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Radiofrequency Intensity Exposure Levels from the Digital Terrestrial Television (DTTV) Broadcasting Transmitters in Kampala Metropolitan; Uganda

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Abstract. In this paper, we present the investigation in the radiofrequency intensity exposure levels from the DTTV broadcasting transmitters in, Nakulabye residential area, Mulago Hospital, Physics Department of Makerere University and Kyambogo Senior Secondary School, all in Kampala metropolitan.The DTTV frequency bands considered in this study were the sub 700MHz (474MHz-694MHz) and the 700 MHz (694 MHz-790 MHz) frequency bands. Investigation was done for three constant days in each of the Measurement Locations (MLos) using the Aaronia Spectran HF-6065 V4 spectrum analyzer, Aaronia AG HyperLOG 4025 Antenna, Aaronia GPS Logger, real time Aaronia MCS spectrum-analysis-software and a T430s Lenovo Laptop.In all these MLos, the mean daily and projected monthly exposure levels ranged from 0.00049 $\mu W/m^2$/day to 0.002542 $\mu W/m^2$/day and from 0.00495$\mu W/m^2$/month to 0.02410 $\mu W/m^2$/month in the sub 700 MHz frequency band while as in the 700 MHz frequency band, it ranged from 0.00076 $\mu W/m^2$/day to 0.00209 $\mu W/m^2$/day and from 0.00769 $\mu W/m^2$/month to 0.07944 $\mu W/m^2$/month. The results of this study show that the maximum exposure levels are very low when compared with the recommended International Commission on Non-Ionizing Radiation Protection (ICNIRP) safety RF intensity exposure level limits.

Keywords: DTTV transmitter, Radiofrequency intensity, Exposure levels

1. Introduction

People get exposed to radiofrequency (RF) radiations from television broadcasting transmitters during their everyday lives while at home, work and elsewhere in the environment. This is because during television signal broadcasting, the TV transmitters keep on radiating electromagnetic fields equally in all directions exposing the public to radiofrequency radiations (AGNIR, 2003). As of December 2008, Uganda had licensed 50 TV stations, 35 on air and 15 off air (Mugabe, 2009).

As the use of TV as a means of communication continue to grow world over, general concern about the potential hazards that may result due to exposure to RF non-ionizing radiation and the tendency to question quality of service of DTTV has increased. Body response to RF radiations occurs due to tissue heating (NRPB, 2003) where the internal electric field and the current density in that tissue are related by Ohms law as;

$$J = \sigma E \tag{1.1}$$

where J is the current density, E is the electric field intensity and σ is the conductivity of the tissue.

Though RF intensities from DTTV transmitters are well known below these values (NRPB, 2003), their potential thermal (due to sufficiently high levels of power densities) and non-thermal (theoretically proposed) effects (Ayugi, 2018) to the public is still something to ponder about.

According to Occupational Safety and Health Administration (OSHA) (OSHA, 2014), at sufficiently high power densities, RF radiations can cause thermal effects that would cause blindness and sterility. In 2015, OSHA's (OSHA, 2015) report on the information about communication towers indicated that high levels of exposure to RF intensities may result in burns but the same report had not thoroughly studied the link between RF radiation exposures and cancer, reproductive diseases and neurological effects. Ahlbom *et al*(Ahlbom *et al,* 2004) concluded that some elevated cancer rates were reported in some residential human populations exposed to TV transmissions. In 2011 when the International Agency for Research on Cancer (IARC) evaluated cancer risks from RF radiation basing on human epidemiological studies, it was evidenced that there were increased risk for gliomas and acoustic neuroma, that led into classifying RF radiation as Group 2B, a possible human carcinogen (IARC, 2011, Hardell, 2017)

While, Occupational Safety and Health Administration (OSHA), Federal Communications Commission (FCC), World Health Organization – International Agency for Research on Cancer (WHO/IARC) and Centers for Disease Control and Prevention (CDC) organizations note that non-thermal health effects have not been fully explored, they have however (individually or collectively) identified potential non-thermal effects due to RF radiations (City of Philadelphia 2008).

