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Application of Frequency Reuse Technique for the Management of Interference in Cellular Network in Port Harcourt.

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ABSTRACT : *The overall throughput and transmission reliability are among the essential measures of the quality of service (QoS) in cellular communication system, such measures are mainly subjected to interference management constraints in a large (Multi-User) network. This research work elaborates on frequency reuse technique that can be employed in the detection, tackling and management of interference encountered in cellular network operations. A simulation (Monte-Carlo simulation) was conducted between MTN 4G LTE and GLO 4G LTE at Garrison Terrain, Port Harcourt, Nigeria to ascertain the probability of interference between the two mobile networks. From the Monte-Carlo simulation result, the value of the probability of interference occurring between MTN 4G LTE and GLO 4G LTE is 2% which is below the threshold value of 5%. From the evaluation of the carrier-to-interference ratio (C/I) using the probability of interference calculation mode (Compatibility mode) based on the unwanted signal type, C/I is equal to 77.13dB. Since the resulting C/I is above the protection criteria of 19dB, the probability of interference displayed by the software SEAMCAT in the Interference Calculation Engine Control section is equal to 0 (zero). This depicts that there's no possibility of interference occurrence or there's minimal rate of interference occurrence between the two radio systems.*
KEYWORDS *Carrier-to-Interference Ratio (C/I), Victim Link Transmitter (VLT), Victim Link Receiver (VLR), Interfering Link Transmitter (ILT) , Interfering Link Receiver (ILR).*

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I. INTRODUCTION

Interference management can be described as a technique or process employed for the control and mitigation of interference. It can be further described as a scheme for interference cancellation, avoidance or reduction in a system. Several mitigation techniques are available to address interference issue in the broadcast industry. Based on recent contributions in both academia and industry, the various interference mitigation techniques may be categorized into the family of active and passive approaches. Mitigation techniques are required either to further reduce the risk of interference or to solve the possible interference cases which would occur despite the application of the general measures in terms of out-of-band emission limitations. Frequency Reuse Technique is an interference avoidance method (Active Approach) [1].

The measure of a wireless communication network's throughput and transmission reliability is essentially conditioned to interference management restrictions in a large network [2], [3]. Moreover, the technologies embedded in cellular communication network has been the catalyst for most religious, social, political, economic and educational activities and development in the global world but the major challenge that obstructs the cellular system's performance and availability is the occurrence of interference [4], [5]. Interference management in cellular network is at the core of wireless regulation and it is important for maintaining a worthy throughput [6], [7]. Numerous techniques have been propounded for the mitigation of interference in cellular network such as power control, filtering, Antenna sectoring, frequency Reuse etc. For this research, the frequency reuse concept and basically the frequency reuse distance calculation was elaborated as a technique used in the management of cellular network interference to ascertain the probability of interference in a cellular network which is gotten from the analysis using Monte-Carlo Simulation Software called SEAMCAT [8]. The research objective is to use SEAMCAT software for simulation and validation of the probability of interference between the two radio systems (MTN and GLO mobile networks) in Port Harcourt. The study area is Garrision in Port Harcourt, Nigeria as shown in Figure 1.

Fig. 1: Cellular Network Signal Map of Garrison, Port Harcourt, Nigeria.

In a research paper [9], engaged in a research work on the several kinds of interference which occur in communication systems but we have some types that are more vividly associated with wireless (cellular) networks; they are Co-Channel Interference (CCI) and Adjacent Channel Interference (ACI). CCI is a kind of interference that occur as a result of induce interference existing between links that communicate in the same geographical location using neighboring frequency bands. In another paper [10], adopted the cell splitting approach for the improvement of channel capacity of a cellular system which helps in increasing the degree of frequency reuse. Cell splitting increases the capacity of a cellular system because it increases the number of times the channels in a cell are been reused. In another related paper [11], carried out a research on coverage and capacity improvement in GSM network by suing repeaters for increasing cell coverage and also using microcell zone concept, frequency reuse, cell sectoring and cell splitting concepts for cellular network capacity increase to mitigate network decrease. In another research paper [12], embarked on a research titled Inter-Cell Interference Management for Cellular Systems using the technique; Inter-Cell Interference Coordination (ICIC) based on Coordinated Beam Forming. A proposed Algorithm enabling excellent antenna power efficiency with low number of iteration and coverage was simulated with significantly reduced ICI (Inter-Cell Interference) and improve performance over non-coordinating systems. Girma et al. [13] carried out a research work titled "Frequency Reuse Distance Calculation in Cellular Systems Based on Monte-Carlo Simulation (MCS). The MCS results are been compared to that of a minimum interference threshold value of 5%. From their simulation, a relative enhancement in capacity of 7/4 has been achieved with 3.3%.

