# Measurement and Modelling of Electromagnetic Exposure from GSM Base Stations in Kampala Uganda

Gertrude Ayugi Akisophel Kisolo Tumps.W. Ireeta
Department of Physics, College of Natural Science, Makerere University, P.O Box 7062, Kampala, Uganda

**Abstract**
Electromagnetic radiations exposure from mobile phone base stations to public health has attracted the attention of many researchers. An extensive survey of GSM exposure in terms of power density in the urban environment of the city of Kampala has been performed. This wide survey was done using the drive test method where a car running at low speed, power supply unit, a calibrated Aaronia Spectran HF-6065 V4 spectrum analyzer, an Aaronia OmniLOG70600 antennas and an Aaronia GPS Logger were used in power density measurements. Maximum power densities of *0.0029*$Wm^{-2}$ *for GSM900 and 0.0013*$Wm^{-2}$ *for GSM1800 were recorded.* Exposure data obtained was lognormally distributed. The investigated power density levels were compared with the international safety level. The measured exposure levels were found to be below the recommended safety levels as provided by international agencies such as the international Commission for Non-Ionising Radiations (ICNIRP).
**Keywords:** GSM, Power density, Exposure, ICNIRP, Kampala

## 1.0 Introduction

Over the past one decade in Uganda, mobile wireless services grew from a small market application to nationally available component of daily life. Kampala city and its neighborhood have over the years also experienced this rise in the use of mobile phones. The number of mobile base stations in the city has also witnessed an increase as a result. Mobile phone network service providers are also mounting their base stations within and around public places such as schools, hospitals, markets, and residential areas. The Global System of Mobile Communication (GSM) is the most versatile mobile communication technology in the world (Ajiboye 2013). GSM mobile phones have dominated the telecom market around the world because of their small size, easy to use and are less sophisticated. The GSM900 system has been allocated two frequency bands, 890-915MHz for the uplink and 935-960MHz for the downlink. The GSM1800 system uses bands of 1710-1785MHz for the uplink and 1805-1880MHz for the downlink.

Mobile phone Base stations are designed to transmit radiofrequency (RF) radiation continuously even when nobody is making a call with a mobile phone (Haumann 2002). The Radio waves emitted by transmitting antennas consists of electric and magnetic energy moving together through space at the speed of light. RF dosimetry describes how external the electromagnetic fields (EMF) are absorbed and distributed in different organs of the body (Ahlbom 2012).

The quantities used for the estimation of RF energy in a medium are the electric field strength**, E** (V/m), magnetic field strength**, H** (A/m), power density **S** (W/$m^2$) and Specific Absorption Rate **SAR**, (W/kg). Power density is the power per unit area normal to the direction of propagation while Specific Absorption Rate is the rate at which RF energy is absorbed a tissue when exposed to a RF electromagnetic field.

**E** and **H** are related to power density by the equation 1 (ICNIRP 1998) while the **SAR** is related to **E** by equation 2.

$$S = EH = \frac{E^2}{377} = 377\Omega H^2 \quad (1)$$

$$SAR = \frac{\sigma|E^2|}{\rho_m} \quad (2)$$

Where $\sigma$ is the conductivity of the body tissue and $\rho_m$ is the mass density of tissue at that point

The International Council on Non-Ionizing Radiation Protection (ICNIRP) standard provides guidelines/standards for RF exposure limits. The ICNIRP standard is used in Uganda and many other countries. Table 1 shows the ICNIRP guidelines for the general public and occupational.

**Table 1: ICNIRP guidelines**

| Application | ICNIRP limit for general public(W/$m^2$) | ICNIRP value for occupational (W/$m^2$) |
|---|---|---|
| GSM900 | 4.5 | 22.5 |
| GSM1800 | 9 | 45 |

### 1.1 Related work

Ajiboye assessed radiofrequency exposure due to GSM900 and GSM1800 at 30 strategic locations in the

University College Hospital (UCH), Ibadan with a frequency selective spectrum analyzer coupled to a calibrated Omni directional antenna. The mean power densities of 38.37 µW/m$^2$ and 8.68 µW/m$^2$ and maximum power densities of 212.40 µW/m$^2$ and 67.40 µW/m$^2$ were obtained for GSM900 and GSM 1800 respectively. The standard deviation of 51.3 µW/m$^2$ and 14.90µW/m$^2$ were also obtained for GSM 900 and GSM 1800 respectively (Ajiboye 2013).