According to OSHA report of 2015, non-thermal effects, such as alteration of the human body's circadian rhythms, immune system and the nature of the electrical and chemical signals communicated through the cell membrane have been demonstrated due to exposure to RF radiations (OSHA, 2015). Non-thermal RF exposures may also be linked with hematologic, neurologic, reproductive, and cardiovascular disorders (NRPB, 2003, WHO,2002).

The basic methods (distance, time and shielding) that are employed to reduce RF radiation exposures from digital television broadcasting transmitters depend primarily on the Effective Radiating Powers (ERP), the position and the nature of the transmitter, whether directional or not.

For the general public, for the nearest distance from the transmitter, the maximum time allowed in any RF field is 6 minutes while as for the occupational worker it is 30 minutes (ICNIRP, 2009). A study in Australia (Hocking, *et al*, 1996) showed that radiation levels of 8.0 μW/cm^2 were cited near TV transmitters, decreasing to 0.2 μW/cm^2 at a radius of 4 kilometers and to 0.02 μW/cm^2 at a radius of 12 kilometers from the transmitter.

James. *et al*(James. *et al, 2006*) in 2006 carried out a study in Colorado USA and concluded that, RF radiations received by the public from TV transmitters where 2.92 μ W/cm^2 for people at a distance of less than 1 kilometer from the transmitter, 1.00 μ W/cm^2 for those in the distance range of 1-2 kilometers from the transmitter, 0.13 μ W/cm^2 for those in the distance range of 2-3 kilometers, and this reduced to 0.06 μ W/cm^2 for those who were at distances greater than 3 kilometers from the transmitter.

Dolk. *et al* (Dolk. *et al, 1997*) concluded that the maximum RF radiation summed across frequencies at only 1 measurement point at 2.5 m above the ground was 0.013 W/m^2 for television transmitters for people in residential areas from 0.5 to 10 km from the transmitter using 10 bands with increasing distance from the transmitter. However rates fell below expected levels in residences from 2.1 - 10 km from the transmitter.

In 2010 (Campisi,*et al*, 2010) carried out a study and found out that there was a DNA damage in human glial cells when exposed for 20 minutes per day for 14, 10 and 5 days to RF radiations at 900 MHz

In comparison to other people, people near TV broadcasting transmitters receive higher RF intensities than people from afar (Burch, *et al,* 2006).According to Federal Communication Commission (FCC, 2009), the power density limit for RF radiation public exposure is 0.2 mW/cm^2 at VHF TV frequencies. For UHF TV channels, the power density depends on the frequency and the formula used to determine the maximum power density (mW/cm²) at UHF channels in areas accessible to the public (in uncontrolled Environments) for an averaging time of 30 minutes is as in equation 1.2;

$$S = \frac{F(MHz)}{1500} \qquad 1.2$$

While for the occupational workers (in controlled environments) for an averaging time of 6 minutes is as in equation 1.3;

$$S = \frac{F(MHz)}{300} \qquad 1.3$$

RF intensity exposure levels are always carried out in form of temporal and spatial measurements. Temporal measurements require repeated measurements of data collected over several different time scales and because of this, it gives better RF measurement values as compared to spatial measurements in which the data is collected over a short period of time.

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Because of increasing number of TV stations in Kampala metropolitan, the purpose of this work is to develop a better knowledge of understanding the temporal characteristics RF intensities from the DTTV transmitter in Kampala metropolitan for the sub 700 MHz (470 MHz-694 MHz) and 700 MHz (694 MHz-790 MHz) frequency bands.

2. Materials and Methods

2.1 Measurement Locations

Temporal investigation of RF intensity exposure levels from the DTTV Transmitters in Kampala metropolitan was performed in four randomly selected locations. The indoor DTTV RF intensity investigated Measurement Locationsincluding their GPS coordinates are shown in table 1.

