AC 2010-1303: ADAPTING A COMMUNICATIONS SYSTEM TO THE ENVIRONMENT OF AN AFRICAN NATION

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Adapting a Communication System to the Environment of an African Nation

Abstract

Communications technology in the developed world has advanced to a very high level. Satellite communication is one such example that ensures communication can be effected across great distances. Another example is the cell phone which is becoming prevalent in many developing nations. In many African nations some urban centers have access to many modern communication systems. This however is not the case in all urban centers and particularly in rural areas.

To improve the situation, a well known technology that can be adapted to suit the African environment is Powerline Communication (PLC). PLC is a technology in which data can be transmitted over electric power lines. With this technology, all facilities in any area that are connected to the electric power grid can have access to Internet applications. While there are some obvious disadvantages, the many advantages that the Internet brings include connection to libraries, research centers and many sources where there are numerous educational materials for both the young and the old. This can also provide access to essentials such as health care. Off-grid areas can be connected by wireless. By this approach different technologies can be combined such that whole nations can be covered by essential communication links. This paper reports the research work being carried out by some students at Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi, Ghana.

Introduction

In the global environment there are various modes of information transmission already in use. Two common examples that may be found everywhere are radio and TV. That is also the case in Ghana. Data transmission is also currently in use in Ghana, but it is in its early stage as an application and is not as pervasive as either radio or TV. However the advantages in data applications are numerous and make that mode of information transmission desirous. One major application is the Internet and that alone provides many advantages. To cite a few examples as a result of this major development, schools can have Internet access to major libraries and electronic learning (*e*-learning) can also be achieved [1]. And along this same line, distance education will experience a phenomenal boost in its delivery. Rural clinics can have connectivity to major hospitals and hence the expertise and services of doctors at such hospitals.

Ghana currently has electrification in most urban centers and some rural areas, and it is further being improved by extending it to areas than previously did not have electricity [2]. The national grid starts off at the generation site with high voltage (HV), goes to medium voltage (MV) and low voltage (LV) lines for distribution [3]. The prime objective for power lines is to supply electricity to places such as homes and industries and the cost for constructing the national grid is borne by that sector. Overlaying the transmission of data over the national grid therefore saves the initial cost of providing the infrastructure for the data transmission. By this approach, all areas that the national grid reaches can also have access to data applications.

PLC Application in Ghana

Electrical power is generated by the Volta River Authority (VRA) and this group has oversight of power distribution. Some of the essential activities that have to be carried out in this industry are power system protection signaling and energy management. For these to be achieved, both control and protection which fall in the area of supervision of the generation and supply are necessary, and communication is essential in this area. VRA employs PLC to reliably carry out these functions. As stated above the application of PLC need not be restricted to only the functions required in power supply but can be extended to providing broadband access to all places connected to the national grid. This leads to Internet access to homes, schools and industries.

The power line basically acts as an antenna as it propagates the signal; this means the power line will radiate electromagnetic energy through the radio space as an antenna would [4]. The radiation can be received by other antennas within the radiation space, and cause interference to other applications. It is therefore important to determine if the emissions from the system will cause significant interference to other users of the radio space [5]. It is to be expected that as any antenna can radiate as well as receive, electromagnetic emissions impacting the line from other sources can equally impart unwanted signals to the line. In both cases stated above, the transfer of energy will occur within specific frequencies of operation, with some harmonics falling outside of the specified range. This provides ample opportunity for student research. As stated above Ghanaian students are already involved in this research. US students will be linked to their Ghanaian counterparts to participate in the project and as the work progresses, US students will be taken to Ghana to complement their Ghanaian counterparts in setting up, testing and analyzing further the results from tests performed. This will also present research opportunities to minority engineering students to relate their college work to applications in the field.

