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ENHANCING THE PERFORMANCE OF ULTRA MOBILE BROADBAND NETWORK USING ADAPTIVE INTERFERENCE AND NOISE CANCELLING TECHNIQUE

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Abstract: This paper focused on enhancing the performance of Ultra mobile broadband networks using Adaptive interference and noise cancelling technique. The test van used during the measurement was driven in the direction of one antenna sector, though there were overlaps from two sectors at some points. In addition, the Global Positioning System (GPS) was used to measure the distance between the base station and the mobile station, i.e., the transmitter–receiver (T-R) separation distances starting from 100m to several multiples of 100m. During the drive test, four numbers of functional base stations were seen and the ray tracer helped to pick the signal of the network of choice amongst several signals from various networks. This is achieved by setting the appropriate frequency on which the desired network operates. As the investigative base station operates at a frequency of 878.87MHz, the ray tracer helped to locate the base station that transmits at that particular frequency. However, the signal strengths of the signals were recorded at various points and the distance of these points from the reference point of the base station also recorded. Results obtained showed that using adaptive interference and cancelling technique yielded a bit error rate in the range of 10^{-2} to 10^{-3}.

Keywords: broadband, noise cancelling, Compensating, Global Positioning System (GPS).

1.0 INTRODUCTION

In ultra-mobile broadband communication network, the system throughput as well as the throughput at a cell edge is among the most important evaluation measures for the requirements on the system performance (Lee W., 2011). Among many candidates on the multiple access schemes, frequency hopping orthogonal frequency division multiple access (FH-OFDMA) has been considered as one of the promising packet-based transmission techniques because FH-OFDMA can easily deal with the frequency selective fading channel and provide not only inner-cell orthogonality but also inter-cell interference (ICI) averaging effect. Thus, it enables us to construct a cellular network with a frequency reuse factor equal to one (Cox D.C, 2012). However, the ICI averaging effect would not work properly in case that there exist interferers with differently allocated power loading in adjacent cells, which makes the ICI pattern highly non-uniform (Ellingson, S.,2001). Therefore, it is very important to manage such non-uniform ICI, especially at cell edge. Several ICI mitigation techniques have been proposed to provide reliable communication to cell-edge users. Traditional frequency reuse schemes, such as a reuse factor 3 deployment, can significantly reduce the average ICI. However, it sacrifices accessible frequency resource in each cell in order to manage the interference levels so that the overall system capacity is quite limited. Another method proposed to handle the ICI is the coordinated symbol-repetition scheme (Bells, 2006). In this method, a repeated symbol mapping in the frequency domain is coordinated to be identical among adjacent cells. Then a user equipment can perform interference cancellation by using a minimum mean square error (MMSE) receiver in the frequency domain. This method can mitigate the ICI and increase the number of allowable interferers. But this scheme also needs additional resource due to the repetition, which ends up with limiting the system performance as well. As an advanced version of the traditional frequency reuse scheme, two frequency reuse schemes have been proposed. One is the partial frequency reuse (PFR) scheme, and the other is the soft frequency reuse (SFR) scheme (Rappaport, 2010). The PFR scheme partitions the whole frequency into two parts, a part with reuse factor 1 and the other with reuse factor less than 1. The reuse factor 1 part is used only by inner cell users and the other part can be used by cell edge users. This scheme greatly solves the limitation of the traditional frequency reuse scheme. However, there still exists inefficiency due to the part for the cell-edge users. In the SFR scheme, a part of the whole frequency is reserved for the cell edge users and is kept being orthogonal among adjacent cells. The remaining frequency band can be used only by inner cell users for each cell. The transmission power can be amplified on the reserved band for the cell-edge users and inner cell users can also use this reserved frequency band. Therefore, the SFR scheme can achieve the reuse factor of 1. But, both the PFR and the SFR schemes need a strict cell planning, which is very hard for a practical system (Darren D. Chang and Olivier L. de Weck,). If an irregular cell pattern is given, such frequency reuse schemes requiring a strict cell planning would lead to an inefficient use of the spectrum. In a soft channel reuse (SCR) scheme using an erasure decoding (ED) method with downlink power control was proposed to handle;/the non-uniform ICI for downlink FHOFDMA systems. In this scheme, no strict cell planning is required due to its sub channel structure. It considered a multi cellular downlink OFDMA system where a power control is performed such that a base station (BS) can use full power for up to a pre-determined number of sub-channels allocated to cell-edge users while the rest of power is used for the sub channels allocated to inner-cell users. So all frequency resources can be utilized in each cell regardless of the cell shape. By erasing highly interfered symbols, it was shown that partially interfered signals can be effectively decoded without any prior knowledge on ICI. However, the ED method is only applicable to the case where a few sub-channels are allowed for the outer cell region such that ICI is concentrated to a small fraction of subcarriers in the sub-channel. As the number of cell edge users increases and demands more sub-channels, the performance of the ED scheme is deteriorated. In this work, we propose an adaptive interference and noise cancelling technique for ultra- mobile broadband network. The key operational features of the Ultra-Mobile Radio interface are support for high data transmission: 384kps with wide area coverage, 2Mbps with local coverage and high service flexibility: support of multiple parallel variable rate services on each connection.