Table 1: GPS Coordinates at the Measurements Location

Measurement Location (MLo)	Latitude	Longitude	Altitude
Kyambogo Senior Secondary School	0.356248	32.6267416	1213
Mulago Hospital (Department of Public Health)	0.3408433	32.5793555	1262
Nakulabye Residential area	0.32762	32.56524	1247
Department of Physics-Makerere University-	0.3367795	32.56573528	1249

2.2 Experimental Setup

At every Measurement Location, the measurement set up (as seen in figure 1) consistedof a calibrated Aaronia Spectran HF-6065 V4 spectrum analyzer, an Aaronia AG HyperLOG 4025 Antenna, a T430s Lenovo Laptop, connected to the spectrum analyzer via a USB cable, and the MCS software. The MSC software is specifically designed to run on Aaronia spectrum analyzers and can easily suit a given measurement since it is easy to configure suiting a given measurement. Shown below in figure 1 is the connection setup. The setup was run continuouslyfor three days. Before real measurements were taken, at each location the noise levels in each DTTV band were obtained by first removing the antenna and recording the maximum noise exposure level for 60 minutes. The spectrum analyzer parameters configurations on the MCS software are as in table 2

Figure 1: Experimental setup for measurement of Radiofrequency intensity exposure levels

Table 2: Spectrum analyzer parameters configuration

Parameter	**Values**
DVB Frequency range	470 MHz-862 MHz
Resolution Band Width	100 KHz
Video Band Width	100 KHz
Sweep time	100 ms
Detection type	RMS
Sample points	100
Attenuation factor	10dB
Reference level	-10
Unit	Wm^{-2}

The mean daily RF intensity exposure levels were used to compute the project monthly exposure levels of the public in these selected MLos according to equations (2.1) below(Opio, 2015).

$$P_M = \frac{M_I}{M_D} x\ 30\ days \qquad 2.1$$

Where P_M is the projected monthly exposure level, M_I is the measured RF intensity in W/m^2 and M_D is the duration of measurement in days.

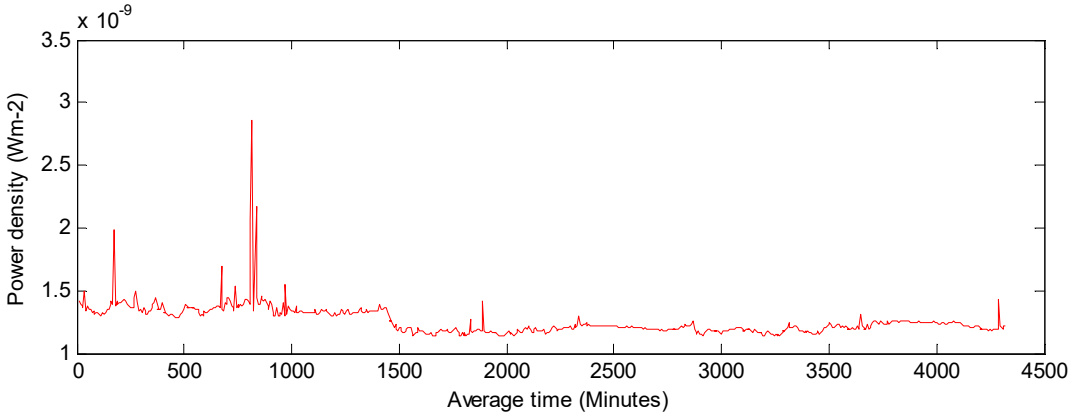
3. Results and Discussion

A continuousaverage power density for every after 6 minutes was obtained on a three day consecutive measurement, that', Monday, Tuesday and Wednesday. The 6 minutes average measurement was done in order to satisfy the ICNRIP guidelines on non-ionizing radiations

