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Penetration Depth Analysis of UMTS Networks Using Received Signal Code Power

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

This paper examines the coverage of three UMTS networks in Calabar, using the received signal code power (RSCP). A drive test conducted with the aid of a TEMS investigation software, collected log files of RSCP which were analyzed as coverage plots by a TEMS discovery software and further put through statistical measures using excel. The low values of calculated standard error depicts that the data used in this study is accurate and not manipulated. The data distribution in MTN and 9mobile network were slightly leptokurtic but slightly mesokurtic for Airtel network. Again, the data distribution for the three networks were approximately symmetric. Finally, 81.5%, 96.36% and 92.1% of the drive test routes for 9 mobile, Airtel and MTN network met with the NCC performance threshold. The result of this study will assist RF engineers in the optimization of UMTS networks and also in designing propagation models for accurate transmission of UMTS network signals in the study area.

Keywords: Network coverage; received signal code power; UMTS network; mobile network.

1. INTRODUCTION

The rapid upswing in the teledensity of cellular networks has become a subject of interest to the operators, the subscribers and regulatory commission which requires cellular networks to be evaluated frequently. The regular assessment of the networks is aimed at optimizing the network to meet with end users' requirements, obligation of the supervising commission and for

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the operators to assess their performance. These cellular networks are evaluated in terms of key performance indicators, one of which is the received signal code power (RSCP), measured in dBm [1-5].

The RSCP is the measure of Radio Frequency (RF) power in a UMTS network after signals are descrambled [6,7]. In descrambling, the signals with the correct code are first filtered out. This creates difficulty in the measurement of the total RF power, rather, the RSCP is measured for specific codes and only these codes are prime to the receiver when judging the quality of service [8].

The RSCP denotes the received power of the primary common pilot channel (CPICH), measured by the user equipment (UE). It can also be measured on downlink and uplink, though, only defined for the downlink and therefore presumed to be measured by the UE and reported to Node B through an uplink channel [9].

The RSCP is an indication of signal strength in UMTS networks, therefore its data is useful in designing, formulating and developing of radio propagation models, useful in downlink power control, used as a criterion to request for a handover and used in RF optimization and planning. The developed propagation models are used for coverage prediction in a UMTS network at a given distance of the receiver away from the transmitter [10–14].

In UMTS networks, RF engineers rely on RSCP for optimal locations of Node B, for the achievement of best possible data rates, for the determination of the required transmission power, to aid appropriate selection of antenna height and pattern, for the allocation of frequency, for interference feasibility studies and to ensure an acceptable QoS [15-19].

Researchers have severally investigated the QoS of mobile networks [20-29]. The authors in [30] evaluated the signal quality of UMTS networks (MTN, 9mobile and Airtel network) over two cities in Nigeria. A total of 10,958, 11,075 and 11,109 Ec/Io measurements were obtained for MTN, 9mobile and Airtel network. These generated signals were analyzed in the form of bar charts, quality plots, calculations of mean, mode, standard deviation, standard errors, excess kurtosis and skewness. Result revealed that 59.64%, 50.45% and 17.02% of the drive test route for Airtel, 9 mobile and MTN network had good signal quality and met with the Nigerian telecommunication regulatory benchmark of at least -9dB for Ec/Io. Also, 40.36%, 49.55% and 82.98% of the drive test area for Airtel, 9mobile and MTN network fell below the regulatory benchmark and subscribers in this region were observed to have experienced dropped calls, blocked calls, handover failures and degraded signal quality due to interference. Airtel network was therefore adjudged the best network while the worst network was MTN network.

In [9], the authors analyzed UMTS networks in both rural and urban areas of Mwanza, Tanzania. The analyzed parameters were RSCP, transmitted power, speech quality index and the received power to noise ratio (Ec/No). Analyzed result of the collected data shows that 24.02% of the study area had good coverage, 23.24% had poor coverage and 52.74% had fair coverage. Also, further analysis of the study area showed that only 27.61% of the region has good service quality, while poor service quality was recorded in 2.76% of the region.

