RADIO FREQUENCY ENERGY MEASUREMENT AND BUDGETING TOWARDS DESIGN, OPTIMIZATION, AND DEVELOPMENT OF RF HARVESTING SYSTEM

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ABSTRACT

The study measured RF energy towards the design, optimization, and development of an efficient RF energy harvesting system in Katsina State, Nigeria. An SRM - 3006 22 (Selective Radiation Meter), frequency selective measuring system was used for the environmental measurement of the high-frequency electromagnetic fields. For each location, a set of measures were taken in numerous zones to better understand each frequency band's variations throughout the study area. This would provide a range of expected power densities and after data post- processing an estimation of the energy that could be harvested in each environment. An SRM - 3006 22 Selective Radiation Meter (-75 to + 16dBm), frequency selective measuring system from NARDA Safety Test Solutions was used for the environmental measurement of the high frequency electromagnetic fields. Each unit of the system was separately modeled, simulated and analyzed using the communication toolbox in high level language MATLAB/SIMULINK environment and CST studio SUITE 3-D electromagnetic simulator. The study's findings indicated that the Received Signal Strength (RSS) values measured in this research vary from -2 to 37dB, and the average power of selected frequently used low power energy devices range from 2.9 to 12 mW which is equivalent to about 4.62 dBm to 10.79 dBm. Comparing this budget with the measured RSS values in Katsina Metropolis shows that there is available RF energy that can be harvested for powering low energy devices in the study area towards design, optimization and development of RFE Harvesting System.

Keywords: Radio Frequency; Energy Harvesting; Cellular Networks; Mobile Phones.

INTRODUCTION

Multiple sources of different Radio Frequency (RF) energy such as WI-FI, cellular networks and broadcast masts, Bluetooth radiate power in all directions in a rich scattering environment. RF energy density will continue to increase over the years, expanding the possibilities of deploying devices powered by ambient RF energy harvesting. RF energy harvesting has drawn much interest recently to provide a possibility of powering low energy devices such as mobile phones, remote sensing devices, and the internet of things (Deep, Rohan, Rhythm, Sahil, &Shivani, 2014). It can reduce the installation and maintenance costs of changing batteries integrated within numerous low power devices. By providing an “always on” source of energy for these devices, ambient RF energy harvesting can reduce the dependency on battery swapping or plug in charging, while unlocking the full potential of providing tracking capability for mobile based stations.

Ambient energy harvesting has so far, been limited by lots of factors (Zhi, 2011). One of the main limiting factors has been the ability to design a system that can operate at a high enough efficiency to harvest the ambient RF energy from the very low power densities (Giuseppina, 2012) that are present in Nigerian cities. This Research explores and proposes an RF energy harvesting technology to improve efficiency and provide maximum power transfer to supply low energy devices. This cannot be achieved without proper ambient RF energy density measurement at various locations to ascertain the energy harvesting system's viability and efficiency. Therefore, the problem of this preliminary study is to carry out ambient RF energy density measurement and study; and conduct energy budget on various low energy devices in Katsina Metropolis, Nigeria.

Objectives of the Study

- ✓ To carry out ambient RF energy density measurement; and
- ✓ To conduct energy budget on various low energy devices.

AMBIENT RADIO FREQUENCY SOURCES IN KATSINA METROPOLIS

RF energy sources comes from abundant radio transmitters. Radio waves, a part of electromagnetic spectrum consists of magnetic and electrical component. Radio waves carry information by varying the amplitude, frequency and phase of the wave within a frequency band. On contact with a conductor such as an antenna, the Electromagnetic (EM) radiation induces electrical current on the conductor’s surface, known as skin effect (Xiao, Ping, Dusit, Dong, & Zhu, 2014). The communication devices uses antenna for transmission and/or reception of data by utilizing the different frequencies spectrum from 10Kz to 30Kz. The maximum theoretical power available for RF energy harvesting is 7.0µW and 1.0µW for 2.4GHz and 900MHz frequency respectively for free space distance of 40 meters. The path loss of signals will differ in the environment other than free space (Taylor, 2014). According to available literature, there are three basic sources of RF energy (Kavuri, & Annapurna, 2012)as shown in Figure 1.