2.0 Interference on Ultra-Mobile Network (UMB)

The type of interference experienced in ultra broadband network is the Multiple Access Interference or the Multi-user Interference. Multiple Access Interference (MAI) is a factor, which limits the capacity and performance of ultra band networks. In contrast to FDMA and TDMA techniques which are frequency bandwidth limited, all users transmit in the same frequency band and are distinguished at the receiver by the user specific spreading code. All other signals are not de-spread because they use different codes. These signals appear as interference to the desired user. As the number of users increase, the signal to interference ratio (SIR) decrease until the resulting performance is no longer acceptable. Thus, this multi–user interference must be reduced to achieve higher capacities.

There are several ways of improving ultra broadband communication network. They are:

Receiver beam forming, voice activation technology, power control, multiuser detection, using rake receivers and soft handoff.

A simple equation for the uplink capacity U of a single Ultra broadband cell is given by (M. Viterbi, A. J. Viterbi (2008):

$$U = 1 + WG/\left(E_b/N_o\right) - \left(\sigma 2/G\right) \qquad (1)$$

Where the value of E_b/N_0 represents that required for adequate link performance. The scalar σ2 is the background noise power and S is the received signal power for each user. Finally, G is the ratio of the antenna gain for the desired user to that of interfering user in that cell. The value of G depends on the beam pattern for each user, but will roughly be proportional to the array size M.

As a result, antenna arrays can improve the capacity in two ways:

1. Increasing the antenna gain G and hence the array M. This reduces the average level of interference from each user in the cell, permitting a capacity increase.
2. Reducing the required, E_b/N_0 antenna array can provide increased space diversity at the base station, which can permit the receiver to operate at lower power signal. This increases the tolerance of the receiver to multiple access interference.

3.0 MATERIALS AND METHODS

In this section, we presented the characterization of the network under study. This was done by firstly carrying out measurement of the received power in dB. This is to ascertain the efficiency of the network. The measure data will now be used to develop the model for the network.

3.1 Measurement Environment

In this paper, field measurements were performed in Port Harcourt city, the capital of Rivers State of Nigeria using the existing wireless network of the Glo network which is a n ultraband base network. This helps to identify the nature of the typical propagation environment for the base station drive route. The drive test was intended to cover base station, using spectrum monitoring equipment such as ray tracers and spectrum analyzer.

The Port Harcourt environment consisted of a sparsely built up environment and small houses with two to three floors and back yards. The houses were of clay bricks and metal roofs. The environment is made up of farm lands and few bushes around. Measurements of received signal strength will be made at intervals of 100m up to 700m from a reference point on the transmitting base station. The base station that was used for the research work is shown below the base station belonging to ultra band network located at a location with Latitude 6˚ 45’N and Longitude: 4˚30’E of Port Harcourt city. The base station carrying sectorized antenna provides coverage for a large area such as suburban environment like Port Harcourt. The base station height is 36m and has a carrier frequency of 878.87MHz.

3.2 Method of Data collection

The measurement carried out on the first scene consist of a base station and a receiver antenna mounted on the roof top of the spectrum monitoring van housing the spectrum monitoring equipment. The base station antenna height is 36m while the mobile antenna was mounted on a 3m high test van. The carrier frequency of the network under consideration is 878.87MHz.

The test van used during the measurement was driven in the direction of one antenna sector, though there were overlaps from two sectors at some points. In addition, the Global Positioning System (GPS) was used to measure the distance between the base station and the mobile station, i.e., the transmitter–receiver (T-R) separation distances starting from 100m to several multiples of 100m.

During the drive test, four numbers of functional base stations were seen and the ray tracer helped to pick the signal of the network of choice amongst several signals from various networks. This is achieved by setting the appropriate frequency on which the desired network operates.

As base station operates at a frequency of 878.87MHz, the ray tracer helped to locate the base station that transmits at that particular frequency. However, the signal strengths of the signals were recorded at various points and the distance of these points from the reference point of the base station also recorded. These distances in kilometers were obtained using Global Positioning System (GPS).