A 3G radio network performance evaluation is presented by the authors in [10] on the basis of their RSCP and Ec/Io. Their focus was aimed at an assessment of 3G network within the borders of Distributed Antenna Systems (DAS). The Tests was carried out with a TEMS Investigation and its practical deployment validated DAS enhancement of indoor coverage and capacity in 3G networks. Therefore, the installation of DAS in high traffic locations will enhance service quality by reducing call blocking and BER.

The authors in [31] evaluated the performance of four GSM networks, taking its RxQual into consideration. Obtained log files showed 10501, 10140, 10415 and 10690 RxQual measurements obtained for MTN, 9mobile, Airtel and Globacom network. These generated data were subjected to statistical analysis in the form of bar charts, quality plots and calculations of measures of central tendency and dispersion. Result shows that 78.43%, 92.18%, 90.68% and 86.93% of the drive test route for MTN, 9mobile, Airtel and Globacom network had good RxQual and met with the NCC benchmark of at least 4dB. It was deduced that for RxQual, 9mobile was the best GSM network, followed by Airtel network, Globacom network and then MTN network.

Based on the unavailability of RSCP data, this article seeks to investigate the coverage routes of UMTS networks in Calabar, Nigeria, using

RSCP data obtained during a drive test. The obtained data are subjected to statistical analysis and compared with the Nigerian Communication Commission (NCC) performance obligation of at least -85dBm [32]. The remaining part of this article is divided into three sections; first, we shall discuss the method at which this research was carried out, followed by the display and discussion of results and finally go into a conclusion.

2. METHODOLOGY

2.1 Materials Used

Materials used in this study is a Garmin Global Positioning System (GPS), three subscriber identity module (SIM) cards (one for each network), a laptop, a car, a car inverter, a universal serial bus (USB) hub, four W995 TEMS mobile phones, TEMS 15.1 investigation software and TEMS 15.1 discovery software.

2.2 Measurement Setup and Data Collection

A windows 10 operating system laptop is powered by connecting it to a car inverter. Installed on the laptop are TEMS investigation and TEMS discovery software. Plugged to the laptop is a USB hub. The three cards, each being a SIM card for each network under investigation (9mobile, MTN and Airtel) are inserted into the three TEMS phones and the TEMS phones are powered by connecting them to the USB hub. Also connected to the USB hub is the GPS. A measurement campaign is established by dialing the TEMS phones for short calls, while tuning the TEMS phone to obtain RSCP of the UMTS networks, irrespective of the transmission frequency. The RSCP is collected as log files by virtue of the TEMS investigation software while the GPS gives the geographic positions of the drive test routes.

2.3 Data Analysis

The collected log files are subjected to statistical analysis using the TEMS discovery software which gives an insight to the network's QoS at the subscribers' end in the form of coverage plots. The log files are subjected to further statistical treatment in the form of calculations of standard deviations, average, mode, standard errors, skewness and kurtosis using Excel spreadsheet.

3. RESULTS AND DISCUSSION

A total of 33142 RSCP data were collected during the drive test for the three networks under study. Out of the measured data collected, Airtel, 9mobile and MTN network had 11109, 11075 and 10958 signals. These generated signals were put through measures of central tendency and dispersion. Bar charts of mean and mode of the three networks under study is also presented in Figs. 1 and 2. Figs. 3 to 8 are bar charts comparing the RSCP of the networks at various thresholds and finally, RSCP plots of the networks based on the drive test routes are shown in Figs. 9, 10 and 11 for Airtel, MTN and 9 mobile network.