Analytical Method

The need for analysis is identified in the assertion above that as data is transmitted along the power line, radiation from the power line can cause interference in other applications in close proximity to the power line just as such applications can cause interference to the data being transmitted. The analysis is done using the Numerical Electromagnetic Code (NEC) [6]. It uses electric-field integral equation (EFIE) and magnetic-field integral equation (MFIE) to model the electromagnetic response of antennas and other metallic structures. EFIE is well suited for thin-wire structures of small or vanishing conductor volume while MFIE, which fails for the thin-wire case, is more suitable for voluminous structures [6]. The NEC is therefore a rigorous and versatile code for electromagnetic analysis. It was used to simulate and calculate the electric field radiation from the PLC. The analytical results obtained were verified by experimental measurements using the Protek 3201 RF Field Analyzer, a hand-held field strength analyzer that has wide band reception ranging from 100 kHz to 2060 MHz.

The VRA PLC System

The modeled power line consisted of three horizontal parallel aluminum wires. Two of these wires were 25m above ground and were separated by 6m in the horizontal plane, and the third was 29m above ground. Each of the three wires had a diameter of 24mm. A balanced system was modeled by driving the signal in opposite directions on the two wires to represent the ‘go’ path and the ‘return’ path. A voltage source of 1 volt was used in series with a resistor which represented the source impedance.

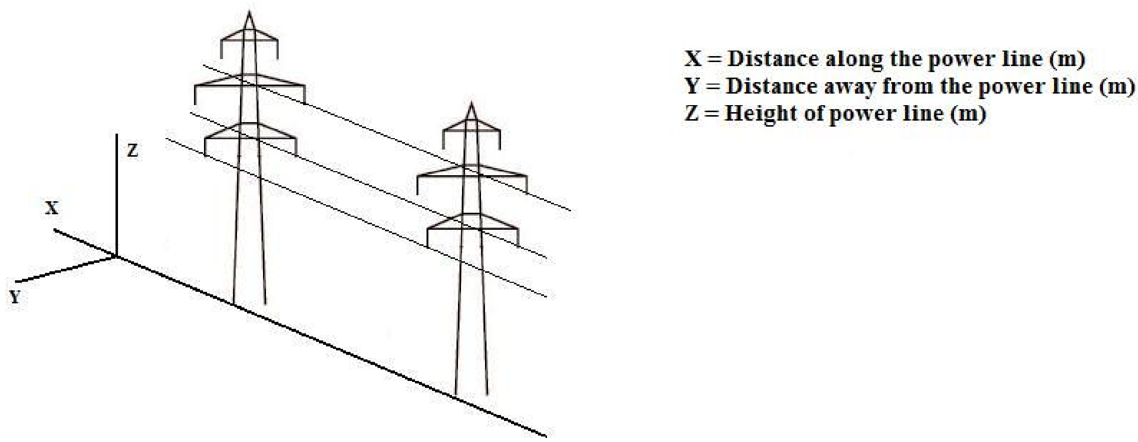

Figure 1. High voltage power line topology in Ghana and the coordinates used in the NEC simulation.

Measurements were performed at the VRA substation in Kumasi where a PLC system is currently being used for line protection and voice communication on the Kumasi-Techiman line. The two channels currently in use are 444 kHz and 482 kHz. Simulation results and experimental data were collected for transmissions along the line, and radiations off the power lines as a result of the transmissions along the power lines.