Figure 1: Three Sources of Radio Frequency Energy

MATERIALS AND METHODS

To determine the level of RF energy density in different locations, a broad power density study in multiple locations in Katsina Metropolis, Nigeria was carried out. These locations include an office in a central city area, schools, retail shops, high streets, and larger retail establishments. An SRM - 3006 22 (-75 to + 16dBm), frequency selective measuring system was used for the environmental measurement of the high frequency electromagnetic fields. Each unit of the system was separately modeled, simulated and analyzed using the communication toolbox in high level language MATLAB/SIMULINK environment and CST studio SUITE 3-D electromagnetic simulator. To assess the feasibility and application areas for energy harvesting, an energy budget was conducted on various frequently-used low energy devices that revealed their average power consumption. This model would then indicate the device's extended battery life using ambient RF energy harvesting system. With this data an estimate could be made using the device's energy consumption and energy harvested over a certain period to calculate the energy budget.

RESULTS

Objective One: Ambient Radio Frequency Energy Measurement

Figure 2 and Figure 3 show the Measured/Original Received Signal Strength Indicator Pattern in Katsina Metropolis. The RSSI (Received Signal Strength Indicator) values vary from -2 to 37dB, and increase logarithmically with signal strength. Values were read out from the device using a digital Energy Meter (RF Power Meter [-75~+ 16dBm]). Before measuring, the noise threshold of the RSSI value was determined to be 0.076. This value was consistently obtained even if the transmitter was not turned on. Consequently, any values measured at or below this value are omitted from graphs.