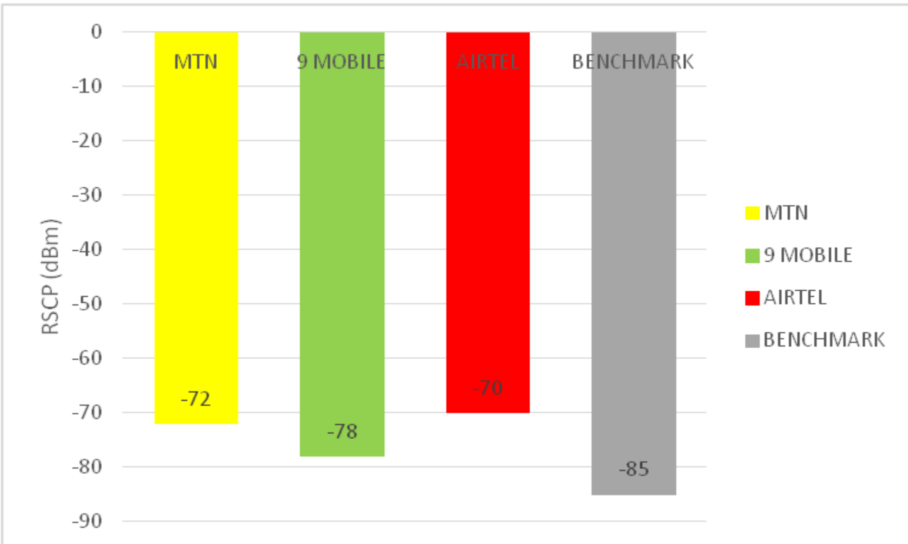

Fig. 1. Mean values of RSCP for the three networks

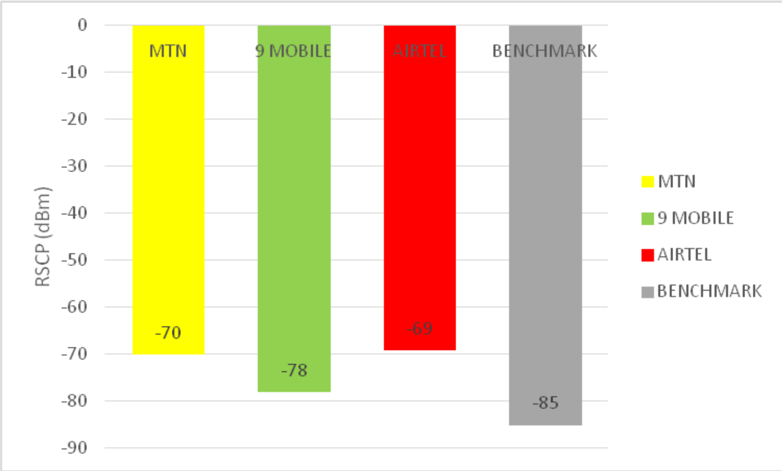

Fig. 2. Most occuring values of RSCP for the three networks

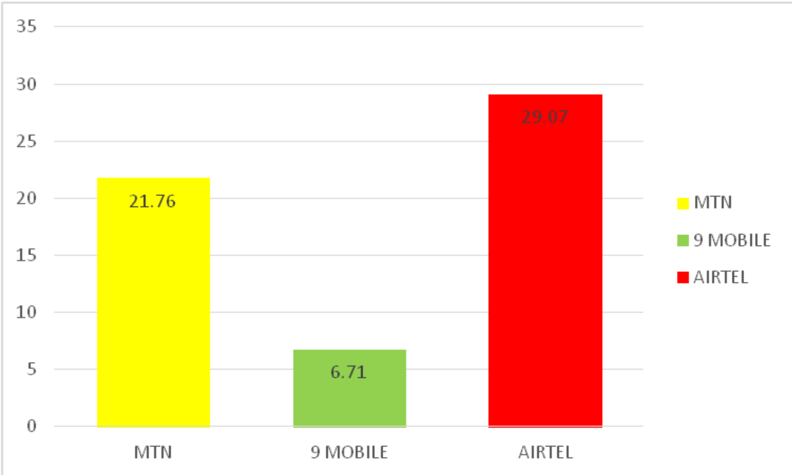

Fig. 3. Percentage of RSCP at -65dBm to -25dBm for the three networks

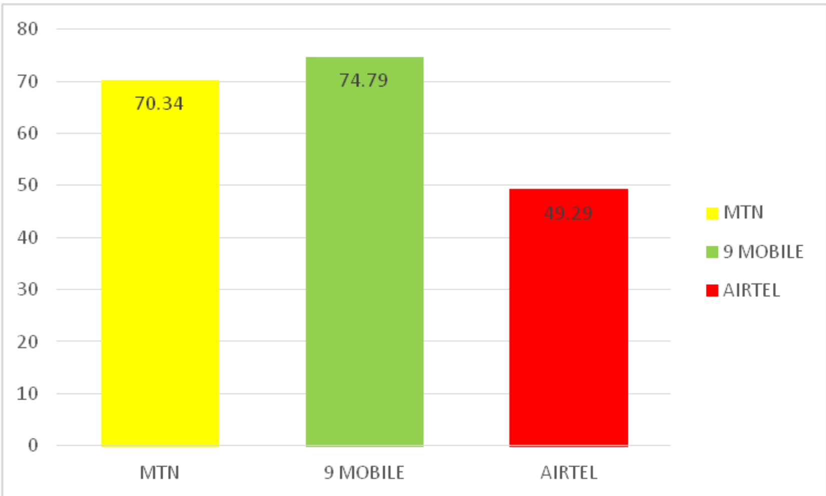

Fig. 4. Percentage of RSCP at -85dBm to -65dBm for the three networks

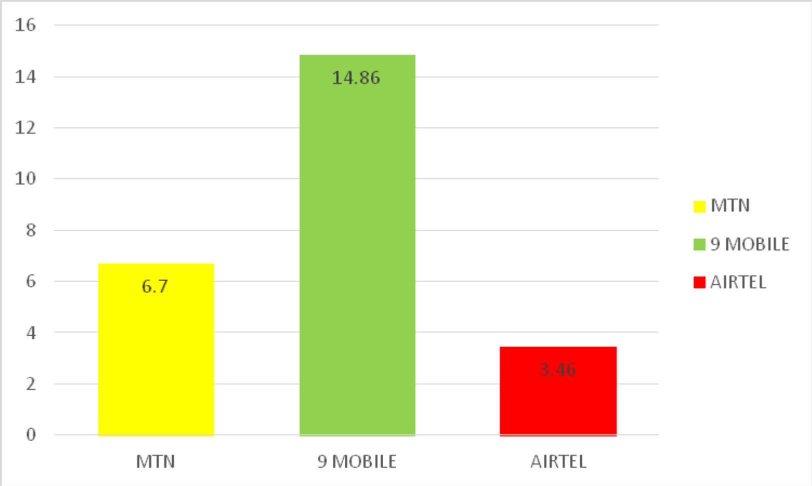