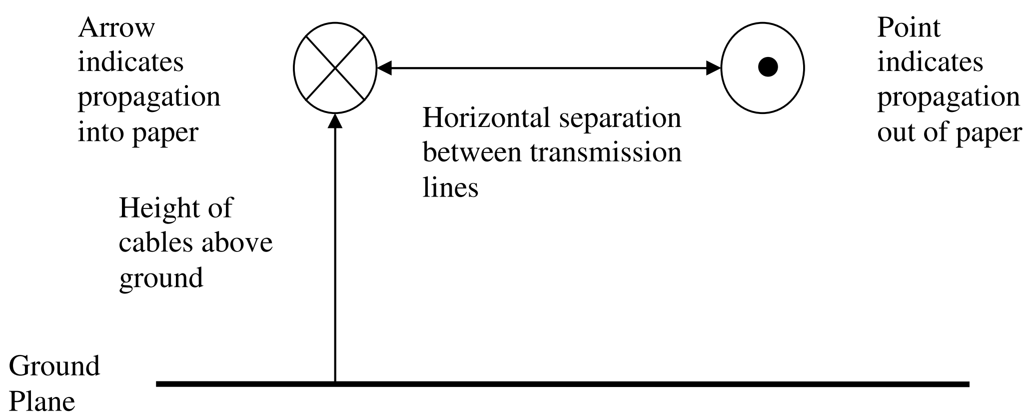

Figure 2. The two parallel horizontal power lines above ground showing directions of signal propagation.

The radiations are normal to the power lines. These were done at the frequencies stated above. The measurements were taken with the RF Field Strength Analyzer held at 2 meters above the ground.

Comparison of Analytical and Experimental Results

While the results below are encouraging, it forms part of the initial work. The objective of this part of the work is to establish a correlation between the numerical analysis and experimental measurements performed on the system while in use.

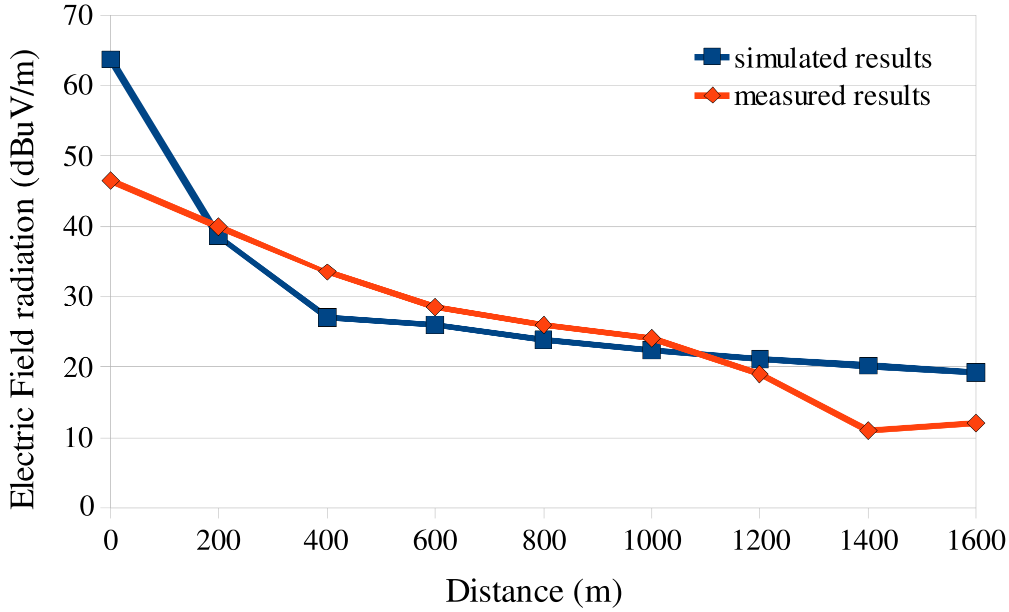

Figure 3. Plot of simulated and measured results of signal propagation along the power lines at a frequency of 444 kHz.

