Radiation from GSM Systems and the Associated Effects on Human Health

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Abstract

In this paper we present the results of four years of field measurement data of the radiation from global systems for mobile (GSM) base stations and commonly used mobile phones across Nigeria. We evaluate the electric field strengths, the power densities, and the specific absorption rate (SAR). The radiated intensities were compared to the international standard limit of 200 $\mu W/cm^2$ and were found to be far below the set limit. The highest intensity level was 5.94 nW/cm^2 from a mobile base station. However, the average radio frequency exposure levels from GSM base stations were considerably lower at 0.806 nW/cm^2, 0.0.451 nW/cm^2, and 0.236 nW/cm^2 for Globacom, MTN, and V-Mobile, respectively. We note that these measured, low, power densities from GSM base stations and mobile phones are safe only when considering thermal effects of these radiations. However, our findings from an epidemiological viewpoint show that there are associated health effects with these levels of radiation, which are purely non-thermal.

Key words: GSM exposure limits, EM radiation, power density.

1. Introduction

The growth of the cell phone industry, and widespread use of GSM mobile telephones, have resulted in numerous complaints and even epidemiological studies claiming that the low-level microwave radiation emitted by these devices are harmful to human health [1,2]. Low-level microwave radio frequencies (RF) are given off not only by the mobile cell phones, but also from cellular telephone communications towers [3]. Our major concern was the radiation emitted by GSM mobile phones and base station antennas. The first goal was to obtain precise measurements of the radiation from these various GSM devices. We considered mobile base stations that are sited within 20m from residential buildings, school premises, offices, public arenas and that have been in use for over two years by October 2003. We therefore looked at 106 of these mobile telephone base stations from 56 towns in Nigeria. These base stations are sited in densely populated areas and were of concern to the local communities. Also, we considered commonly used GSM mobile handsets. Sometimes an uncontrolled emission from this mobile equipment may cause radiation levels that are likely to be harmful to the body [4]. Also, there could be some isolated cases in which particular installations of this equipment could deviate from preferred radiation levels. The second goal was to determine from epidemiological and scientific studies, the associated effect on human health caused by this level of radiation. Our observations from previous epidemiological studies suggest that questionnaires were employed to obtain data [5]. We decided to carry out an epidemiological study by oral interview rather than the use of questionnaires due to factors that are peculiar to Nigeria. This paper did not discuss this study, which was conducted from July 2003 to December 2007 [6]. However, relevant findings from the results of this study were used. This was to enable the weighting of public claims in respect to long time exposure to GSM radiation as it relates to both thermal and non-thermal health effects. For the purpose of this research, therefore, we selected the three major service providers that provided GSM coverage to all the regions under consideration.

Table 1 shows the frequency bands, uplink and downlink, for the selected GSM service providers in Nigeria.

Table 1 Frequency bands of selected GSM service provider

S/No	GSM service providers	Frequency Band 900MHz	Frequency Band 1800 MHz
1	(A) Globacom	Downlink (945-950)	1820-1835
		Uplink (900-905)	1725-1740
2	(B) MTN	Downlink (950-955)	1835-1850
		Uplink (905-910)	1740-1755
3	(C) V-Mobile	Downlink (955-960)	1850-1865
		Uplink (910-915)	1756-1770

2. General measurements procedures

The base station antennas in the selected sites were the more common panel antennas, which divide the area around the base station into three sectors. With this arrangement of the three antennas the entire region around the base stations were covered. The terrain determined the antenna mast height, which ranged from 30m to 45m. The signals radiated are for digital mobile telephone systems that operate with GSM frequency bands of 900 MHz and 1800 MHz.

All measurements were made with an Agilent Technologies model E4407B ESA-E series spectrum analyser. This equipment functions as a sophisticated radio receiver, which allows each received radio signal, in the range of 9 KHz to 26.5 GHz to be analysed, thus, allowing the accurate measurement of the signal magnitude and frequency. This spectrum analyzer has an inbuilt software program that controls the operation of the analyzer and records all relevant data. A horn antenna that is connected to the analyzer via a coaxial cable, receives the signals measured by the analyzer over the frequency bands of interest. The spectrum analyzer measured the received signal power in dBm and the signal amplitude in dBV.