II. MATERIALS AND METHOD

2.1 MATERIALS

The materials used for the actualization of the objectives of this research are as follows;

- **Mobile App. Spectrum Analyzer**.

The interface of the Spectrum Analyzer is shown in figure 2

Fig. 2: Spectrum Analyzer Network Gauge

- **SEAMCAT Software used for simulation**

SEAMCAT is used for the implementation of Monte-Carlo Simulation Model. It has four basic useful elements namely Victim Link Transmitter (VLT), Victim Link Receiver (VLR), Interfering Link Transmitter (ILT) and Interfering Link Receiver (ILR) applicable for interference mitigation technique as shown in figure 3.

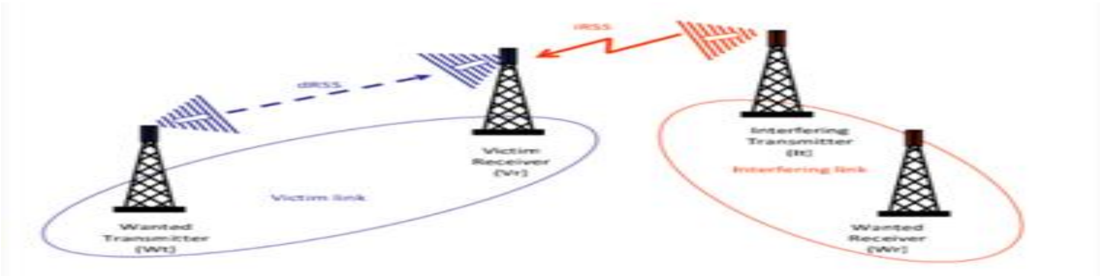

Fig. 3: Typical Scenario of Victim and interfering link

- **Data collection.**

Data collected from two mobile radios (MTN and GLO) at Garrison Terrain, Port Harcourt, Nigeria.

TABLE I: PARAMETERS OF THE VICTIM LINK (MTN 4G LTE) AT GARRISON, PORT HARCOURT, NIGERIA

Parameters	Values	Units
Operating frequency	800	MHz
Transmitter power	37.26	dBm
Bandwidth	30	MHz
Antenna Type	Directional	
Antenna Gain	12	dBi
Antenna Height	30	M
Cell Pattern	Three sector	
Cell size	2	Km
Propagation model	Free Space Model	
Distance	2	Km
C/I Protection criteria	19	dB
C/(N+I) protection criteria	16	dB
Sensitivity	-98.0	dBm

Table II: PARAMETERS OF THE INTERFERING LINK (GLO 4G LTE) AT GARRISON, PORT HARCOURT, NIGERIA

Parameters	Values	Units
Operating frequency	700	MHz
Transmitter power	23	dBm
Bandwidth	10	MHz
Antenna Type	Directional	
Antenna Gain	12	DBi
Antenna Height	33	M
Propagation model	Free Space Model	
Cell size	2	Km
Cell Pattern	Three Sector	
Distance	2	Km

2.2 Method

The method used in the mitigation of cellular network interference for this research is the frequency reuse concept by calculating the frequency reuse distance using Monte-Carlo Simulation to determine the probability of interference between two radio networks, MTN and GLO at Garrison, Port Harcourt, Nigeria. Frequency reuse is described as a concept of using the same radio frequencies within a given cell that are separated a considerable minimal distance. Two radio systems are been considered for this research and they experience co-channel interference because they reuse same frequency channel i.e same 4G LTE frequency band in Nigeria, MTN 4G LTE as the Victim Link with a frequency of 800MHZ and GLO 4G LTE as the interfering Link with frequency of 700 MHZ as shown in Table 1 and Table 2. In cellular network interference source detection, the frequency of an interfering signal is the fundamental parameter that leads to the detection of the interference source. Thus, the problem of interference in cellular network can be classified by its frequency features as modeled in a spectrum analyzer with analyzing parameters namely; frequency range, sensitivity, bandwidth, dynamic range, power level and accuracy [14], [15].