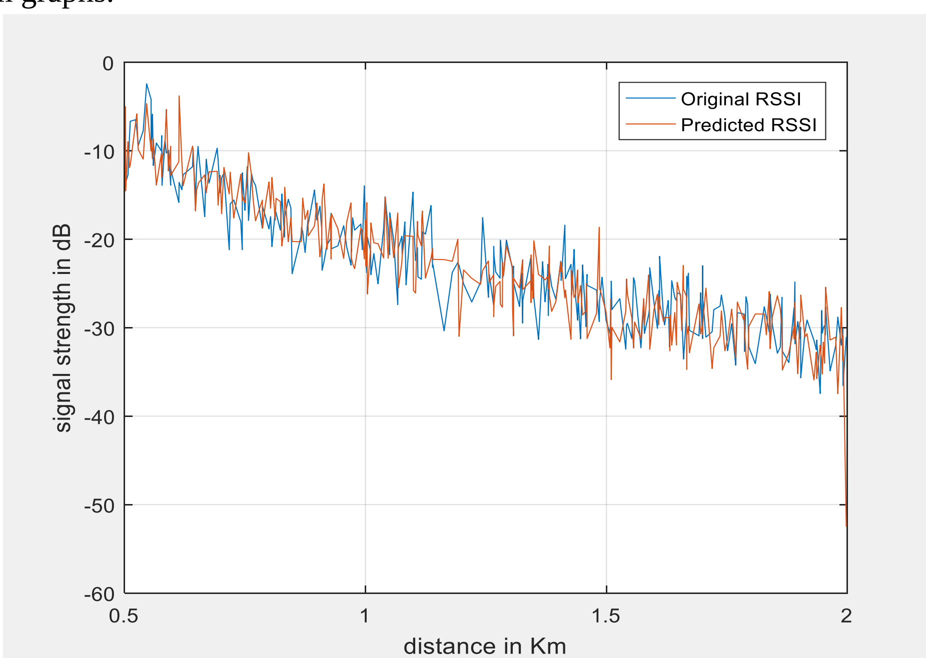

Figure 2: Measured/Original Received Signal Strength Indicator Pattern

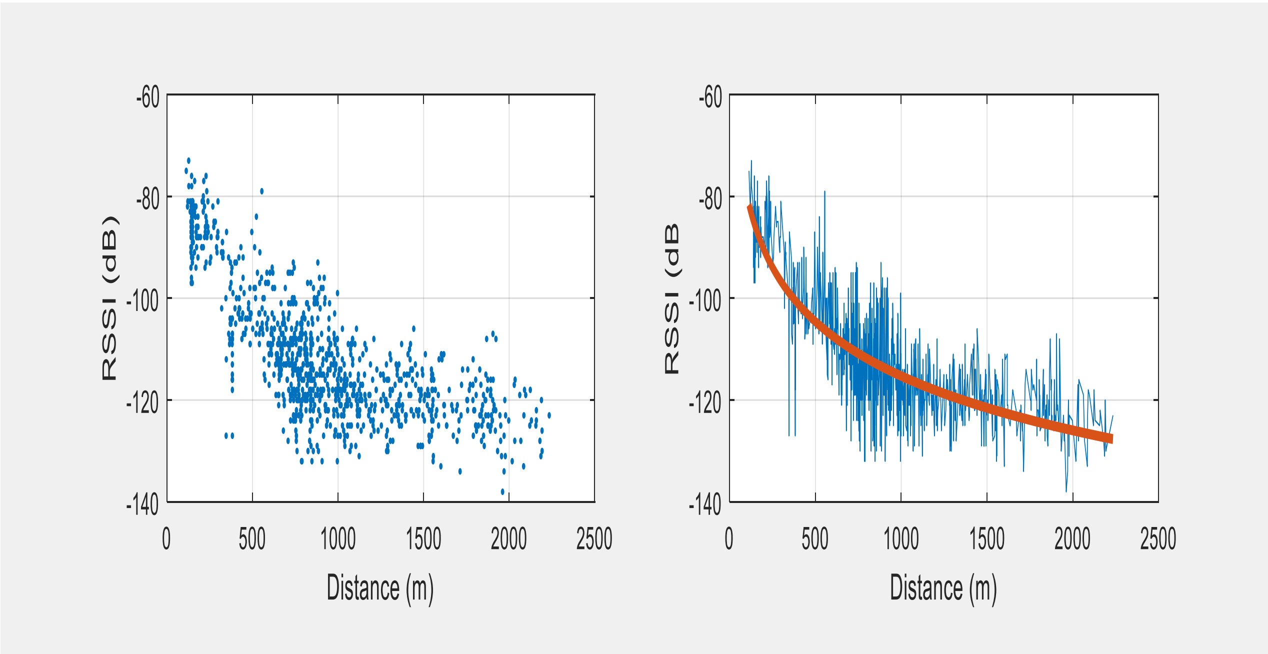

Figure 3: Measured/Original Received Signal Strength Indicator Pattern

Objective Two: Energy Budget on Various Low Energy Devices

Data for average energy budget of some selected frequently-used low power devices is shown in Table 1.

Table 1: Energy Budget of Selected Frequently-Used Low Power Devices

Status	Device A	Device B	Device C	Device D
Call Transmission	21 mA	16.5 mA	31.5 mA	34 mA
Call Reception	19 mA	15.5 mA	29.5 mA	32 mA
Data Mode	250 Kbps	250 Kbps	250 Kbps	250 Kbps
Sleep Mode	16 µA	14µA	15 µA	14 µA
General Mode	31 mA	25 mA	34 mA	33 mA
Charge Voltage	4.4 V	3.2 V	4.0 V	3.5 V
Average Power	2.9 mW	3.0 mW	12 mW	3.3 mW

CONCLUSION

Data analyzed revealed that the Received Signal Strength (RSS) values measured in this research vary from -2 to 37dB, and increase logarithmically with signal strength. Data on energy budget indicated the average power of anonymous frequently used low power energy devices range from 2.9 to 12 mW which is equivalent to about 4.62 dBm to 10.79 dBm. Comparing this budget with the measured RSS values in Katsina Metropolis shows that RF energy can be harvested for powering low energy devices towards design, optimization, and development of RF Energy Harvesting System.

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Appendices

Few screen shots during RF Energy Measurement