IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 9, Issue 5 Ver. I (Sep. - Oct. 2017), PP 09-15
www.iosrjournals.org

Temporal Variation of Radiofrequency Electromagnetic Field Exposure from Mobile Phone Base Stations in Sensitive Environments

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Abstract: *Temporal variation in exposure to radiofrequency electromagnetic waves from mobile phone technology has been assessed in sensitive areas like residential areas, schools, commercial areas and hospitals. The mobile phone technologies considered in the study are GSM900, GSM1800, UMTS2100 and LTE2600. Exposure was determined using the Aaronia Spectran HF-6065 V4, OmniLOG 70600 antenna, HyperLOG 70600 antenna, Aaronia GPS Logger, Real Time MCS Spectrum-Analysis-Software and a laptop. The maximum exposures recorded were compared with the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines and they were found to be very low relative to the set guidelines. This showed that the public is safe from these radiations.*

Keywords: *Radiofrequency, electromagnetic fields, electromagnetic hypersensitivity, temporal variation*

Date of Submission: 11-08-2017 Date of acceptance: 05-09-2017

I. Introduction

There has been a rapid development and increase in the use of wireless telecommunication technologies and this has led to a substantial change in the radiofrequency electromagnetic field exposure to the general population. However little is known about the temporal variation of these fields in sensitive environment like residential areas, schools, commercial areas. These environments consist of people who are electromagnetic hypersensitive. It is mandatory to take temporal variations of exposure to wireless telecommunication technologies into account when assessing exposure for compliance with existing exposure guidelines [1]. It is also stated in the World Health Organization's research agenda [2] that it is important to permanently monitor these fields. Temporal Measurements are time-consuming, expensive, and difficult to execute in practice, therefore compliance is often only evaluated by performing short time spatial measurements [3,4,5]

Several studies have been conducted to characterize radiofrequency electromagnetic field exposure levels in different microenvironments and various cities.

According to the ICNIRP, the recommended safe power density limit is as low as 4.5 Wm^{-2} for GSM900, 9 Wm^{-2} for GSM1800 and 10 Wm^{-2} for UMTS2100 and LTE2600 for the general public. Manassas in 2012 carried out a continuous electromagnetic radiation monitoring of variations in fields due to broadcasting and mobile telecommunication in Greece and provided median variations [6].Miclaus carried out a study on the long term exposure to mobile communication radiation in the GSM900 downlink in 2013. In this study, it was stated that short term exposure assessment is not reliable for evaluation of long term exposure [7].Radio frequency electromagnetic field exposure assessment studies using exposimeters have also been reported, investigating spatial and temporal variation of radiofrequency field [8,9,10,11]. However, these assessments are difficult for accurate evaluation of temporal exposures due to limitations of the exposimeters and the use of exposimeters on the body can extremely influence the results. For data to be more reliable, temporal variation analysis requires a substantial amount of data from different environments collected with the same methodology [12].According to Röösli efficiency is achieved when a high number of repeated measurements per microenvironment are performed with portable measurement devices [13]

In this paper temporal measurements and distribution of exposure to Global Systems for Mobile Communication (GSM), Universal Mobile Telecommunication Systems (UMTS) and Long Term Evolution (LTE) during 24hours at different indoor sites are presented.

II. Methods

Five measurement sites were selected for indoor temporal assessment of RF exposure in sensitive areas. The investigated indoor micro environments were residential area (Kyebando), secondary school (Kitante secondary school), primary school (Bateefu Primary School) daycare and kindergarten (Lyna daycare), hospital (Mengo hospital) and commercial area (Nabukeera plaza) with in Kampala. Table 1 shows the latitude and longitude of the measurement locations.

Table 1: GPS coordinates of measurement sites

Site	Latitude	Longitude
Kyebando	0.457537	32.579692
Kitante secondary school	0.3338579	32.58496639
Bateefu primary school	0.2831953	32.5259728
Lyna kindergarten	0.311535	32.558497
Mengo hospital	0.313032	32.55857
Nabukeera plaza	0.313999	32.573215

At every location, the measurement setup used consisted of a calibrated Aaronia Spectran HF-6065 V4 spectrum analyzer, an Aaronia OmniLOG70600 antenna, a laptop that is connected to the spectrum analyzer via a USB cable, and an MCS software. The MCS software is easily configured to suit a given measuring. The setup is connected as shown in Fig 1.The setup was left to run for 24hours for three weekdays (Monday, Wednesday and Friday). The spectrum analyzer parameters configuration on the MCS software are as in Table 2.