Radiation measurements

Two separate measurements were considered and these were:

(i) Measurement of the base station signals conducted from 9:00 am to 5:00 pm local time. During this time interval the maximum hold button on the spectrum analyzer was enabled. Field measurements were conducted on Mondays, Thursdays and Saturdays, excluding public holidays. This study lasted from November 2003 to January 2008.

(ii) Measurement of the radiation from mobile phones that were commonly used in Nigeria (i.e Nokia 3310, Nokia 1110, Nokia 6110, Motorola V95, Siemens 6510, Samsung 6500, Sagem MY x-7, Sendo X and Sony Ericsson 6515).

The spectrum analyser was powered, on site by two fully charged 12V, 60AH, sealed batteries. The power radiated by mobile base stations depends on the number of subscribers making calls at the same time. Thus, the measured radiated power depends on time, place, and season. Fig. 1 and 2 shows a typical general spectrum of the radiated power of GSM signals for the 900 MHz and 1800 MHz bands respectively.

Fig. 3 shows a typical spectrum of the radiated power of GSM signals from mobile phones.

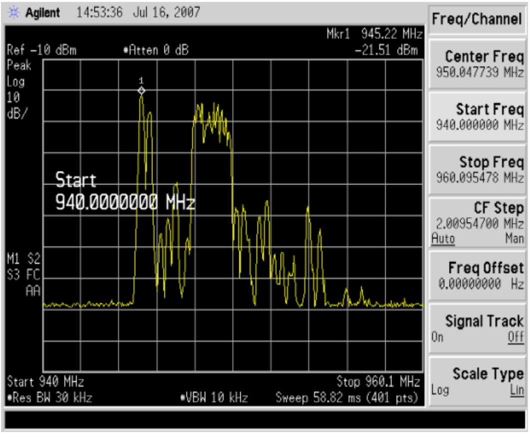

Fig. 1 Radiation from Globacom cell site, operating at 900 MHz, located at Ujuelen Ekpoma, Edo State, Nigeria

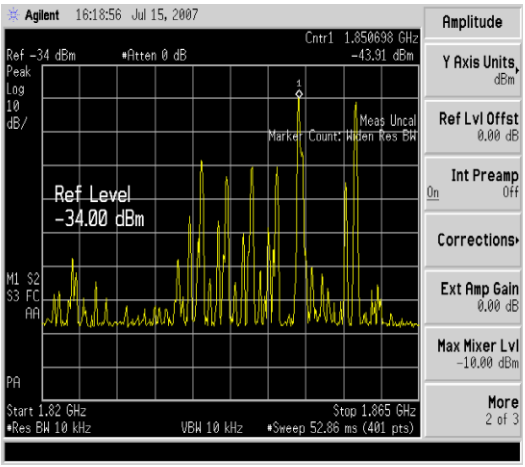

Fig 2 Radiation from 1800 MHz band V-mobile cell site located at Ebhokpe quarters Irrukpen, Edo State, Nigeria. The spectrum shows other significant radiation from other nearby cell sites.

3. Analysis of Results

The electromagnetic radiated (EMR) power from a base station varies from one site to another. In Fig 1, the spectrum of the field measured radiation frequency, of a mobile base station antenna under consideration, was 945.22 MHz at a radiated power (P_i) of -21.51 dBm. Also the figure shows detected radiation from six other different cell sites. Two of these cell sites are for Globacom (947 and 949 MHz) and four are from MTN (950.4, 951.0, 951.9, 952.65 MHz) cell sites. The detected powers radiated by these six cell sites are; -49.5, -24.2, -57.3, -55.8, -72.1 and -58.8 dBm. Similarly, Fig. 2 shows the radiated powers from eight mobile base stations that are operated in the 1800 MHz band. In this case, the mobile base station antenna under measurement has a frequency of 1.8507 MHz and a radiated power of -43.91 dBm. We observed that the radiated power from mobile base station antennas operating in the 900 MHz band is higher than those operated in the 1800 MHz band {e.g. -21.51 (dBm) > -43.91 (dBm)} as shown in Figs 1 and 2. These significant differences in the radiated powers between the two bands allowed the 1800 MHz band to be used mainly in densely populated areas. The 1800 MHz band antennas were mainly used in urban areas.