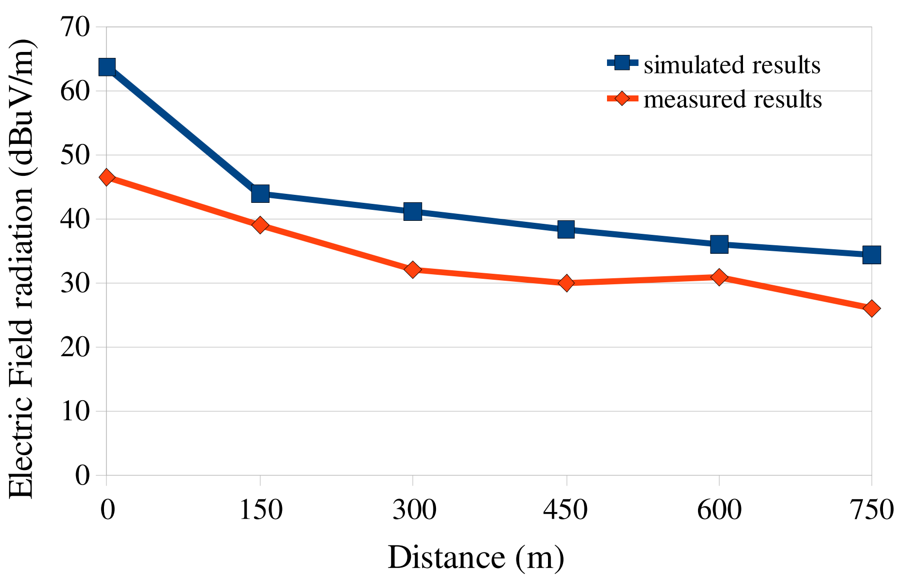

Figure 4. Plot of simulated and measured results of electric field radiation normal to the power lines at a frequency of 444 kHz.

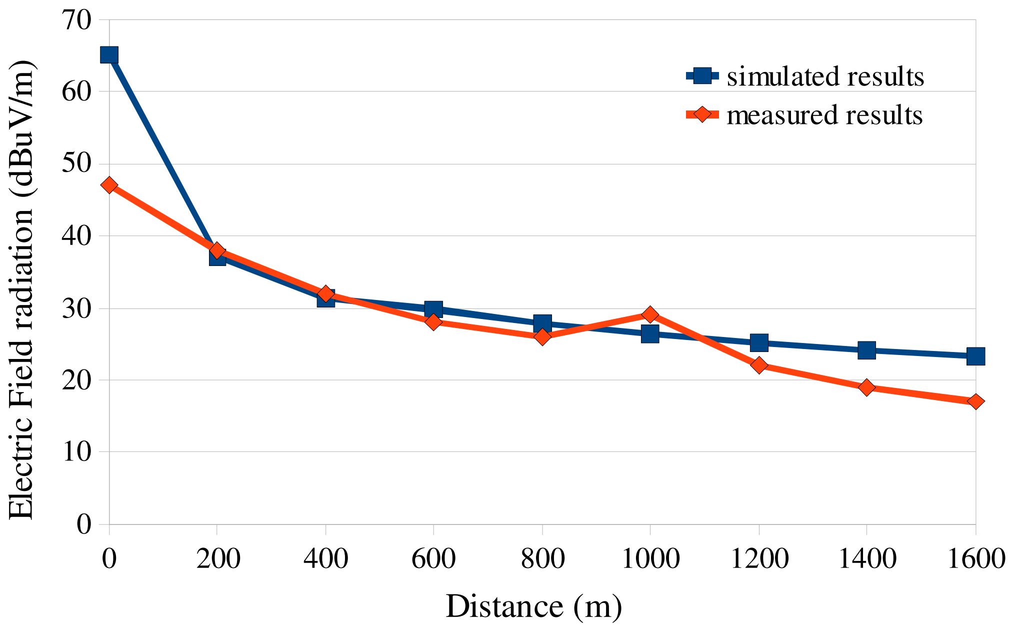

Figure 5. Plot of simulated and measured results of signal propagation along the power lines at a frequency of 482 kHz.