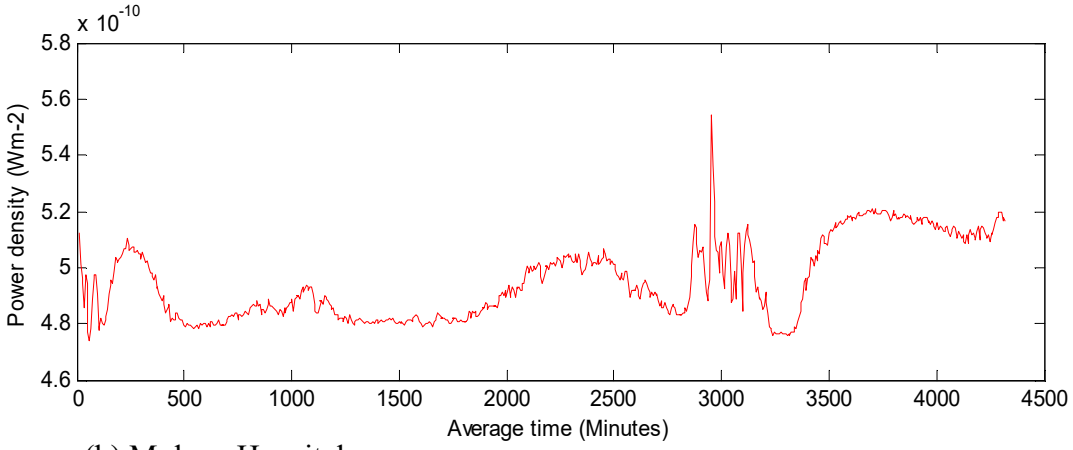
3.1 Radiofrequency Intensity exposure levels in the sub 700 MHz (470MHz-694MHz) frequency band

Figure 2 shows the RF intensity exposure levels for a period of three days for the 6 minute average at the four Measurement Locations (MLos). From the figure, it's observed that;

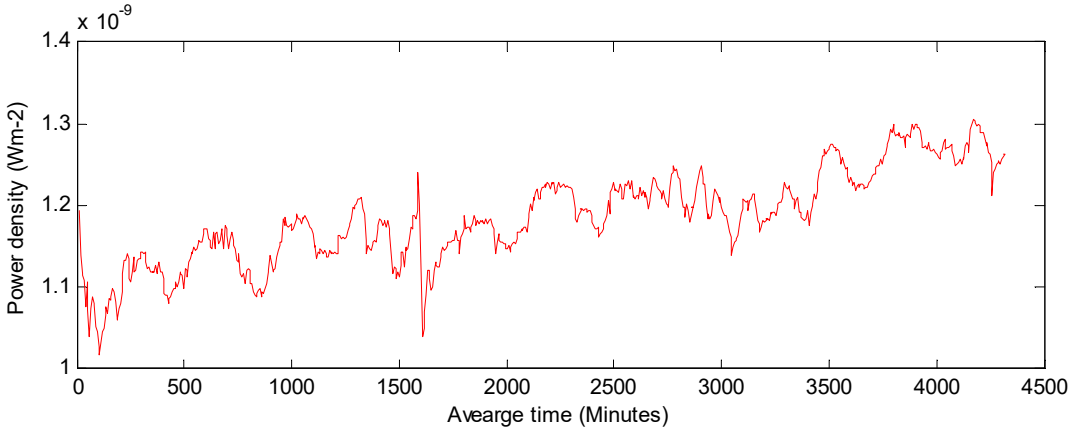
In Nakulabye, RF intensity exposure levels are high in the first day of the measurement as compared to the second and third day at about the 100 and 850 minutes. The exposure levels in the second and third days were almost constant. At Mulago hospital, there is only noise in the sub 700 MHz frequency band and the highest noise level is observed around the 2700-2800 minutes. Therefore there is no DTTV RF intensity exposure. This is because Mulago hospital is surrounded by many buildings making the hospital to be obstructed from direct DTTV RF intensity exposures. At the physics department of Makerere University, the exposure levels are non-uniformly increasing from the first day to the third day of the measurement with the highest exposure levels observed in the third day. At Kyambogo secondary school, the exposure levels are non-uniformly increasing from the first to the third day of the measurement with slight decreases at around the 100, 1800, 2500 and the 2700 minute.