Fig. 5. Percentage of RSCP at -95dBm to -85dBm for the three networks

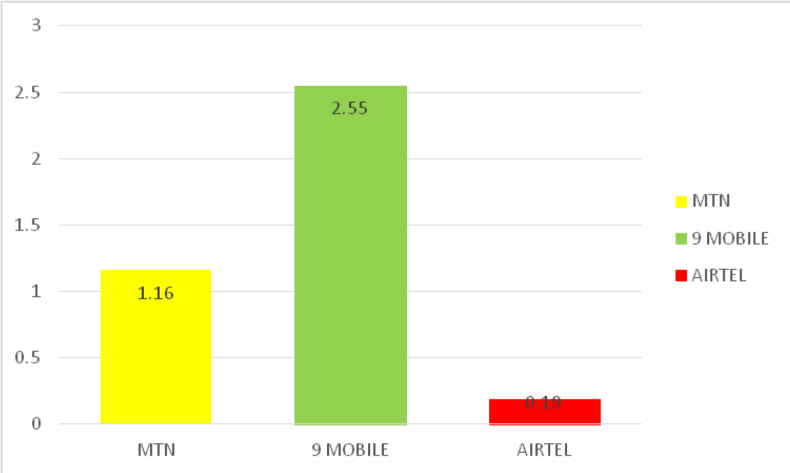

Fig. 6. Percentage of RSCP at -105dBm to -95dBm for the three networks

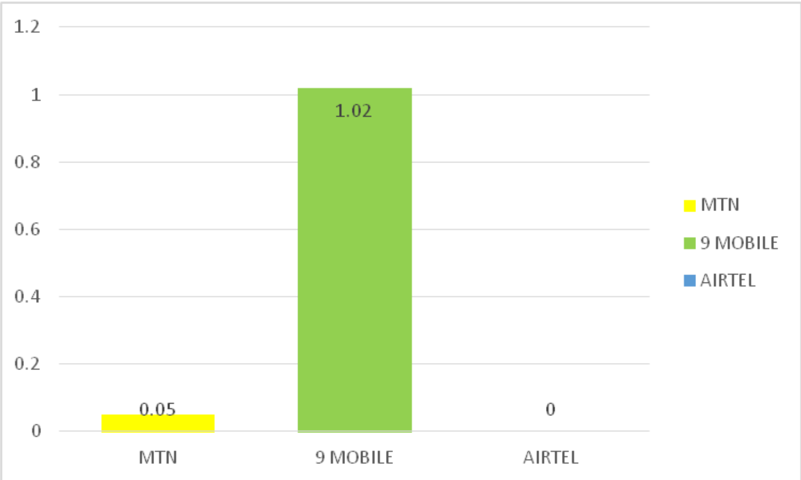

Fig. 7. Percentage of RSCP at -115dBm to -105dBm for the three networks

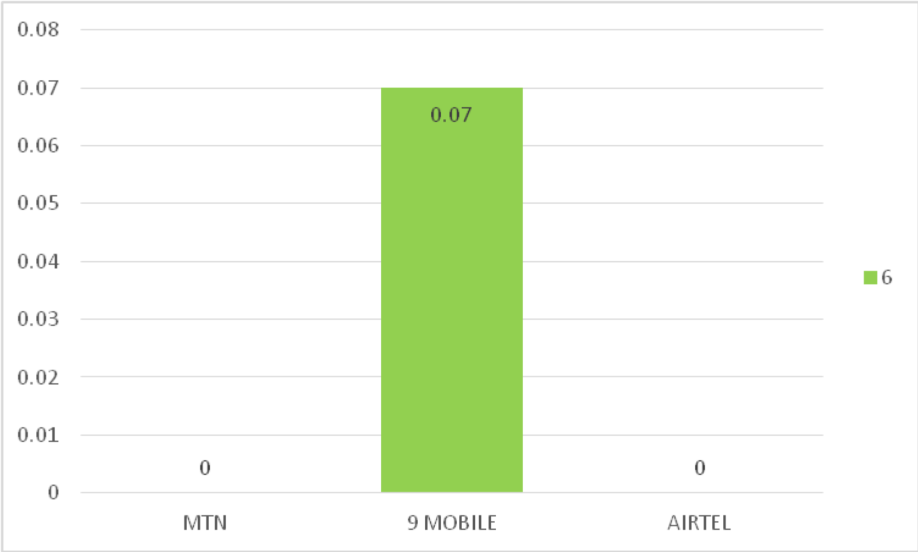

Fig. 8. Percentage of Ec/Io at -125dBm to -115dBm for the three networks

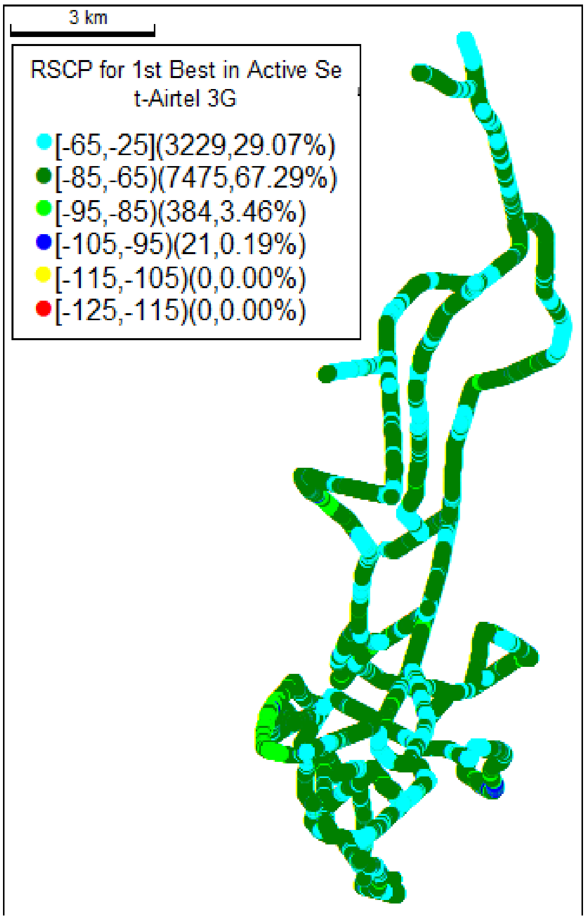