In situ electromagnetic RF exposure to existing and emerging wireless technologies was assessed using spectrum analyzer in Belgium, Netherlands, and Sweden were by Wout Joseph in 2012. The maximal total field value 3.9V/m was measured in a residential environment, mainly due to GSM900 signals and exposures were lognormally distributed (Wout 2012).

Perez-Vega carried out measurements to register the total radiation levels contributed by all radio communication systems along streets, covering most of the urban area of Santander Spain using a broad band instrument. A car running at low speed was used in data collection and registered by means of a portable computer and in-house PC control software. The data obtained was statistically analysed and obtained a best fit with the Nakagami-m probability distribution function (Pérez-Vega 2008).

Hubregt assessed the feasibility of ambient RF energy scavenging, a survey of expected power density levels distant from GSM900 and GSM1800 base stations was conducted and power density measurements were performed in a WLAN environment. Results show that for distances ranging from 25m to 100m from a GSM base station, power density levels ranging from 0.1mW/m$^2$ to 3.0mW/m$^2$ may be expected (Hubregt 2008).

In this study, electromagnetic exposure from GSM base stations in Kampala has been assessed. Peak power density is the quantity that has been used in assessing the exposure levels.

## 2.0 Methodology

### 2.1 Geographic description of Kampala

Kampala is the capital city of Uganda and has a population 1,516,210 people (*UBOS 2014).* It is located at Latitude, 0°18′58″N and Longitude, 32°34′55″E and an elevation of 1223m above sea level. Figure1 shows the aerial view of the Kampala.

**Figure 1: Aerial view of Kampala City**

## 1.0 Drive Test routes and experimental setup

Routes for the drive test were planned to include accessible roads in Kampala. The drive measurement setup consisted of a power supply unit, a calibrated Aaronia Spectran HF-6065 V4 spectrum analyzer with a range of 10MHz-6GHz, an Aaronia OmniLOG 70600 antenna with a range of 700MHz to 6.0GHz, an *Aaronia GPS Logger, a* laptop that is connected to the spectrum analyzer via a USB cable, and an MCS software specially designed to run on Aaronia spectrum analyzers. The samples were collected using a car running at low speed. The data obtained during the drive test include: power density, frequency, time and GPS location.

The configuration of the parameters for the spectrum analyzer during the measurements are given in Table I.

**Table 2: Spectrum Analyzer Parameters configuration**

| **Parameter** | ***Value*** |
|---|---|
| Frequency Range | 700MHz-1900MHz |
| Resolution Band width | 300kHz |
| Video Band width | 300kHz |
| Sweep time | 1ms |
| Detection type | RMS |
| Sample points | 1280 |
| Attenuation factor | 10dB |
| Reference level | -10 |

The post-processing data analysis was carried out with ArcGis software and statistical modeling was done using MatLab.

 

### 3.0 Results

During the drive test, a total of 15,000 measurement points were collected. GIS software was used to visualize the exposure along the drive test routes of GSM900MHz and GSM1800MHz power density distribution in Kampala. Figure 2 and figure 3 show peak power density for GSM900 and GSM1800 at different locations in Kampala.