Figure 1: Experimental setup

Table 2 Spectrum Analyzer Parameters configuration

Parameter	Value
Resolution Band width	300kHz
Video Band width	300kHz
Sweep time	1000ms
Detection type	RMS
Sample points	1000
Attenuation factor	10dB
Reference level	-10
Unit	Wm^{-2}

III. Results And Discussion

To satisfy the ICNRIP guidelines for assessing RF exposures, 6 minutes averages of power density were obtained for each of the sample days that is Monday, Wednesday and Friday. In order to improve on the accuracy in determining the time of maximum average exposure, the average exposure for the three days was obtained. Before assessing temporal exposure, noise levels in each telecommunication band were obtained by removing the antenna and recording maximum noise in exposure (power density) for 3600 seconds.

3.1 Temporal Variations of the GSM900

Fig 2 shows temporal variation of GSM900 signal for 24hours at the six measurement location. From the figure the following observations can be made:

In Kitante Hill High School, exposure to GSM900 signal was almost constant. There was a slight increase in exposure between 10:00-12:00hours and between 16:00-21:00hours and hence it is best to test for compliance during these time intervals. GSM900 exposure at Lyna kindergarten was fairly constant. Exposure during the day was slightly higher than exposure during the night. UCC can test for compliance of the GSM900 signal at any time during the day. At Bateefu Primary school in Mutundwe, exposure due to GSM900 signal is roughly constant. The best time to test for compliance is between7:00-13:00hours. Mengo hospital exposure to GSM900 signal has high temporal variations. Highest exposure is observed between 6:00-11:00hours and 16:00 -22:00hours and hence the best time for regulatory body (UCC) to test for compliance of this signal. At Nabukeera commercial plaza, there is only noise in the GSM900 signal. At the top of this building transmitters have been put up and the absence of GSM900 signal shows that none of these transmitters are for this telecommunication band. GSM900 exposures in Kyebando are high and also the temporal variation observed in the signal is high. Exposure could be assessed at any time apart from 10:00-19:00hours