Fig. 3 shows the spectrum of power radiated by six different mobile handsets that were simultaneously making calls. During the time of these measurements, the mobile handset closest to the horn antenna was operating at a frequency of 1.7527 MHz and at a radiated power of -2.454 dBm. It was clear from Fig 3, that the radiation from mobile handsets are significantly higher than those radiated from mobile base station antennas. These mobile handsets were placed within 1.0 to 10 cm from the horn antenna. We note that mobile handsets are usually placed very close to the head.

We computed the relative amount of EMR emitted by these various sources. Measurements of power density levels were made at a position, which maximizes the exposure from the mobile phone base stations.

The electric field strength, E, and the power density, P_D, were computed as follows: The electric field strength, **E**, is given by:

$$\mathbf{E}\ (dB\mu V/m) = V\ (dB\mu V) + AF\ (dB) + CL\ (dB) \quad (1)$$

where V is the detected radiated signal voltage, AF is the mobile horn antenna factor and CL is the signal attenuation.

The free space impedance (η)= 377Ω. Given E in the unit V/m, and η in ohms, we have the power density, P_D , of the radiated electromagnetic waves as [7]:

$$P_D\ (mW/cm^2) = E^2/3770 \quad (2)$$

$$V = 107 + P_i, \quad (3)$$

where P_i is the power measured by the spectrum analyser.

$$P_{Davr} = (P_{D1} + P_{D2} + P_{D3} + \ldots\ldots + P_{D106})/106 \quad (4)$$

where P_{Davr} is the average power density over the entire frequency bands and P_{D1}, P_{D2},…P_{D106} are the various computed power densities. For example, from Fig 1, we have P_i = -21.51 dBm. Then, from equations 1, 2 and 3 we compute V, **E** and P_D to be: V = 85.49 dBμV, **E** = 103.5 dBμ V/m and P_D = 5.94 nW/cm^2.

The values of the electric field strength and the power densities are highly dependent on the number of callers per cell site and the distance of measurement. Following the above computational steps we therefore computed the electric field strengths and the power densities for the entire frequency bands using equations 1, 2 and 3. The computed average power density was approximately 0.5 nW/cm^2. Fig. 4 shows the graph of power density versus distance for a typical base station. This figure shows that from each base station antenna the radiation is directed to a point in the far field zone. We observed that the intensity of the radiation was higher in the far field (90m to 150m for 900 MHz band and 200m to 250m for 1800 MHz band) region of each antenna than anywhere else around each cell site. Thus, the maximum measured radiation is at the far field region.

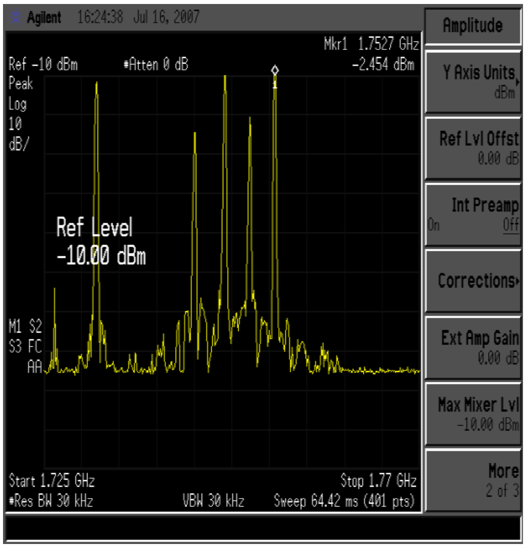

Fig. 3 Spectrum of radiation from mobile phones.