Simulation is an imitation of the operation of a real-world process or system. Before live implementation, testing of the developed technique is required. Most of the time, testing and evaluating the protocols or theories proposed is not practically feasible through real experiments as it would be more complex, time consuming and even costly. So, to overcome this problem, "SIMULATORS and TESTBEDS are effective tools to test and analyze the performance of protocols and algorithms proposed [16]. Furthermore, the emulation of the operation of a real live system or process is called simulation [17].

- **Calculating Frequency Reuse Distance Using Monte-Carlo Simulation**

In wireless communication, the accommodation of many users is the goal of operation and this is been done by very dense frequency reuse, the area to be covered is been divided into many small cells and each of these cells uses different frequency. If a frequency is been used in a geographical area; it can be reused in another area, this is called Frequency Reuse. Relative to the size of the cell, we can make the distance between the cells that use the same frequency as small as possible i.e actualization of a minimum considerable frequency reuse distance; the effect of this is the emergence of interference from one cell to another cell or other cells. To mitigate this interference, a system is simulated for the receivers to be relatively immune to interfering signals. A reuse distance can be described as a minimum distance between two cells using same frequency (channel) for a satisfactory signal-to-interference ratio [18], [19].

Dividing radio application into different spectrum is a fundamental issue with complex systems which utilizes a similar frequency (channel) over gain to create dispersing of a similar radio recurrence over some separation. At some point, when some radio frequencies are used over again in a range of short separation, it increases the frequencies usage factor (Frequency Reuse Factor) and also cause interference in the process and this type of interference is called Co-Channel Interference and the Co-Channel Interference scenario consist of the Victim, Interferer and Interfering Power [20].

Wireless (Radio) Spectrum rules is an important aspect of spectrum utilization. Since there's no predominant and dependable interference avoidance method in a radio system, the proper selection of sharing conditions is the only means of achieving total co-existence and ideal (Optimal) spectrum usage n radio communication system. Spectrum sharing rule for spectrum analysis can be gotten by an analytical or statistical method. Example of an analytical method is the Minimum Coupling Loss (MCL) method which establish rigid rules of minimum separation and it is difficult to actualize that of statistical method which is based on Monte-Carlo method, establishes the probability of interference for a given realistic deployment scenario basically for random process [13].

The probability of interference is actualized using the Software called SEAMCAT which is an acronym for spectrum Engineering Advance Monte Carlo Analysis Tool. SEAMCAT is a statistical simulation model that applies a method of analysis termed Monte-Carlo to access the potential interference between radio communications

The flow chart of interference analysis between the victim link (MTN 4G LTE) and the interfering Link (GLO 4G LTE) is shown in Figure. 4 .