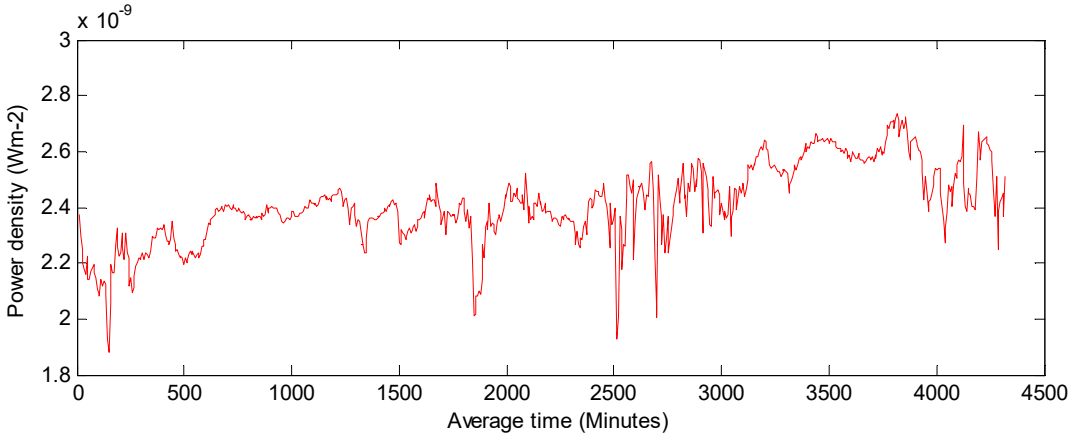
(a) Nakulabye residential area



(b) Mulago Hospital



(c) Physics Department-Makerere University



(d) Kyambogo Senior Secondary School

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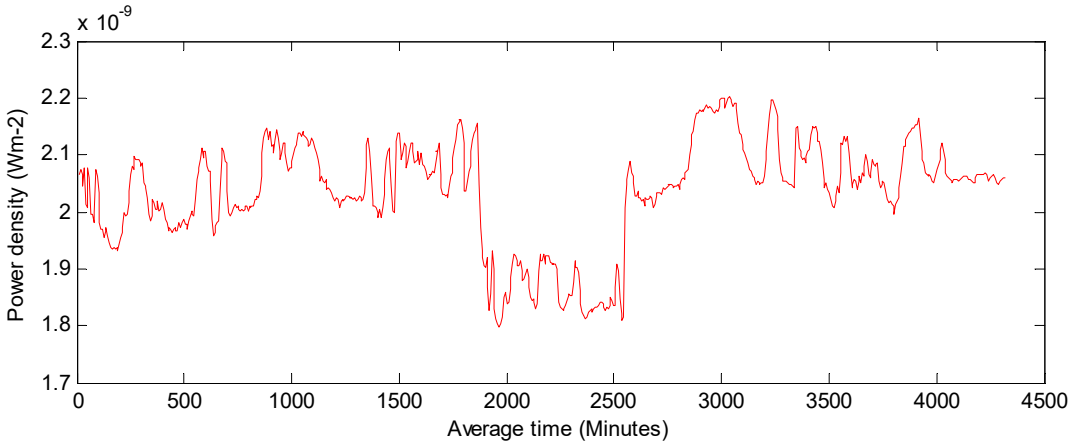
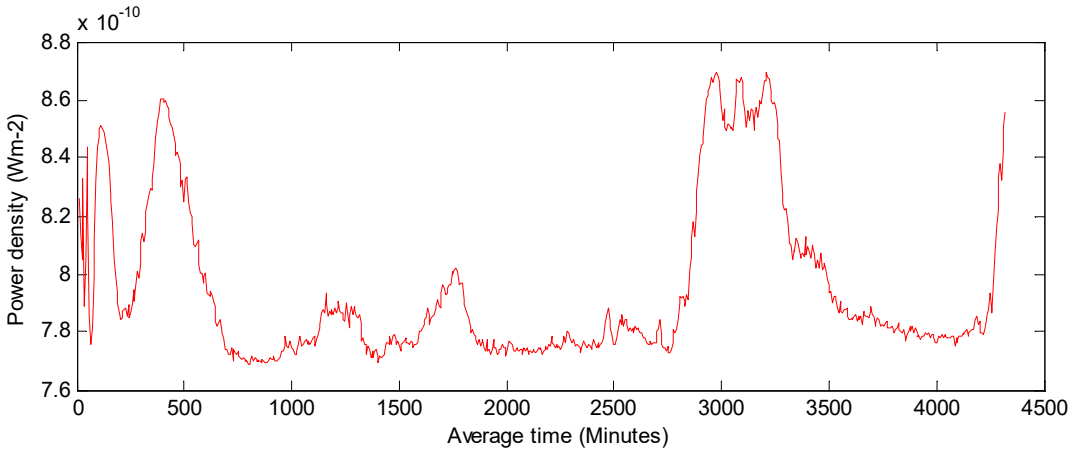
3.2 Radiofrequency Intensity exposure levels in the 700 MHz (694MHz-790 MHz) frequency band

