorbing objects around the visited sites lead to highly non uniform field distribution in the environment of BSA. As a consequence, this brought about shadowing and fast fading effects. Houses, trees, cars, and other objects, seen around the sites can lead to signal variations that can only be determined by very large measurement campaigns. The buildings alone can cause a strong shadowing effect that makes the field distribution to be very heterogeneous [20],[21]. However, the maximum power density measured was compared with the ICNIRP safety level standard, and found to be about 0.06 percent of the recommended safety level.

6.0 Conclusion

From the foregoing, it was clear that the search for maximum field level was a very crucial issue because of the need to compare results with the international limits on exposure as given by International Commission for non ionization radiation protection (ICNIRP). The paper has so far presented the outcome of simulation and field results. The free space simulation model is ideal condition. It allows gross assessment in the far field region of the antenna, which generally over estimates the real exposure. The measured values also showed a low level of radiation when compared with the international standard [ICNIRP] due to environmental factors prevalent in other places as earlier explained. How the radiations differ from one base station to the other was also presented. This study has shown that radiation varies with distance. As the distance increases the radiation decreases. In conclusion, it was observed that generally many people are electro-sensitive but do not realize it; they have the symptoms, but because they are permanently exposed to the radiations, they regard them as 'normal'. It should therefore be noted that cause and effects are not immediate. Radiation remains a health hazard.

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REFERENCES

[1] Thomas Haumann et al, HF- Radiation levels of GSM cellular phone towers. pp. 327-333, 2000.

[2] 8th WSEAS International Conference on Simulation Modeling and Optimization (SMO '08) Santander, Cantabria, Spain, September 23-25, 2008.

[3] The Authors. International Journal of Andrology © 2010 European Academy of Andrology

[4] Dr. Fareeha Zafar survey work presented at a Science Technology Workshop & Exposition, University of Nigeria, 2013.

[5] Pozar, D.M. Microwave Engineering, John Wiley and Sons, Inc .3rd Edition, 2005.

[6] Hayts, W.H. and Buck, J.A., Engineering Electromagnetics, McGraw Hill, 2002

[7] S.M. Mann, T.G. Cooper, S.G. Allen, R.P. Blackwell, A.J. Lowe, Exposure to Radio Waves near Mobile Phone Base Stations, NRPB, June 2000

[8] Wiart, Data on COST 244bis`Short term Mission on Base Station Exposure, 2001.

[9] R. Cicchetti, A. Faraone; Estimation of the Peak Power Density in the Vicinity of Cellular and Radio Base Station Antennas, IEEE Trans. On Electromagnetic Compatibility, vol. 46, no. 2, May 2004.

[10] IEEE Recommended Practice for the measurement of Potentially Hazardous EM Fields-RF and Microwaves, IEEE Standard C95.3, 1999, IEEE New York.

[11] Md. Rafiqul Islam, et al, Radiation Measurement from Mobile Base Station at a University Campus in Malaysia, American Journal of Applied Sciences 3(4): 1781-1784, 2006.

[12] www.gsma.com/publicpolicy/wp-content

[13] Thisday Newspaper ''Effects of Information Communication Technology on the Environment'' Vol. 11, No. 4107, Page 39, Thursday, July 20, 2006.

[14] The Guardian Wednesday January 9, pp 39, 2008..

[15] ETSI (1996). `Radio Network Planning aspects'. ETR 364 (GSM 03.30 Version 5.0.0) European Technical Standards Institute. November, 1996.

[16] Spectran 6080 Manual (2007): Hw Rev /Firmware V1.101 by Aaronia AG, Germany. www.aaronia.de

[17] Dina, Simunic ''Measurement and Exposure Assessment for Standard Compliance'' Report of Bulgaria National Program Committee 2003. http//:www.who.int./entity/publications/reports/en/Bulgaria.

[18] Miclausi, S. and P. Bechet, "Estimated and measured values of the radiofrequency radiation power density around cellular base stations," Romanian Journal Physics Vol. 52, Nos 3-4, Pp429-440. Bucharest, 2007

[19] T.G Cooper, et al 'Journal of Radiological Protection' Institute of Physics Publishing. Pp199-211, 2006.

[20] Y. Hamnerius, T, Uddmar, "Microwave Exposure from Mobile Phones and Base Stations in Sweden", Internal Report, Department of Electromagnetics, Chalmers University of Technology, 2008, pp. 52-63.

[21] P. Stewart, "The Mobile Phone System and Health Effects", Australian Radiation Protection and Nuclear Safety Agency, 8 June 2000, pp. 323-331.