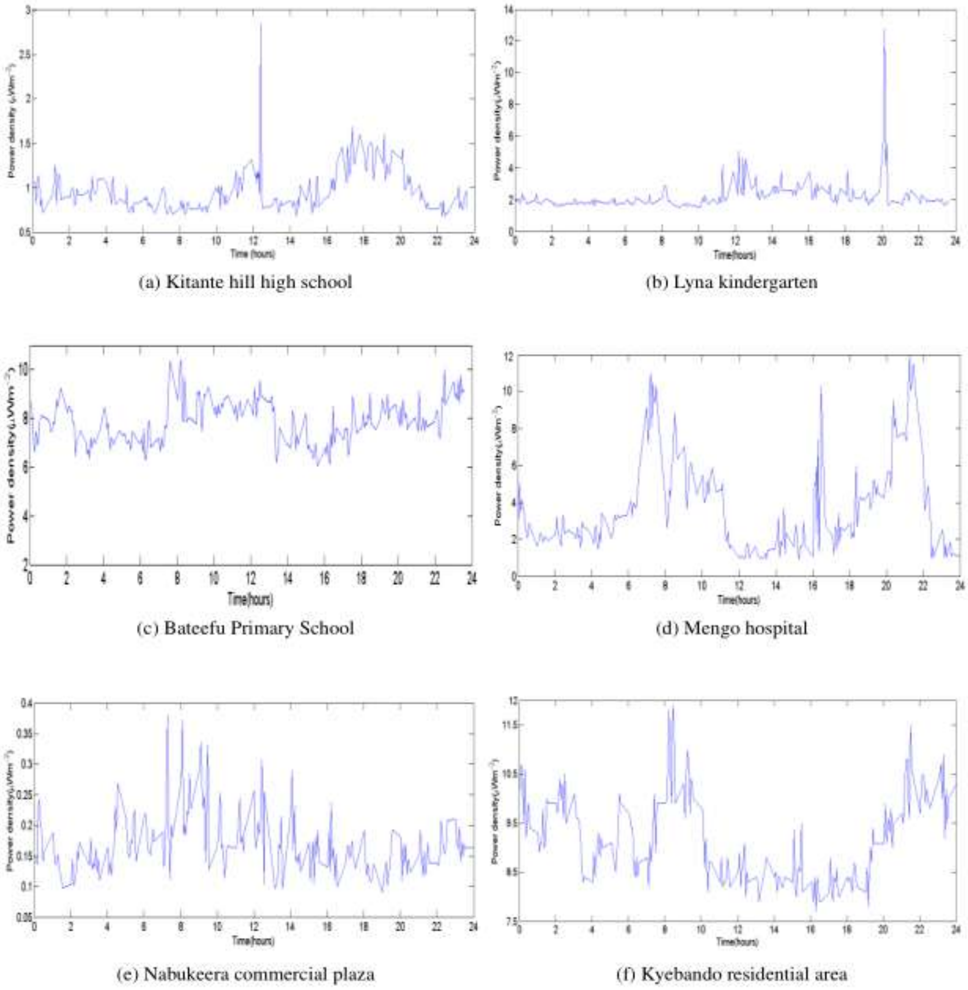
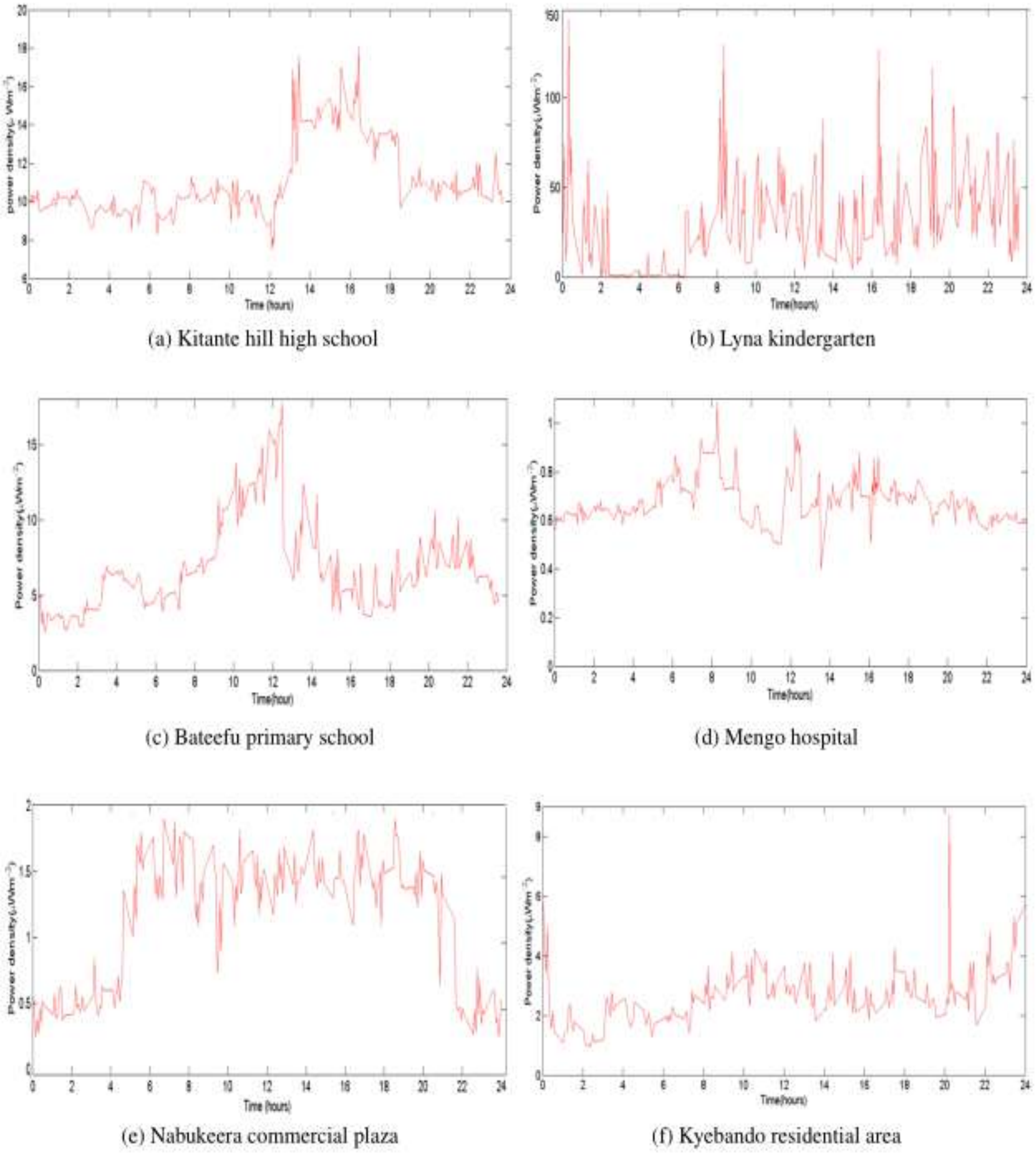