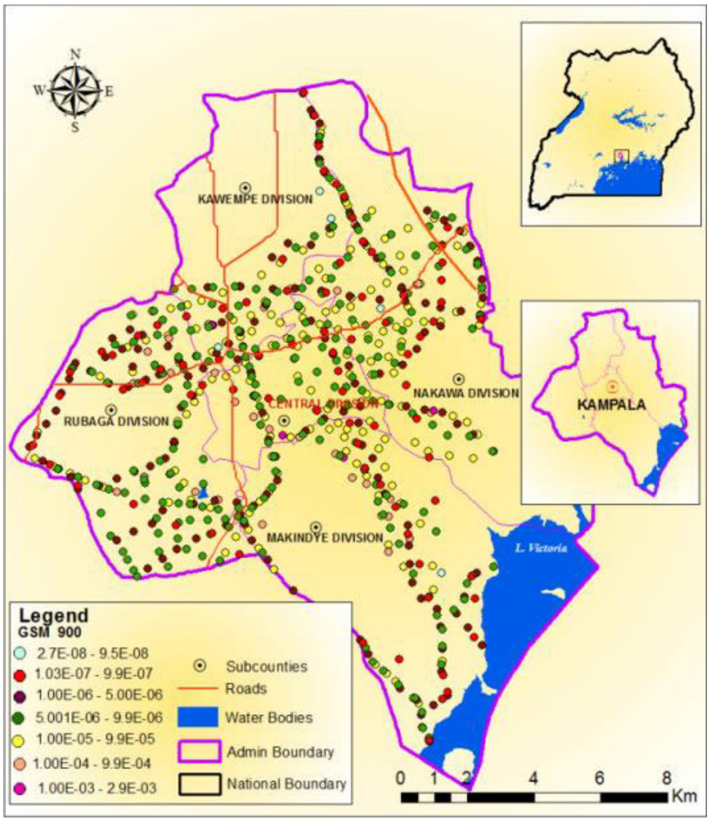


**Figure 2: GSM900 power density in Kampala**

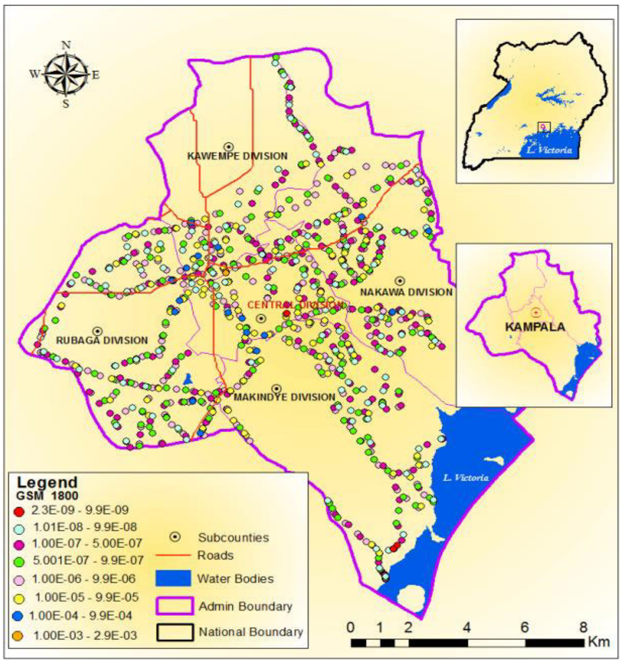


**Figure 3: GSM1800 power density in Kampala**

Figure 4 shows the percentage power density contributions of GSM in Kampala city. For the GSM900, $10^{-6}Wm^{-2}$ has the highest contribution while for GSM1800 highest contribution is due to the power density in the range $10^{-6}$ $Wm^{-2}$.

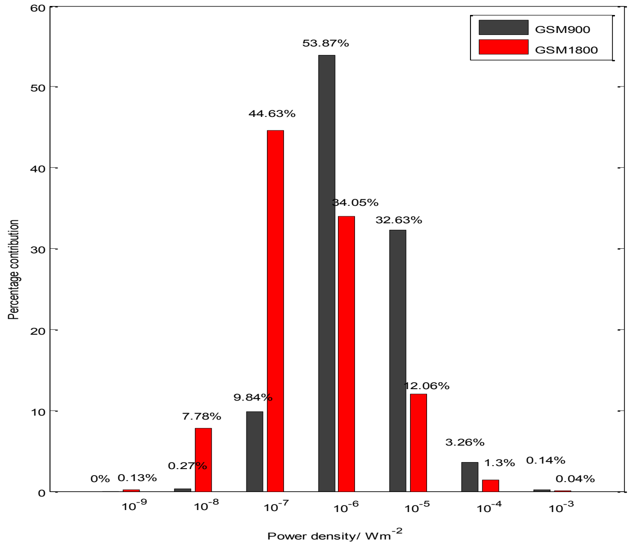


**Figure 4:Percentage contributions of GSM in Kampala**

### 3.1 Statistical analysis and modeling

The measured data was processed and statistically analysed using MatLab to obtain a model for GSM power density distributions in Kampala. Measured data was fitted to the Lognormal, Nakagami, Rayleigh and Ricain. The Lognormal Cumulative Distribution Function(CDF) (equation 3) was identified to be the most suitable model to power density distribution in Kampala. This model yielded the highest log likelihood. The higher value of log likelihood indicates better fit for the data.

$$F(x|\mu,\sigma) = \frac{1}{\sigma\sqrt{2\pi}}\int_0^x \frac{e^{\frac{-(\ln(t)-\mu)^2}{2\sigma^2}}dt}{t} \quad (3)$$

Where $\mu$ and $\sigma$ *are the parameter estimates for the mean and standard deviation*

The mean $m$ and variance $v$ of a lognormal random variable are functions of $\mu$ and $\sigma$ that can be calculated using equations 4 and 5

$$m = exp^{(\mu+\sigma/2)} \quad (4)$$

$$v = exp(2\mu+\sigma^2)(exp(\sigma^2)-1) \quad (5)$$

**GSM900**

Figure 5 shows the best fit with the Lognormal CDF. The highest exposure for GSM900 is 0.0029Wm$^{-2}$. The mean value obtained was 0.000015Wm$^{-2}$ and variance of 0.0146 Wm$^{-2}$. The parameter estimates for the Lognormal distributions are $\mu_{est}$=-12.7887 and $\sigma_{est}$=0.989.