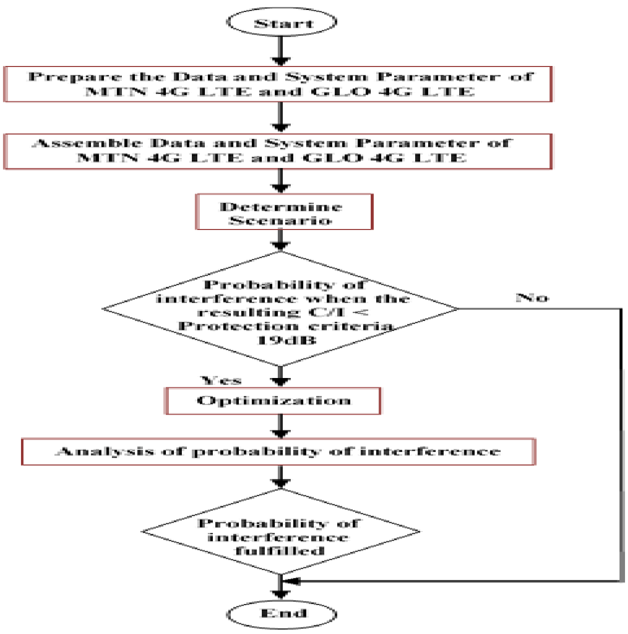

Fig 4: Flow Chat of Analysis of Interference between MTN 4G LTE and GLO 4G LTE

➢ **Analysis of Co-Channel Interference Using Analytical Method**

In analytical methodology, the process is applied to ordinary or partial differential equations that describe same underlying physical and mathematical systems. In reviewing a fully hexagon-shaped cellular system, we have 6*y co-channel cells in the y^{th} tier, irrespective of the number of cell per cluster. The center cell which contains VLR could be interfered by the 6 Co-channel cells on the first tier, 12 Co-channel cells on the second tier and 18 Co-channel cells on the third tier and so on [21]. At the VLR that is being served by VLT on the cluster, dRSS is been calculated using Equation (1) [21].

$$dRSS \propto {}^{1}/_{R^{\propto}} \qquad (1)$$

Where: $R = Distance\ between\ VLR\ and\ VLT\ (m)$
$\propto = Pathloss\ Constant$

Using Equation (2), we can calculate the total interference, iRSS from all the co-channel ILT [12]

$$iRSS \propto \left(\frac{6\times1}{D^{\propto}} + \frac{6\times2}{(2D)^{\propto}} + \frac{6\times3}{(3D)^{\propto}} + \cdots\right) \qquad (2)$$

Where: $D = Frequency\ Reuse\ Distance\ (\ m)$
$\propto = Pathloss\ Constant$

Hence,

$$iRSS \propto \sum_{y=1}^{n} \frac{6y}{(yD)^{\propto}} \qquad (3)$$

Where: $n = Number\ of\ Tier$
$\propto = Pathloss\ Constant$

Equating Equation (1) and (3), we have:

$$\frac{dRSS}{iRSS} = \left(\frac{D}{R}\right)^{\propto} \frac{1}{6\sum_{y=1}^{n}\frac{1}{y^{\propto-1}}} \qquad (4)$$

For the first tier co-channel cell, Equation (4) is simplified as

$$\frac{C}{I} = \frac{dRSS}{iRSS} = \frac{({}^{D}/_{R})^{\propto}}{6} \qquad (5)$$

Express*ing* Equation (5) in decibel we have:

$$\frac{C}{I} = \frac{dRSS}{iRSS} = 10\log_{10} D - 10\log_{10} R - 10\log_{10} 6 \qquad (6)$$

Where $R = Distance\ between\ a\ VLR\ and\ VLT\ (m),\ \propto = Pathloss\ constant$ and
$D = Frequency\ reuse\ Distance\ \ (m)$

When the size of each cell is approaching or approximately the same and the base stations transmit the same power, the co-channel signal-to- interference ratio (C/I) is independent of the transmitted power and becomes a function of the path loss exponent, $'\propto'$ radius of the cell, 'R' and frequency Reuse distance, 'D' [8].

The carrier-to-interference ratio (C/I) as the measure used to rate between signal quality (strength) and interference is of a greater consideration and it is expressed mathematically as:

$$C/I = \frac{Carrier}{Interference} = \frac{All\ Useful\ Signals}{All\ Useless\ Signals} \qquad (7)$$

$$C/I = \frac{dRSS}{iRSS} = dRSS - iRSS \qquad (8)$$

Where dRSS is Desired Received Signal Strength and iRSS is Interfering Received Signal Strength.

III RESULTS AND DISCUSION

The dRSS describes the strength of the victim (wanted) signal, a computation of link budget between VLR and VLT. Fig. 5, Fig. 6 and Fig. 7 illustrates the cumulative distribution function of the victim link signal strength, the vector pattern of victim link signal strength and the probability density function of the victim link signal strength respectively.

