On the Study of Received Signal Intensity Profile for Effective Planning and Optimization of Radio Network at GSM Frequencies

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Abstract—The study of propagation of radio wave in wireless channel is a function of environmental terrain profile. Hence, the measurement and statistical analysis of the received signal intensity (RSI) profile towards the planning and optimization of radio network. This information are not sufficiently available for characterization of wireless channel and development of models. This article presents the measurement of RSI profile of a particular base station at 900 and 1800 MHz, with a particular reference to MTN network, along three routes of Akure metropolis, Nigeria. Three major routes of measurements were marked: Akure-to-Ilesa highway (Route A), Akure-to-Iju-to-Ado way (Route B), and Oyemekun-to-Oba-ile way (Route C). Furthermore, the terrain information of the study area (such as buildings, hills, power lines, foliage, vehicular movements, and distance between the base station and the mobile station) was acquired in order to incorporate the special features of the environment. The statistical analysis of the measured RSI shows that the present cellular network capacity is insufficient in meeting the future mobile communication requirements. In addition, the significance and degree of correlations between the RSI and the parameter of the terrain shows how the terrain affects the RSI profile. Finally, the results presented in this paper are motivating enough for cellular radio network engineer for estimating radio coverage, path loss prediction, handover optimization, and adjustment of transmitting power.

Keyword: RSI, GSM radio network, transmission power, channel, planning, optimization, path loss, network engineer, measurements.

I. Introduction

In meeting the high demand of coverage and capacity requirements of future mobile communications, the study of received signal intensity profile has attracted appreciable interest in both academia and industry. Received signal intensity (RSI) measurement provides a direct and simple method for identification and tracking of node locations. The knowledge of RSI provides cellular radio network engineer for estimating radio coverage, path loss prediction, handover optimization, and adjustment of transmitting power towards achieving quality service required [1]-[10]. Therefore, conducting measurement and analysis RSI is significantly important.

RSI measurements remain crucial in many applications. Some practical applications are presented here. Some companies (e.g. Tutela, OpenSignal, etc. [10], [11]) provide cellular radio measurements and sell to mobile network operators for network enhancement. The RSI intensity profile observed by customers is a major metric to analyze and

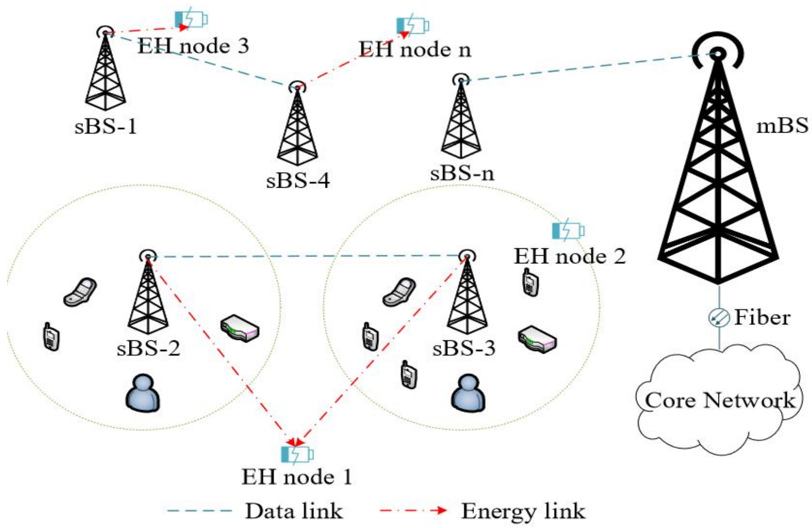

Figure 1. A radio cellular network consisting of a single base station and *K* users [2].

evaluate radio cellular network (as in Figure 1) and make technical decision as to where to position more cells. Mobile operators make use of the information provided by RSI to better understand how competing the market is. Furthermore, big European works (e.g. Interphone [9], EMF-NET [10], etc.) study the effect of electromagnetic (EM) field radiation on human body. Conversely, all the works have challenges ranging from correct exposure quantification of the population to RF EM fields.