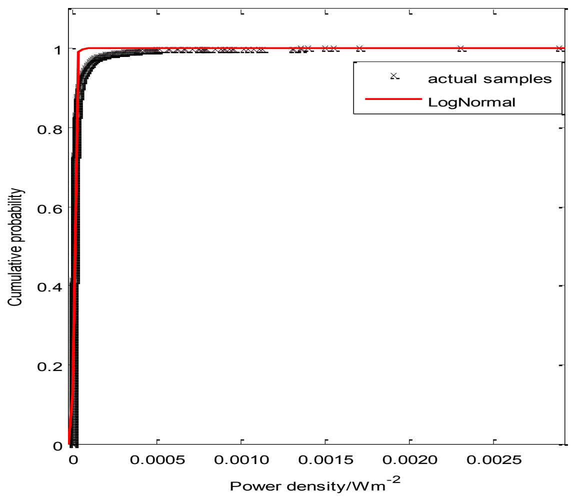


**Figure 5: GSM900 Cumulative probability for the power density**

**GSM1800**

Figure 6 shows the best fit with the Lognormal CDF. Maximum exposure obtained with GSM1800 was 193 $\mu Wm^{-1}$ with a mean of $0.00000598 Wm^{-2}$ and a standard deviation of $1.56181\ Wm^{-2}$. The parameter estimates for the Lognormal distributions are $\mu_{est}$=-13.74 and $\sigma_{est}$=1.851

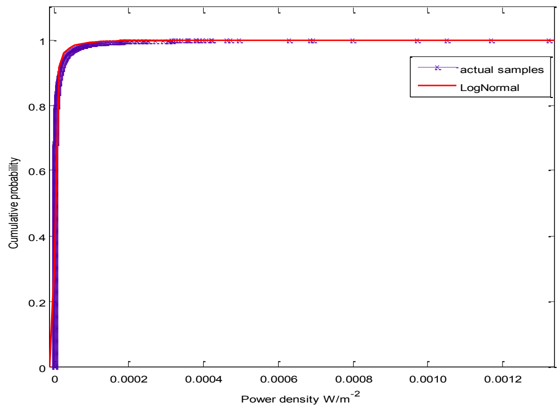


**Figure 6:GSM1800 Cumulative probability for the power density**

## 4.0 Conclusion

Statistical modeling of the power density distribution in Kampala follows a LogNormal distribution. The study shows all measured peak power densities are well below the established ICNIRP standards.

## References

Ahlbom A, Feychting M, Hamnerius Y and Hillert I (2012). Radiofrequency Electromagnetic Fields and Risk of Disease and Health: Research During the last Ten Years. Stockholm, Swedish Council for Working Life and Social Research (FAS).

Ajiboye Y and Osiele M. O (2013). Assessment of spatial exposure to RF radiation due to GSM 900 and GSM1800 – A case study of UCH, Ibadan, Nigeria. *IOSR Journal of Applied Physics,* 4, 2, 44-48.

Haumann T , Munzenberg , Maes W and Sierck P (2002). HF-radiation levels of GSM cellular phone towers in residential areas. *Proc. 2nd Int. Workshop on Biological Effects of EMFS*, 1, 327 -333

Hubregt J. Visser, Adrianus C.F. Reniers and Jeroen A.C. Theeuwes (2008). Ambient RF energy scavenging: GSM and WLan power density measurements. *Proceedings of the 38th European Microwave Conference.* 721-724.

ICNIRP (1998). Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz). *Health Physics*. 74,494-522.

Pérez-Vega C, Zamanillo J.M and Herran L.F (2008). Measurement and Model of Non-Ionizing Radiation Levels in an urban environment. *8th WSEAS International Conference on Simulation, Modelling and Optimization (SMO '08).* Santander Cantabria Spain.

*Uganda Bureau Of Statistics (UBOS) ( 2014). National Population And Housing Census 2014. Provisional Results. 7.*

Wout Joseph, Leen Verloock, Francis Goeminne, Gunter Vermeeren, and Luc Martens (2012). Assessment of RF exposures from emerging wireless communication technologies in different environments. *Health Physics*, 102, 2, 161-172.