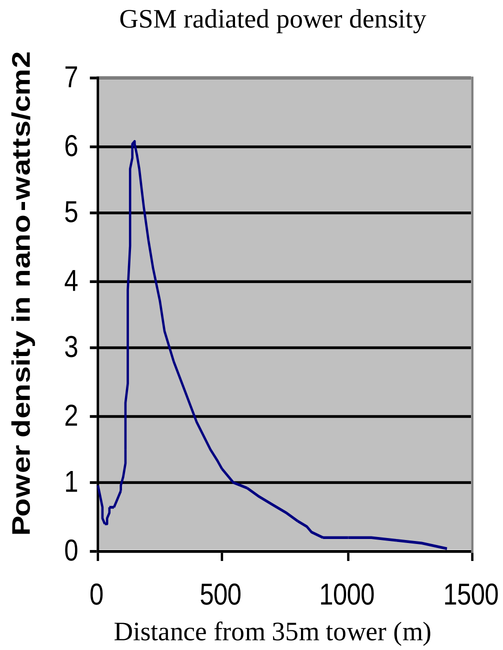

Fig. 4 Power density versus distance

Fig. 5 shows the distribution of the power density for a typical cell site. This figure indicates that, at every cell site, there were different levels of GSM radiation intensity as a result of other neighbouring cell sites. The highest intensity was from the sectoral antenna under observation.

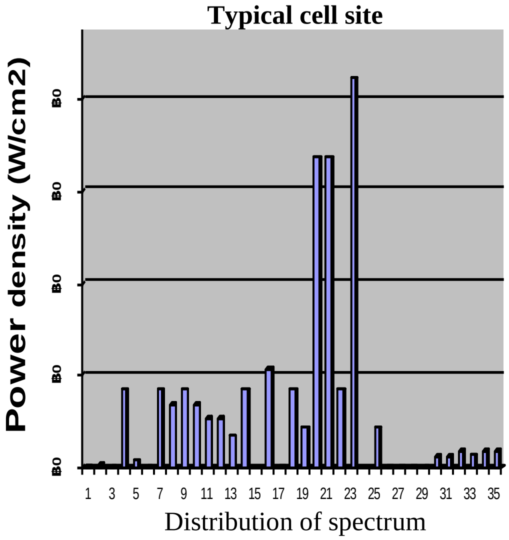

Fig. 5 Distribution of power density in a typical cell site in Nigeria

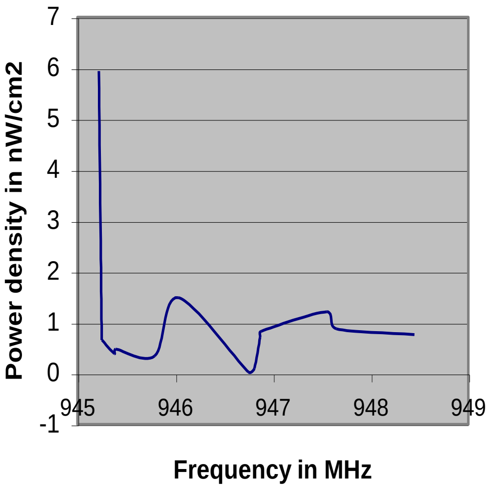

Fig. 6 Power density versus frequency

Fig. 6 is a plot of power density against frequency for a typical cell site. The intensity does not depend on the frequency of transmission as depicted in this Figure. However, the radiated power depends on number of subscribers that are simultaneously making calls. We observed that the radiation from cell sites in urban areas were lower than those measured in rural areas. This was due to the fact that the distance between the cells sites were less in urban areas compared to those that were found in rural areas. The highest measured P_D radiated value from these mobile handsets was 94.95 $\mu W/cm^2$. This gives an SAR of 0.164W/Kg. In this case, the P_D was approximately 2 times less than the 200 $\mu W/cm^2$ limit, while the SAR was about 10 times lower than the 1.6 W/Kg limit [8,9]. The radiation emitted by mobile handsets was far higher than that radiated from base stations.