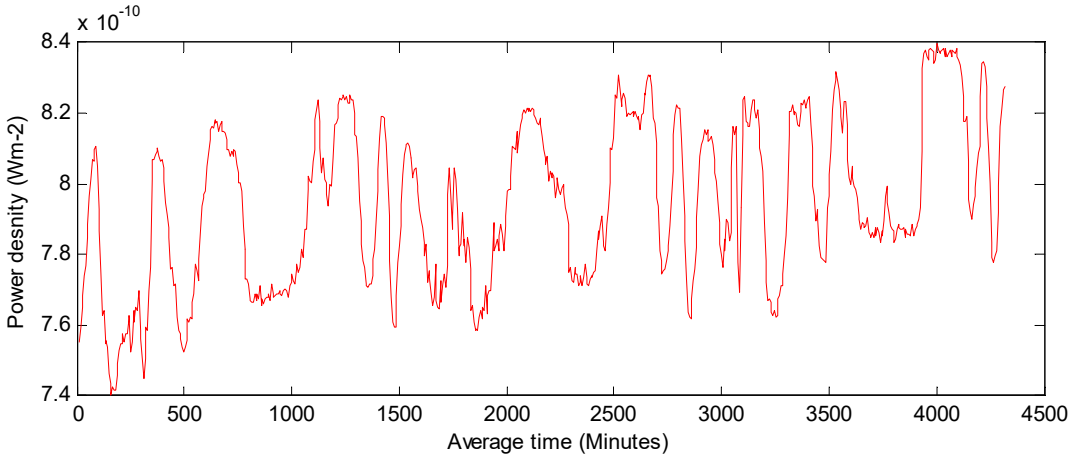
Figure 3 shows the RF intensity exposure levels for a period of three days for the 6 minute average at the four Measurement Locations (MLos). From the figure, it's observed that;

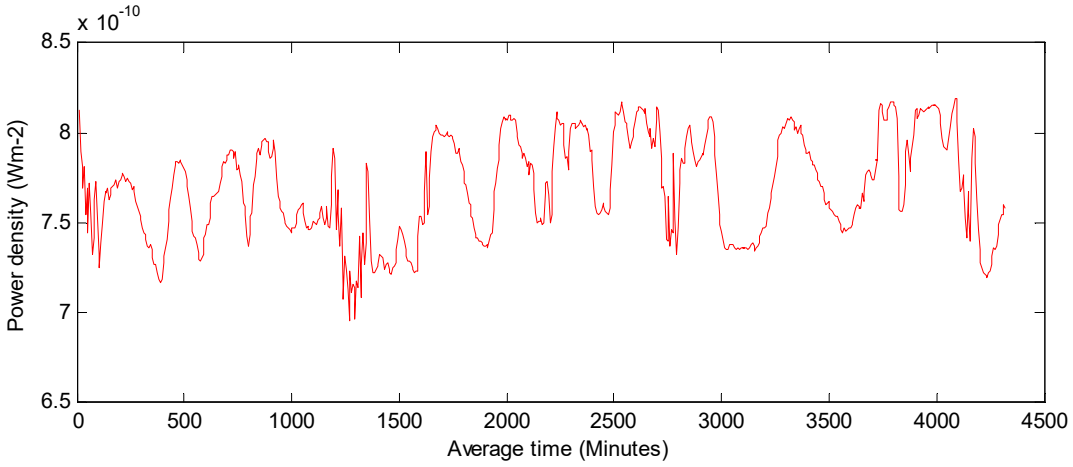
At Nakulabye residential area, exposure levels in the 700 MHz frequency band was fairly constant with a slight decrease from around the 1900-2600 minute during the measurement period and there after a non-uniform increase from around the 2600 minute up to the end of the third day of measurement.