Fig. 9. Quality plots of Ec/Io for airtel network

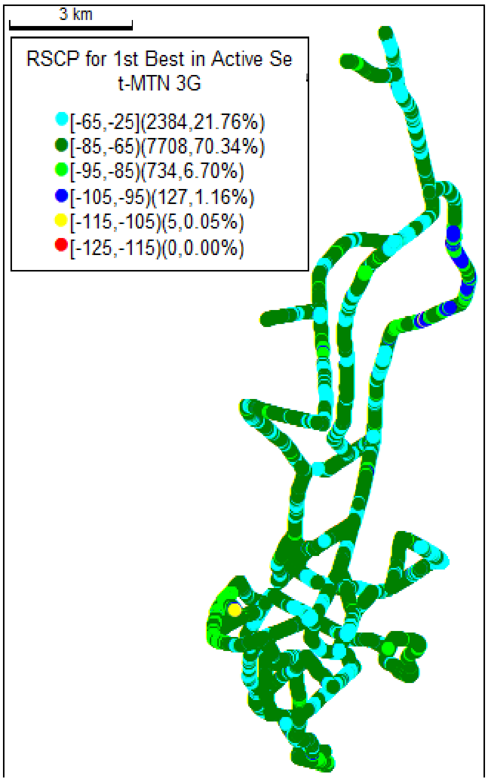

Fig. 10. Quality plots of Ec/Io for MTN network

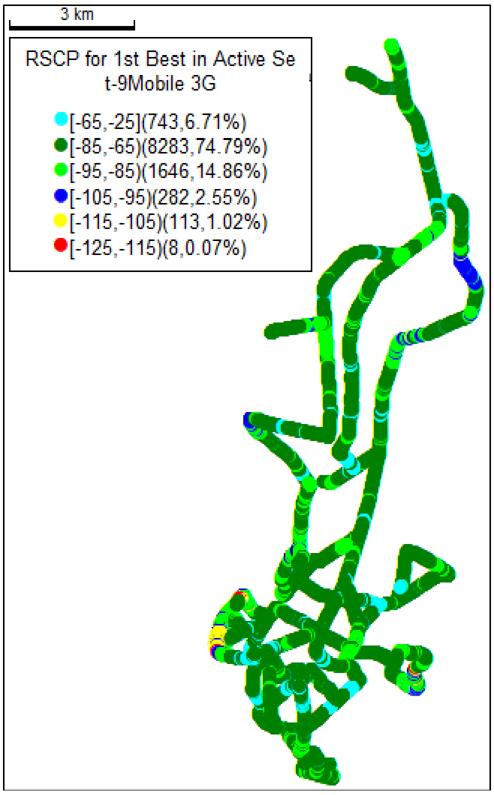

Fig. 11. Quality plots of Ec/Io for 9 mobile Network

In Fig. 1, the mean RSCP values of the network under study were presented in the form of bar charts and compared with the NCC performance benchmark of at least -85dBm. Mean values of -70dBm, -72dBm and -78dBm were collected for Airtel, MTN and 9mobile network. This shows that the all the networks had good coverage as the average values obtained were within the NCC benchmark of -85dBm. Also, Fig. 2 gives an expression of the most received RSCP values of the three networks. These values were -69dBm, -70dBm and -78dBm for Airtel, MTN and 9mobile network, which shows that the networks had good coverage and were within the NCC benchmark for RSCP.