Figure 2: GSM900 temporal exposure

3.2 Temporal Variations of the GSM1800

Fig 3 shows temporal variation of GSM1800 signal for 24hours at the six measurement location. The following observations can be made from the figure: Kitante Hill High School temporal variations in the GSM1800 signal were low. Maximum exposure was observed between 12:00-18:00hours and therefore compliance tests should be performed during this time. At Lyna Kindergarten exposure to GSM1800 was relatively high throughout the measurement time with very high temporal variations. Lyna Kindergarten is located 20 meters from a nearby base station. The high exposures recorded for GSM1800 signal at this measurement point indicate that the base station is a GSM1800 base station. Exposure to GSM1800 at Bateefu primary school in Mutundwe was highest between 8:00-15:00hours. At Mengo hospital, exposure to GSM1800 was really low with low temporal variations throughout the measurement time. Nabukeera commercial plaza had low exposure to GSM1800 signal. The time interval appropriate to test for compliance of this signals at this location is between 5:00-21:00hours.GSM1800 exposure at Kyebando was fairly constant and low throughout the measurement time.



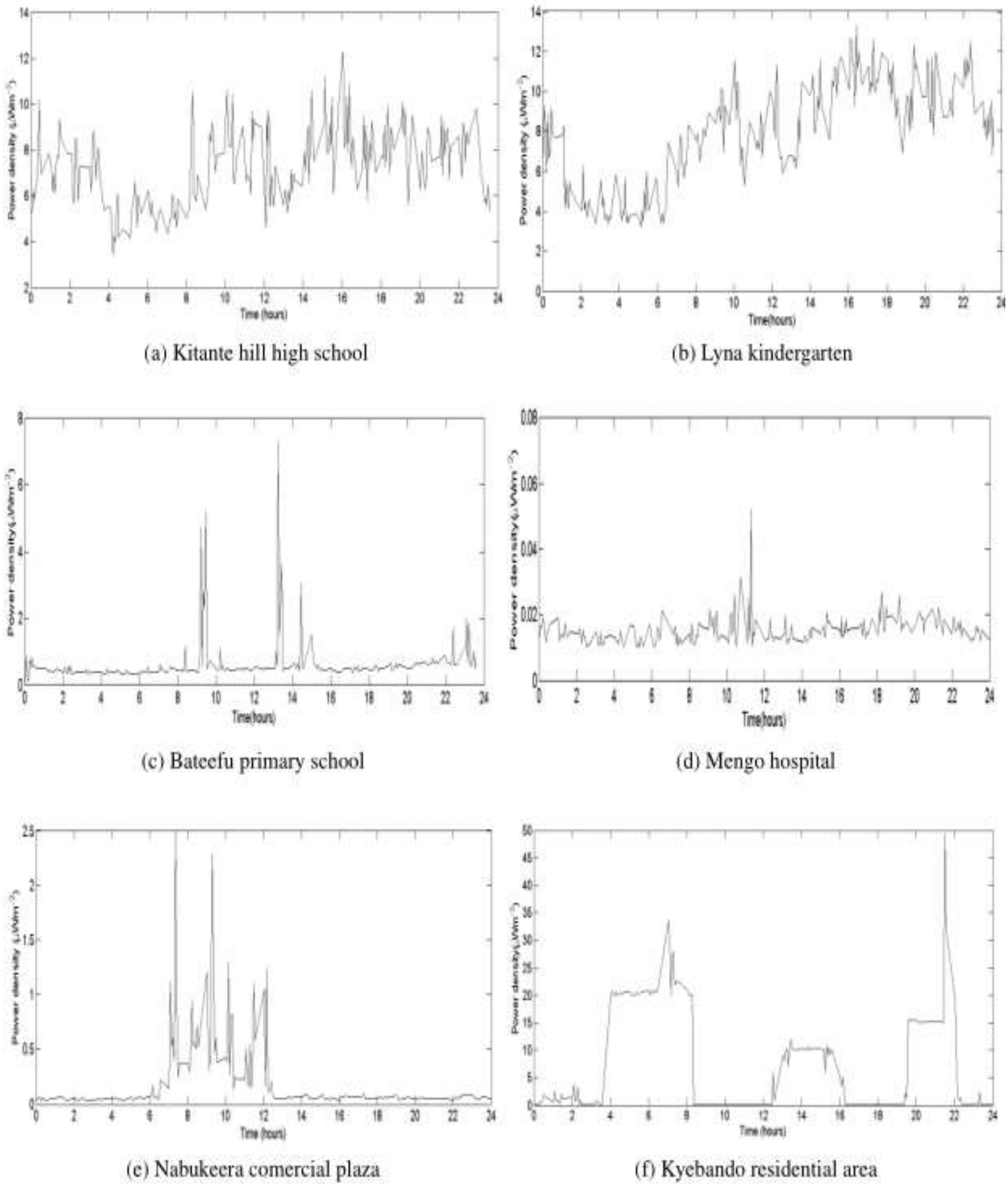
(a) Kitante hill high school
(b) Lyna kindergarten
(c) Bateefu primary school
(d) Mengo hospital
(e) Nabukeera commercial plaza
(f) Kyebando residential area