Some other works that attempted RSI measurement are found in literature. The measurements are site-specific, as such, difficult to generalize. Zhang *et al.* [11] developed a spectrum analyzer that employs commodity WiFi cards with frequency translators in sensing wide band frequencies. More measurements of cellular networks are provided in various works [9]-[23]. All the works employed different systems or devices for the measurements, such as, TEMS (transmission evaluation and monitoring system) software, EMF meter, Electromagnetic radiation detector, Radio frequency EM field intensity meter, EM field testers-Lutron instruments, etc.

The effect of polarization on RSI and application has been treated in literature. Li *et. al*. [23] demonstrated how RSI varies by more than 15 dB across various orientations. Pasku *et. al.* [18] evaluated the impact of directivity and receiver on RSI for different applications. They demonstrated how RSI obtained from wireless system that contains four nodes of ZigBee has a 5 dB variation at various angles along azimuth. The developed a method for getting one calibrated RSI of mobile network by performing average of each RSIs obtained from four nodes. The authors were able to mitigate the RSI variation to about 2 dB. Since measurement data taken at a location cannot be assumed for other locations [24]-[26], there is still a need for more measurements to cover various locations of concerns. The contributions and finding of this article are as summarized below.

a) This article presents the measurement of RSI profile of MTN network base station at GSM frequencies, along three routes of Akure metropolis, Nigeria. Three major routes of measurements were marked: Akure-to-Ilesa highway (Route A), Akure-to-Iju-to-Ado way (Route B), and Oyemekun-to-Oba-ile way (Route C).
b) Furthermore, the terrain information of the study area (such as buildings, hills, power lines, foliage, vehicular movements, and distance between the base station and the mobile station) were acquired in order to incorporate the special features of the environment.
c) The statistical analysis of the measured RSI shows that the present radio network connection capacity is insufficient in meeting the future mobile communication requirements. Technical recommendations were made for adequate and effective quality of service of the radio cellular network.
d) Finally, the RSI measurement data is made available for both industrial and academic use, this is in addition to the existing data. The available data can be used for estimating radio coverage, path loss prediction, handover optimization, and adjustment of transmitting power etc. It also helps in network planning and link budgetary.

II. Measurement Campaign

The study area; Akure city, Ondo state, Nigeria is situated at longitude 5.2^0 E, latitude 7.25^0N, and altitude 420 m over the sea. Three major routes of measurements were marked: Akure-to-Ilesa highway (Route A), Akure-to-Iju-to-Ado way (Route B), and Oyemekun-to-Oba-ile way (Route C). The three routes as a presented in Figure 2 to investigate the coverage area of a base station at GSM frequencies. The study area can be classified as suburban area because of the presence of buildings, hills, foliage, and power lines. The weather conditions were good when the measurement campaign was carried out. A good vehicle access was ensured to site locations for quality test drive. Long distance is covered to ensure the receiver noise floor is ascertained. The measurement was taken using TEMS (transmission evaluation and monitoring system) software. This software is installed on a personal computer with 16 GB RAM, 1 Terabyte Hard drive, and Intel core i7 8th Gen. The TEMS, USB dongle, and GPS were connected to the laptop. The system is put inside vehicle, and driven at 35 km/h throughout to reduce Doppler effects.

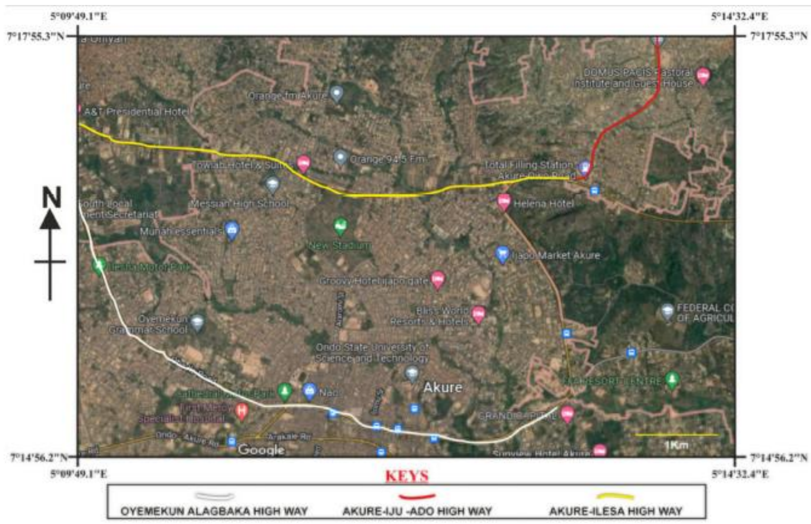

Figure 2. Measurements routes of the study area.