In Fig. 3, RSCP data values in the range -65dBm to -25dBm was presented in the form of a bar chart in percentages. 29.07%, 21.76% and 6.71% of the drive test routes had excellent signals for Airtel, MTN and 9mobile network. Again, for Airtel, MTN and 9mobile network, 67.29%, 70.34% and 74.79% of the drive test route were in the range -85dBm to -65dBm and had very good signals, as presented in the bar chart in Fig. 4. Furthermore, Fig. 5 presents RSCP data values in percentage for data range of -95dBm to -85dBm, where 3.46%, 6.70% and 14.86% in a bar chart for Airtel, MTN and 9mobile network while Fig. 6 gives a bar chart of RSCP data values ranging from -105dBm to -95dBm which is 0.19%, 1.16% and 2.55% for Airtel, MTN and 9mobile network. The bar chart in Fig. 7 presents RSCP data values in the range -115dBm to -105dBm in percentages where Airtel, MTN and 9mobile network had 0%, 0.05% and 1.02% while the bar chart in Fig. 8 describes the RSCP data values in percentage with 0%, 0% and 0.07% of the test route for Airtel, MTN and 9 mobile network.

Figs. 9, 10 and 11 presents coverage plots for Airtel, MTN and 9mobile network. These coverage plots further explain data samples during the drive test routes which was earlier presented in Figs. 3 to 8. In the coverage plot, the area with cyan colour is that which the RSCP values were excellent and the subscribers were very satisfied. Subscribers presented in the bar chart in Fig. 3 fall into this category. The areas with the dark green colour was earlier presented in Fig. 4. Here, subscribers are satisfied because the RSCP values are very good.

RSCP coverage plots with light-green, blue, yellow and red colour are areas that are not within the NCC regulatory benchmark and are not regarded as having good coverage. These were earlier presented in the bar charts in Figs. 5 to 8 respectively. Subscribers in this region are dissatisfied because of low coverage, therefore, poor quality of service.

To check the dispersion of the distribution around the mean, standard deviation values of 9.13, 9.15 and 8.56 were obtained. This means that 68% of the measured data were ±9.13dBm away from the mean value of MTN network, ±9.15dBm away from the mean value of 9mobile network and ±8.56dBm away from the mean value of Airtel network. Furthermore, 95% of the measured data were ±18.26dBm away from the mean value of MTN network, ±18.30dBm away from the mean value of 9mobile network and ±17.12dBm away from the mean value of Airtel network. Finally, 99.7% of the measured data were ±27.39dBm away from the mean value of MTN network, ±27.45dBm away from the mean value of 9mobile network and ±25.68dBm away from the mean value of Airtel network.

In considering the shape of the distribution, we calculated skewness and kurtosis for the distribution. MTN, 9mobile and Airtel network were seen to have excess kurtosis of 0.26, 1.08 and 0.06. This shows that the data distribution in MTN and 9mobile network were slightly leptokurtic while that of Airtel network was slightly mesokurtic. Again, MTN, 9mobile and Airtel network had skewness values -0.20, -0.44 and 0. This means that the data distribution for the three networks were approximately symmetric.

Finally, to estimate the efficiency, accuracy and consistency of the measured data, root mean square error of the various data were calculated. Low values (0.09, 0.09 and 0.08) were obtained, showing that the data used in this study were not doctored.

4. CONCLUSION

A penetration depth analysis of UMTS radio access signals over Calabar has been conducted, taking the RSCP as the key performance indicator in consideration. Based on the analysis of drive test log files, Airtel network penetrated 96.36% of the drive test route, MTN network penetrated 92.10% of the drive test route while 9mobile network penetrated 81.50% of the drive test route. While cellular network operators are advised to build new Node B’s and visit the existing ones for optimization of their networks, log files generated in this drive test will be useful to RF engineers for path loss modelling and link budget design.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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