Figure 3: GSM1800 temporal exposure

3.3 Temporal Variations of the UMTS2100

Fig 4. shows temporal variation of UMTS2100 signal for 24hours at the six measurement location. The following can be observed from the graphs in Fig 4.

UMTS2100 exposure at Kitante Hill high school has very high temporal variation throughout the measurement time. Compliance tests by the regulatory body could be carried out any time of the day around this area. At Lyna kindergarten, exposure due to UMTS2100 signal has high temporal variations. UCC can test for compliance during any time of the day. Bateefu primary school had low temperature variations and exposure to the UMTS2100 signal was very except at around 9:00hours and 13:00hours. There is only noise in the UMTS2100 signal at Mengo hospital hence no exposure. Exposure to UMTS2100 signal at Nabukeera comercial plaza was low except between 7:00-12:00hours. Temporal variations recorded were also low. At Kyebando exposure due to UMTS2100 signal was relatively high. Compliance tests should be performed during 04:00-08:00hours, 13:00-16:00hours and 20:00-22:00hours time interval.



(a) Kitante hill high school

(b) Lyna kindergarten

(c) Bateefu primary school

(d) Mengo hospital

(e) Nabukeera comercial plaza

(f) Kyebando residential area

Figure 4: UMTS2100 temporal exposure

3.4 Temporal Variations of the LTE2600

Fig 5 shows temporal variation of LTE2600 signal for 24hours at the six measurement location. Observations made from the figure include:

Kitante Hill high school exposure to LTE2600 signal was relatively high with high temporal variations from 08:00-01:00hours and compliance tests can be carried out during this time. Lyna kindergarten exposure to LTE2600 was fairly constant with minimum variation of the signal with time throughout the measurement time. Bateefu primary school had low temporal variations in exposure due to the LTE2600 signal and compliance could be tested at any time as it can be observed from the figure. There is only noise in the LTE2600 signal at Mengo hospital and Nabukeera commercial plaza therefore no exposure. Kyebando residential area had high temporal variation in LTE2600 exposure.