III. Results and Discussion

This section provides the results of analysis of the measured data obtained. Figures 3-5 show the plot of measured received signal strength against the distance along the three routes considered. The statistical results of analysis of the measured RSI profile for all the 3 sectors of the base station are shown in Table 1.

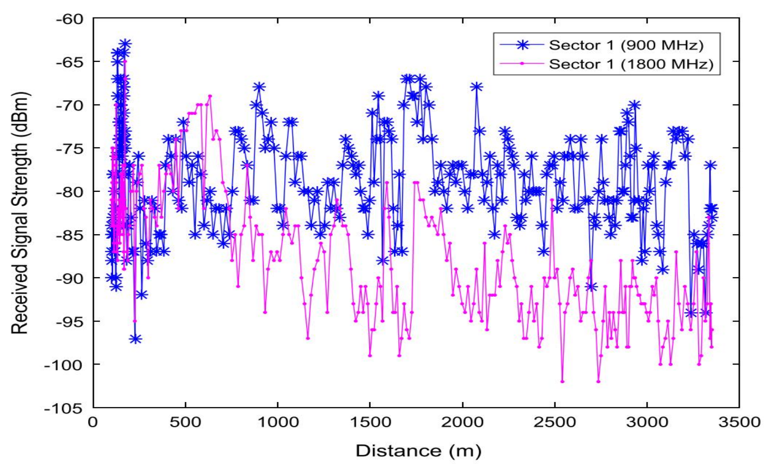

Figure 3. Plot of RSI against distance for route A.

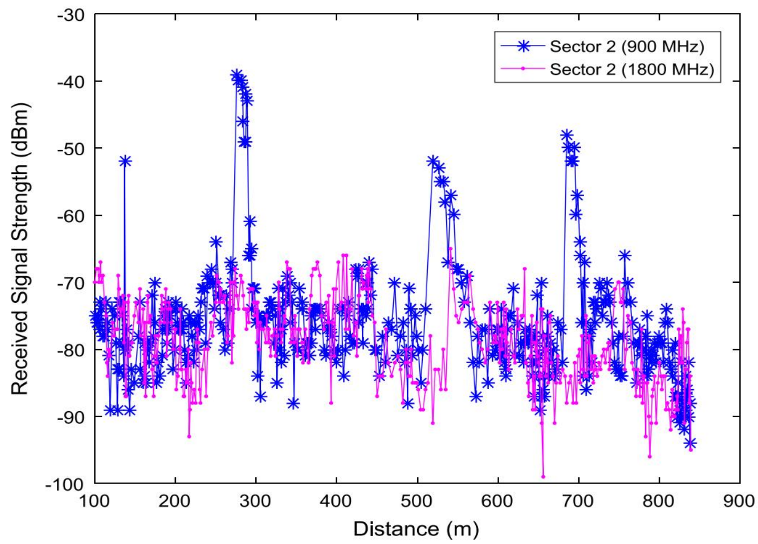

Figure 4. Plot of RSI against distance for route B.

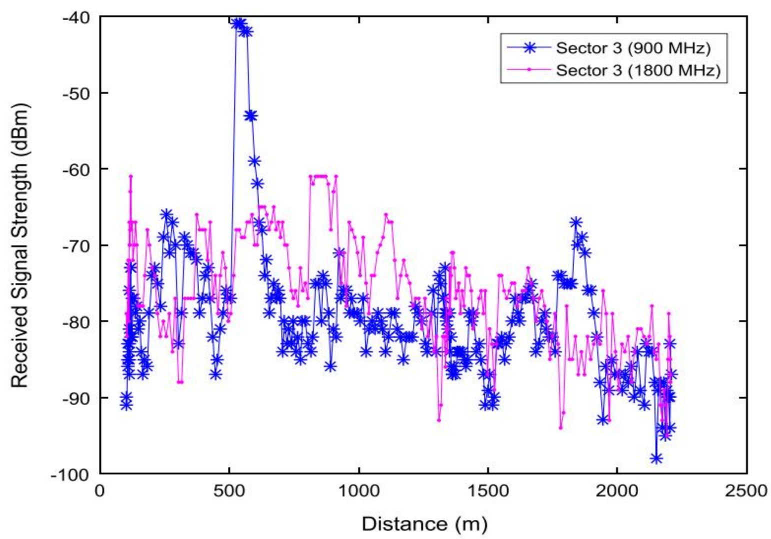

Figure 5. Plot of RSI against distance for route C.