There is generally only noise in the 700 MHz frequency band at Mulago Hospital, Physics Department-Makerere University and at Kyambogo Senior Secondary School throughout the three days of constant measurement and therefore, there are no DTTV RF intensity exposures in these places. This is an indication that there are few TV stations operating within this frequency range.









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3.3 Average daily DTTV RF intensity exposure levels

Tables 3 and 4 shows the average daily intensity exposure levels in the sub 700 MHz (470-694) and the 700 MHz (694-790) frequency bands respectively

Table 3: Average daily intensity exposure levels in the sub 700 MHz frequency band

Measurement Location	Day one ($\mu W/m^2$)	Day two ($\mu W/m^2$)	Day three($\mu W/m^2$)
Nakulabye	0.00137	0.00119	0.00121
Mulago Hospital	0.00049	0.00049	0.00051
Physics Department-Makerere University	0.00114	0.00118	0.00124
Kyambogo Senior Secondary School	0.00232	0.00237	0.002542

Table 4: Average daily intensity exposure levels in the700 MHz frequency band

Measurement Location	Day one ($\mu W/m^2$)	Day two ($\mu W/m^2$)	Day three($\mu W/m^2$)
Nakulabye	0.00204	0.00197	0.00209
Mulago Hospital	0.00080	0.00078	0.00081
Physics Department-Makerere University	0.00079	0.00079	0.00080
Kyambogo Senior Secondary School	0.00076	0.00078	0.00077

From table 3, in the 700 MHz frequency band, on average, maximum exposure levels in all the MLos wereobserved in the third day of measurement and the least exposure levels were in the first day of measurement. In the 700 MHz frequency band, from table 4, on average, maximum exposure levels in all the MLos were observed in the third day of measurement and the least exposure levels were in the second day of measurement.

3.4 Projected monthlyDTTV RF intensity exposure levels

The results of the projected monthly DTTV RF intensity exposure levels for the MLos are given in table 5 as given by equation 2.1.

Table 5: Projected monthly exposure levels

Measurement Location	In the Sub 700 MHz (470-694) frequency band ($\mu W/m^2$)	In the 700 MHz (694-790) frequency band ($\mu W/m^2$)
Nakulabye	0.01257	0.02035
Mulago Hospital	0.00495	0.01485
Physics Department-Makerere University	0.01186	0.07944
Kyambogo Senior Secondary School	0.02410	0.00769

From table 5, in the sub 700 MHz frequency band, Nakulabye residential area had the highest DTTV monthly intensity exposure levels and Mulago Hospital had the least while as in the 700 MHz frequency band, the physics Department of Makerere University had the highest monthly exposure level and Kyambogo Senior Secondary School had the least.

Conclusion:

The study shows that RF intensity exposure levels were generally higher in the 700 MHz frequency band than in the sub 700 MHz frequency band, in all the selected areas. Both the mean daily and projected monthly RF intensity exposure levels in these MLos are low and do not pose radiation risks to people living in them. The results from the study indicate that the exposure levels for both frequency ranges are really low compared to the recommended ICNIRP safety RF intensity exposure level limits. Because of this,there should not be any cause for alarm to the general public about the presence of DTTV

transmitters. The study still reveals that the two frequency bands in Kampala metropolitan are underutilized.

With this study, the Uganda Communications Commission will be able to find out how much DTTV RF intensity exposure levels persons leaving in these measurement locations receive on a daily and on a monthly basisand also be able to know the appropriate time interval for doing compliance measurements and test in these locations and other locations.

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