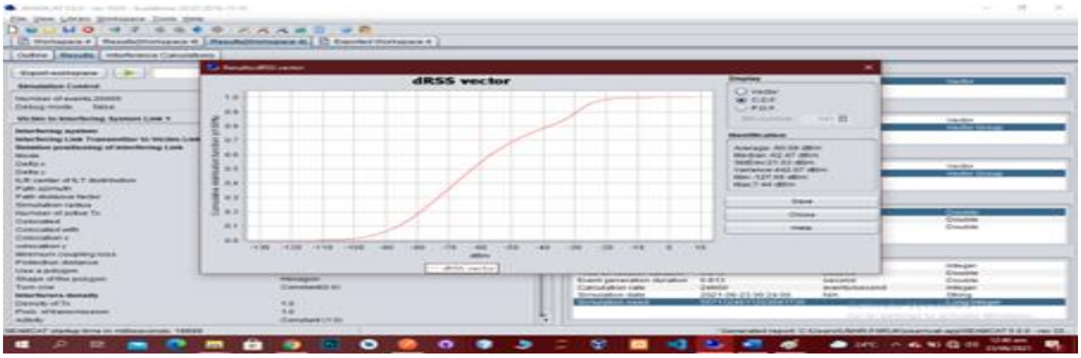

Fig. 5: dRSS C.D.F

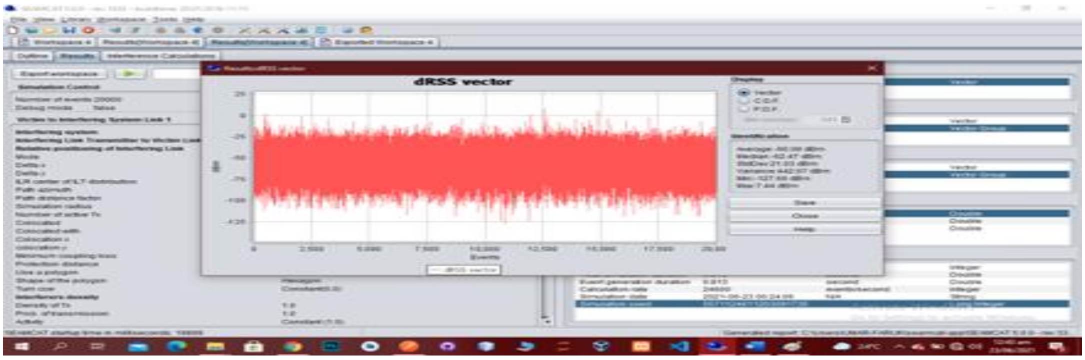

Fig. 6: dRSS Vector

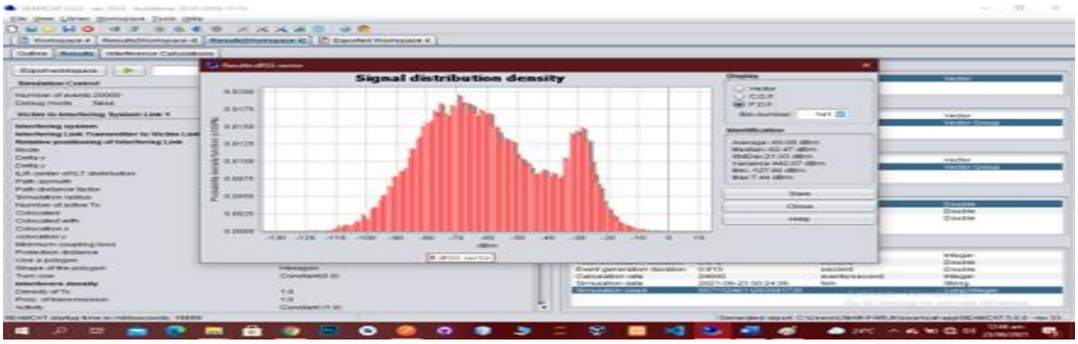

Fig. 7: dRSS P.D.F

The iRSS describes the strength of the Interfering (unwanted) Signal, calculation of the link budget between VLR and ILT. Fig. 8, Fig. 9 and Fig. 10 illustrates the cumulative distribution function of the Interfering Link Signal Strength, the Vector Pattern of the Interfering Link Signal Strength and the probability density function of the interfering link signal strength respectively.