4. Discussion

Figures 1 and 2, represents the typical field measurements of the radiated power spectrum pattern for the 106 mobile base station antennas. While Fig 1 represents the radiated power distribution in the 900 MHz band, Fig 2 represents that in the 1800 MHz band. Therefore the computed values of the radiated power densities shows that the radiated power densities of GSM base stations in Nigeria are very low microwave radiation. The power densities have an average value of 0.5 nW/cm^2 and a peak value of 5.94 nW/cm^2. Equally the radiation from mobile handsets is very low. Using equations 1, 2 and 3, the results of the computed power densities of the radiation from GSM base stations in Nigeria showed that the radiated powers are far below the standard limit of 200 $\mu W/cm^2$. In other words, when we compared these computed radiated power densities with the standard limit of 200 $\mu W/cm^2$, the computed values were far below the standard limit. These values are therefore very low microwaves intensities. It therefore implies that no thermal health effect can be associated with these radiated power densities. Microwaves have proprieties other than intensity [10]. The pulsed microwave radiation used in the GSM systems has certain well-defined frequencies, which facilitate its absorption by the living human organism, and via which the organism can, in turn, be affected in a purely non-thermal way. The rates at which the microwaves are emitted in distinct groups of pulses are close to the frequencies of some of the brain's own electrical and electrochemical rhythms, which make them particularly vulnerable to interference or even entrainment by the radiation [11]. The basic ‘pulse rate’, is 217 Hz, but the pulses are emitted in groups of 25 at the rate of 8.34 Hz. From findings in our earlier epidemiological studies we observed that this weak radiation recorded from field measurements has the following associated non-thermal effects on human health and are in complete agreement with other epidemiolo-gical studies [12-17]. It causes headache which is one of the most persistently reported adverse health effects; stress, earaches, “Hot Ear”, chronic fatigue, insomnia, weakened immune system, blurred vision, dizziness, lack of concen-tration, memory loss, nausea, sinus infec-tions, muscle pains, drastic mood changes, behavioural disabilities, and reduced sex drive [18].

In Nigeria, exposure to this kind of radiation is below the 10 to 15 years latency period of cancer.

The measured microwave radiation does not have enough energy to break chemical bonds in DNA. However, expo-sure to this radiation can cause interference with the natural DNA repair process, and produces chromosome aberrations and micronuclei. It is important to note that not everyone will be equally susceptible, even under the same exposure conditions. This is perhaps the reason why most experimental results cannot be replicated. The level of the measured radiation can provoke adverse health reactions in some people, the severity of which will again vary from person to person, according to the robustness of their immune system [19, 20].

It is worrisome to note that virtually all the installation of GSM antennas go up in neighbourhood locations, near schools, churches and homes in most part of Nigeria. These wireless antennas expose people to involuntary, chronic EMR. Low levels of EMR, which have been shown to be bioactive, are associated with changes in cell proliferation and DNA damage [21]. Unfortunately, there is no evidence of any local agencies to consider EMR health and safety issues in sitting or zoning of these GSM masts in Nigeria. Due to the poor medical facilities in Nigeria no one was willing to be a volunteer in a study full of uncertainties. Thus, epidemiological study of any associated health hazard, due to radiation from GSM services can be frus-trateing in a developing country like Nigeria.

5. Conclusion

In this work we presented field measurement data of the radiation from GSM mobile phones and base stations in Nigeria. We evaluated the electric field strengths and the power densities of GSM base stations in Nigeria. We equally evaluated these values for commonly used GSM mobile phones. We were able to determine the maximum SAR of these handsets. We computed an average power density of 0.5 nW/cm^2 and a peak power density of 5.94 nW/cm^2. For thermal effect consideration this level of intensity is safe. However, we presented the non-thermal associated effects on human health caused by this radiation.

It is advisable that GSM masts should not be mounted within 300m from school buildings, residential buildings, youth centres, and other places where children are found, to avoid a situation of endangered health and well-being. It is recommended that limiting the number and length of calls, or using “hands-free” devices to keep the mobile phones away from the head and body should limit children’s exposures to EMR.

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