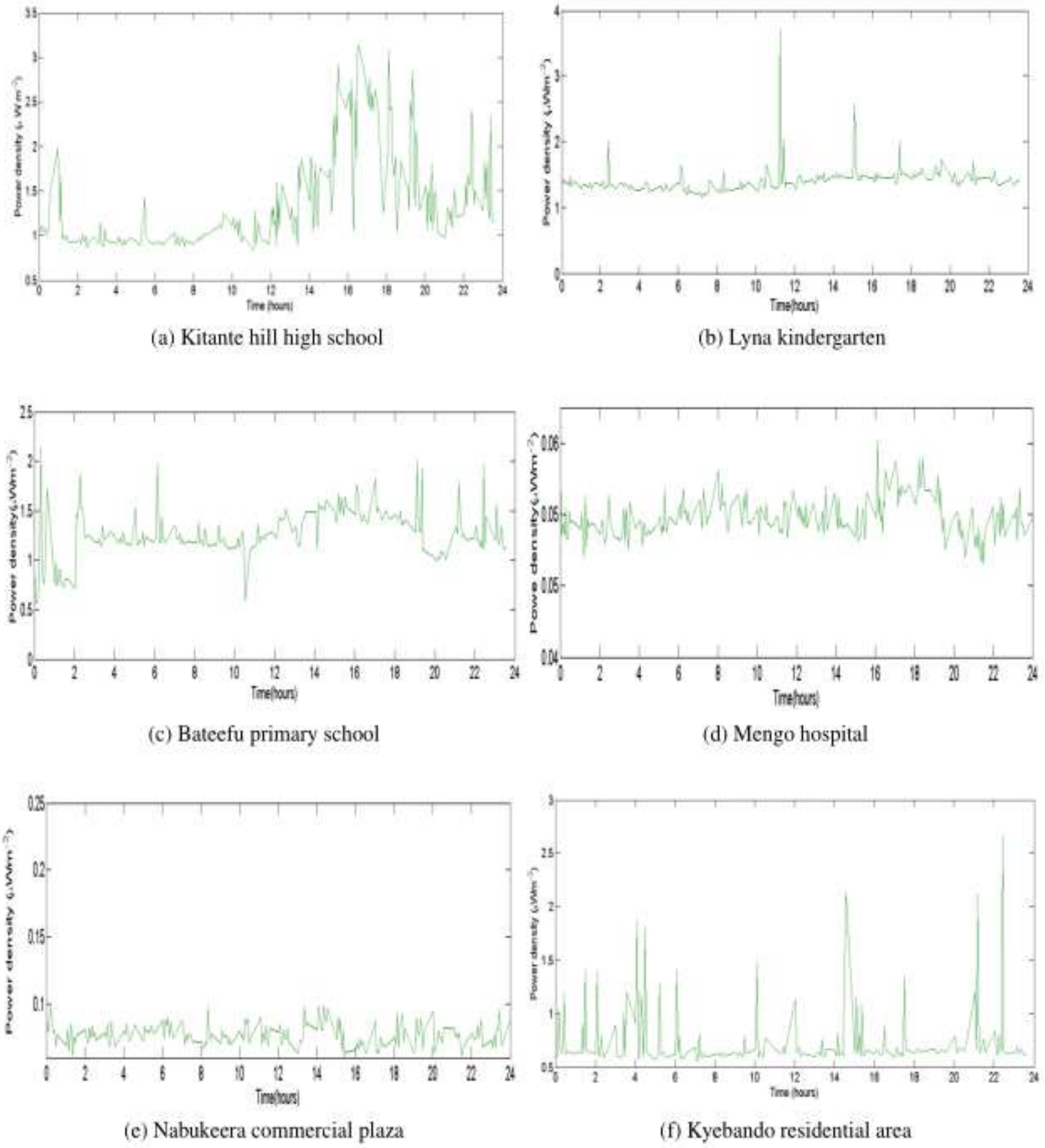


Figure 5: LTE2600 temporal exposure

3.5 Comparison of RF Electromagnetic Field Exposure Levels with ICNIRP Guidelines

Maximum exposure at every measurement location was evaluated. The maximum exposure recorded at every point for each signal was compared with the ICNIRP Limit/guidelines for the general public. Table 3 shows maximum exposure of the GSM900, GSM1800, UMTS2100 and LTE2600 signals at Kitante Hill High School, Lyna kindergarten, Bateefu primary school, Mengo hospital, Nabukeera commercial plaza and Kyebando.

Table 3: Maximum Exposure

Location	Maximum Exposure/ μ Wm $^{-2}$			
	GSM900	GSM1800	UMTS2100	LTE2600
Kitante Hill High School	2.86	18.25	12.32	3.28
Lyna kindergarten	13.24	142.31	13.61	3.74
Bateefu primary school	10.34	19.51	7.14	2.18
Mengo hospital	11.86	1.18	0.052	0.062
Nabukeera commercial plaza	0.38	1.93	2.49	0.095
Kyebando	11.87	8.72	49.12	2.64

Comparing the maximum values in with the ICNIRP guidelines for the general public, it can be seen that the maximum values recorded for each signal for all the measurement locations are way below the set guidelines hence assurance of public safety.

IV. Conclusions

Temporal exposure in sensitive areas should not be alarming to the general public. The results from the study indicate that the exposure is really low compared to the ICNIRP safety guidelines. The study has come up with appropriate time intervals for the regulatory body Uganda Communication Commission to do compliance tests in the areas around the measurement locations chosen in the study

Acknowledgement

This work was supported by the African Development Bank under the AfDB HEST PhD scholarship Project.

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Gertrude Ayugi. “Temporal Variation of Radiofrequency Electromagnetic Field Exposure from Mobile Phone Base Stations in Sensitive Environments.” IOSR Journal of Applied Physics (IOSR-JAP) , vol. 9, no. 5, 2017, pp. 09–15.