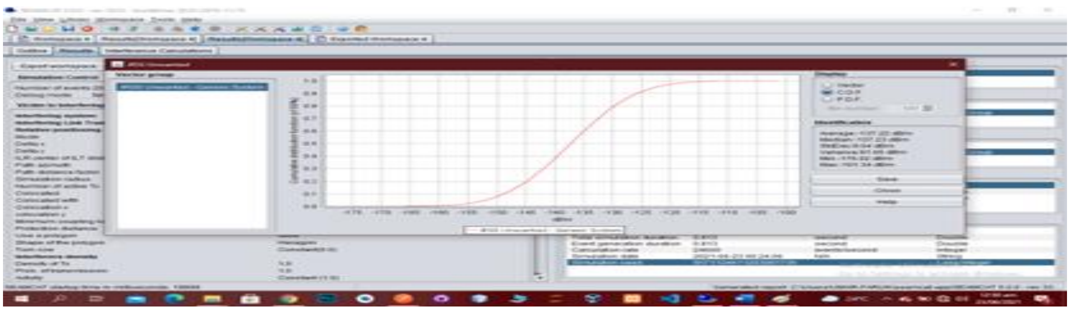

Fig. 8: iRSS C.D.F (Unwanted)

Fig. 9: iRSS Vector (Unwanted)

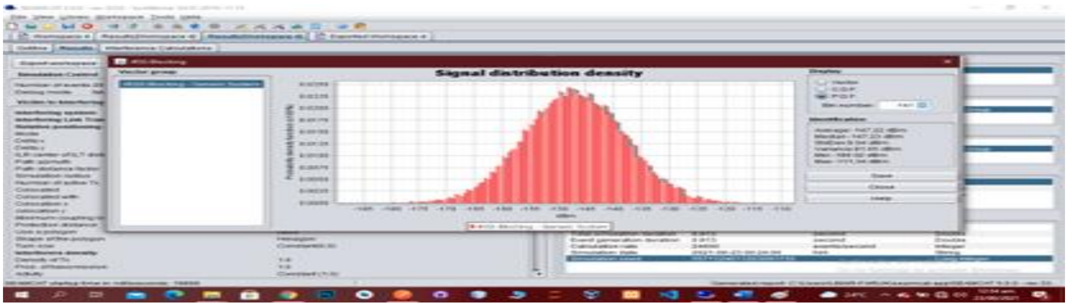

Figure 10: iRSS P.D.F (Unwanted)

The Probability of Interference Calculated Based on Unwanted Signal Type: From the Monte Carlo Simulation result in Fig. 11 , the probability of interference occurring between MTN 4G LTE and GLO 4G LTE at Garrison , Port Harcourt, Nigeria is 2%.

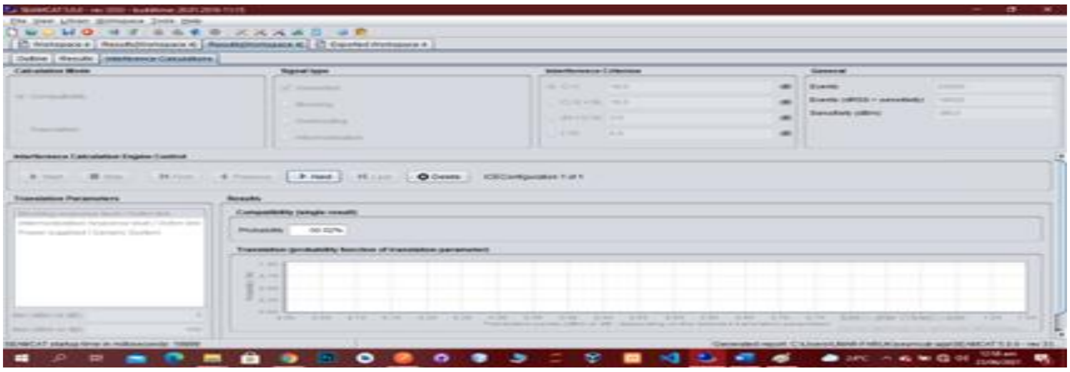

Fig. 11: Probability of Interference (Compatibility Mode) for C/I

The simulation summary result in Fig. 12, gives a quick access to the mean, median and standard deviation of dRSS, iRSS (unwanted) and iRSS (blocking) which is measured in decibel (dB). The progress bar in the simulation status reflects the proportion of carried out events with respect to the overall number of scheduled events. During the event generation, the involved transceivers (VLR, ILR, VLT and ILT) are plotted in graphical display window placed on the simulation outline tab page as shown in Fig. 12.