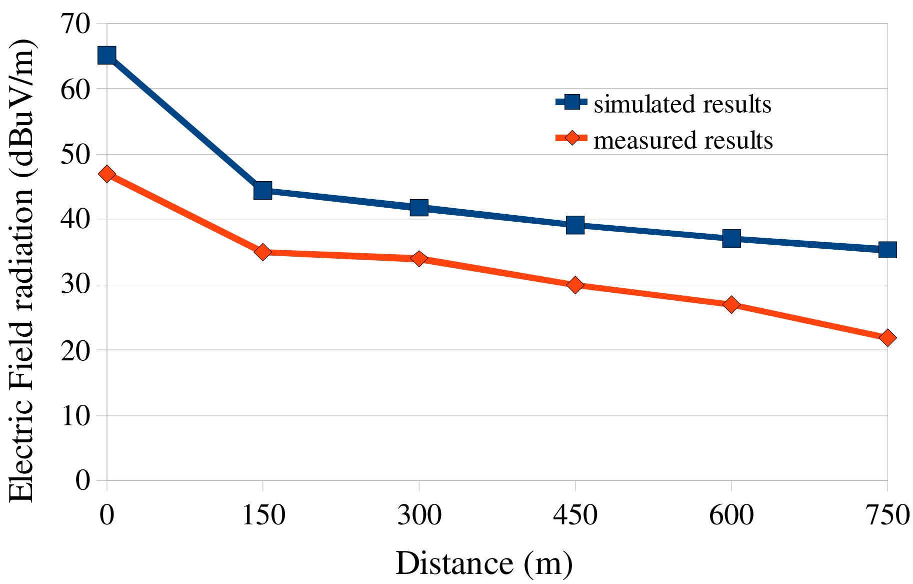

Figure 6. Plot of simulated and measured results of electric field radiation normal to the power lines at a frequency of 482 kHz.

The analytical and experimental results at both frequencies for transmission along the power line show very close comparison. For both frequencies, the two results show a reduction of from -5 to -10 dBuV/m after a distance of 1000 meters from the source point. This may suggest that for the specific system in Ghana, the distance for propagation without appreciable loss to the integrity of the signal is up to 1000 meters, and hence couplers may be spaced by that distance.

In the case of radiation of electromagnetic energy away from the power lines for both frequencies, a consistent reduction of -8 to -15 dBuV/m is observed. This can be attributed in part to the level from the ground at which the experimental measurements were taken. The conducting cables are 25 meters above ground and the measurements were taken at 2 meters above ground. It is expected that the correlation between these results would be closer if the measurements were taken closer to the cables. Measurable results went up to 750 meters, and it is expected that other applications within this distance can have interference from the PLC system.

Further Work

The frequencies currently being used for voice and control and supervision are 444 kHz and 482 kHz. Frequencies for other applications such as data transmission and Internet will be selected bearing in mind that Internet applications will be video intensive.

It has been stated that with the power lines acting as antennas, the lines will radiate as well as absorb electromagnetic energy to, and from other sources. This point is yet to be investigated to ensure that the interference levels to other applications in close proximity to the power lines are not significant. The signal propagated along the power lines will also have to be investigated further to determine the level of noise as interference on the lines. Further work also needs to be done to determine the most efficient spacing between couplers on the system.

Some of the aspects that need complete studies are ground effect on the transmission and the number of terminals that can be connected to any segment of the power line for efficient reception. The influence of the architecture of the power distribution network on the PLC system, and coupler fields [5] also have to be studied.

Conclusion

The initial work shows encouraging results that answer some useful questions. The power lines can function as required in PLC applications, even though the current use is limited to voice and supervisory and control purposes. Propagation along the lines are reasonable up to about 1000 meters with minimal attenuation effects. Beyond this limit attenuation becomes worse. Further work will be done as outlined above and it is expected that as progress is made other factors that will need to be investigated will become apparent.

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Acknowledgements

I thank EiF for its grant that provided some pieces of equipment one of which, the Protek 3201 RF Field Analyzer has been valuable in the experimental measurements. My appreciation also goes to Prof. Mohsen Kavehrad for his encouragement in this work.