Table 1: Statistical results of the measured RSI.

Statistical Parameter	Sector 1 (900 MHz)	Sector 1 (1800 MHz)	Sector 2 (900 MHz)	Sector 2 (1800 MHz)	Sector 3 (900 MHz)	Sector 3 (1800 MHz)
Maximum	-64.00	-66.00	-40.00	-66.00	-42.00	-62.00
Minimum	-98.00	-103.00	-95.00	-100.00	-99.00	-96.00
Range	35	38.00	56.00	35.00	58.00	35.00
Skewness	0.06	0.53	2.74	-0.16	3.04	-0.08
Kurtosis	3.93	2.77	8.58	3.52	10.80	3.79
Variance	36.26	54.55	74.54	40.17	74.98	55.24
Standard Deviation	6.95	8.42	9.59	7.27	9.70	8.37
Mode	-83.00	-95.00	-80.00	-78.00	-80.00	-78.00
Median	-80.00	-89.00	-78.00	-80.00	-82.00	-77.00
Mean	-79.62	-88.24	-77.14	-79.79	-80.60	-77.12

Because of the continuous growth in the number of connected mobile devices, wireless technologies and services requiring connection to radio cellular networks under different conditions and situations keeps increasing. According to [17], the current trend in machine-to-machine communication and internet of everything has connected over 100 dillions smart sensors and devices. There are majorly three commercial cellular network in the study area: GLO network, Airtel network, and MTN network. The one employed for this experiment is MTN network. Both the network parameters and specifications were seriously taken into consideration based on the manufacturer's prescription. The data made available in Figures 3-5 facilitates advancement in research, particularly in the characterization of the channel accounting for the terrain characteristics of a propagation environment in Akure, Nigeria. Akure city is situated in the tropical region. The RSI data and the environmental features give important information for the development, formulation, and design of radio propagation model. This model is employed for the prediction of the mean RSI of any mobile network at a specific distance of the receiving antenna from the transmitting antenna. Adequate and effective models generate RSI prediction at various points of observation within the coverage area when planning, budgeting, and optimizing radio cellular network. The RSI data and terrain features provided assists the network engineers in the determination of the base station positions for optimal performance. The RSI profile made it possible to get the best data rate. The network coverage estimation, power level of transmission determination, efficient antenna pattern and height selection, adequate frequency allocation performance, optimization of radio cellular network, and feasibility studies of the interference with possible attenuation are made available by RSI data. In addition, RSI data ensures a desired quality of service with no need of costly measurements.

The statistical analysis of the measured RSI data shows that the channel condition, such as foliage, buildings, hills, etc. affect the quality of the network in Akure metropolis. The results of different statistical analysis performed on the data obtained as depicted in Table 1 show that the state-of-the-art network capacity is insufficient in meeting the future mobile communication requirements, as there is increase in the population in the Akure city. Hence, there is a need for more base station in Akure to improve the quality of service provided in the area.

IV. Conclusion

In conclusion, the study of RSI measurement profile of a base station at GSM frequencies in Akure metropolis, Nigeria is presented. The measurement campaign was conducted along three routes. There is a presence of buildings, hills, foliage, river, power lines along the three routes. As such, the effects of the environmental special features are incorporated. Various statistical analysis was conducted on the data obtained, and the results show that the state-of-the-art network capacity is insufficient to meet the future wireless communication requirements as the population increases. There is a need for more base station in the study area to improve the quality of service provided. In addition, radio communication network engineers can use the measured data for handover optimization, adjustment of transmitting power level, path loss prediction, and radio coverage estimation. Hence, this study provides a good knowledge of EM wave propagation towards effective cellular network planning and optimization.

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