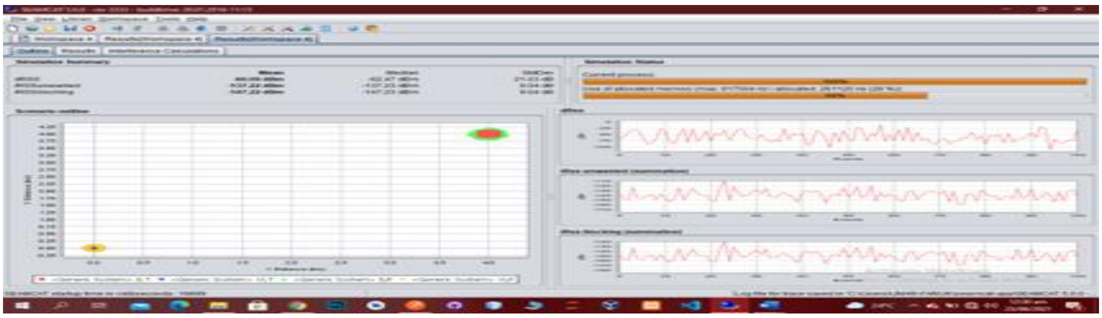

Fig. 12: Outline of the Simulated Stations Indicating Summary Results and VLR and VLT Positional Indicators.

The dRSS and iRSS vectors are shown for 100 events maximum to avoid overloading the memory and to speed the computation time. The iRSS is shown as a summation of all the interferes. From Fig. 12 in the simulation scenario outline, the distance between the VLR and ILT is calculated as 4km which is taken as the correlated distance but the distance between VLT and VLR or ILT and ILR is given as 2km from data in table 1 and table 2. The distance between ILT and ILR is same as that of VLT and VLR, this is deduced from the principle of positioning ILT against ILR that is similar to that of positioning VLT against VLR. From simulation summary result in Fig. 12; the mean value of dRSS, iRSS (unwanted) and iRSS (blocking) is given as -60.09dBm, -1.37.22dBm and -147.22dBm respectively which is used in the probability of interference calculation. Using the probability of interference calculation (compatibility mode) based on the unwanted signal type; it is possible to derive the value for C/I using Equation (8) which is measured in decibel (dB). The dRSS mean value and iRSS (unwanted) mean value are -60.09dBm and -137.22dBm respectively, all gotten from the simulation result in Fig. 12.

From equation 8.

$$\frac{C}{I} = \frac{dRSS}{iRSS(unwanted)}$$

$$= dRSS - iRSS\ (unwanted)$$

$$= -60.09dBm - (-137.22dBm)$$

$$= 77.13dBm$$

$$= 77.13dB$$

Since the resulting C/I is above the protection criteria of 19dB, the probability of interference by SEAMCAT Software in the interference calculation Engine control is equal to 0 (zero). This depicts that there's no possibility of interference occurrence of there's minimal rate of interference occurrence [8].

IV CONCLUSION

The simulation analysis result using SEAMCAT produced a good result which justify the research objectives. The end result of the simulation produces the probability of interference between the two radio systems (MTN 4G LTE as the victim Link and GLO 4G LTE as the Interfering Link) at Garrison Terrain, Port Harcourt, Nigeria as 2% which is below the threshold value of 5%. Also, from the simulation result, the mean values of dRSS and iRSS (unwanted) are used to estimate the value of the carrier-to-interference ratio, and the outcome of this computation gives the value of 77.13dB which is below the protection criteria of 19dB. From the above results, SEAMCAT in the Interference Calculation Engine Control section, interprets that the probability of interference as been equal to 0 (zero). This result depicts that there's no possibility of interference occurrence or there's minimal rate of interference occurrence between the two radio networks.

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