Generally speaking, the received signal strength from a base station decreases with distance when measured at various points along a radial path leading away from the base station. Ideally, signal-strength measurements would be made by monitoring and recording the signal received by a mobile unit in the van as it moves away from the base station. The measurements were carried out between 8.00am till 6.00pm each day for the whole period of measurement.

3.3. Experimental Setup

In other to provide good analysis of the network system that will ensure such good quality of service to users, quality of service parameters which will help in the system analysis are sought for. To achieve this, real time measurements were carried out and the data obtained were used to ascertain the efficiency of the existing infrastructure. It shows the base station transceiver (BTS) from where the transmitted signals emanate. The transmitted signal strengths are measured with the help of ray tracer. Ray tracer are software developed to indicate the presence of a signal and also its strength at a particular spot. The quality of the received signal in any channel can be ascertained by the ray tracer. While the ray tracer gives the level of signal strength, the global positioning system (GPS) shows the distance of the mobile unit or another transmitting base station from the base station under consideration. The GPS can also be used to measure the angular locations of the mobile unit with respect to the transmitting base station. The entire data that were measured were recorded and analyzed using spectrum analyzer. Real time measurements of received signal strength, distance of mobile station (MS) from base station (BS), and angle of arrival (AOA) signal from the base station are carried out at a test bed. The results obtained were necessary in the simulation and performance analysis of adaptive antenna array in ultra mobile broadband network.

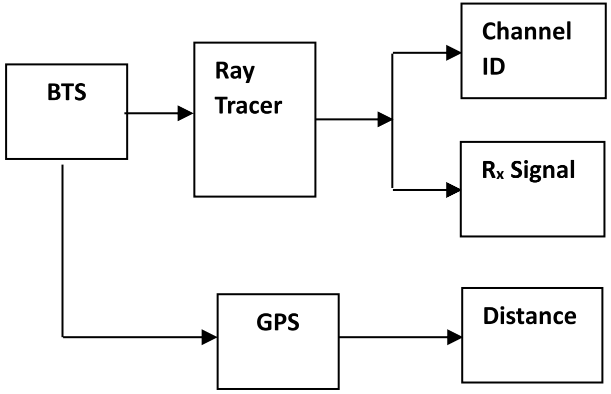

Figure 3.3: Block diagram of the test bed

3.4 Characterization and Development of the Model for the Network under Study

Table 1: Technical Summary For Ultra-Mobile broadband network (UMB)

Channel bandwidth	5MHZ
Frequency band	1920MHz-1980MHz(uplink) 2110MHz-2170MHz(downlink)
Duplex mode	FDD and TDD
Chip rate	3.84MCPS
Frame Length	10ms
Modulation	QPSK
Carrier Spacing	4.4MHz-5.2MHz
Number of Chips/slot	2560chips
Channel bit rate	5.7Mbps
Channel coding	Convolutional and Turbo codes
Physical layer Spreading Factors	4-256(uplink),4-512(downlink)
Number of base station codes	512/frequency
Power control period:Time slot	1500Hz rate
Power control step size	0.5,1,1.5 and 2dB(variable)
Power control range	80dB(uplink),30dB(downlink)
Multirate	Variable spreading and multicode
Downlink RF channel	Direct spread
Pulse shaping	Root raised cosine, roll off=0.22
Data types	Packet and circuit switch
Receiver	Rake

TABLE 2: AVERAGE OF THE RECEIVED SIGNAL STRENGTH MEASUREMENT CARRIED OUT (Cell site: 641, Frequency, f=878.87MHz, Transmitted Power, Tx =44.4dBm)

Distance (m)	RSS (dBm)
100.00	-68.64
200.00	-75.64
300.00	-94.99
400.00	-94.89
500.00	-98.73
600.00	-104.09
700.00	-107.29

TABLE 3: AVERAGE OF THE MEASUREMENT OF RECEIVED SIGNAL STRENGTH CARRIED OUT (Cell site:641, Frequency, f =878.87MHz, Transmitted Power, Tx =44.4dBm).
TIME OF MEASUREMENT:8.00AM -6.00PM

Distance(m)	RSS (dBm)
100.00	-67.94
200.00	-74.16
300.00	-86.84
400.00	-87.04
500.00	-91.64
600.00	-99.33
700.00	-103.13

3.2.1 Characterization of the Ultraband Mobile network Radio Under Study.

In order to characterize the mobile radio propagation environment under study, we made use of equation of pathloss to obtain the pathloss exponent, of the test bed environment and empirical propagation pathloss model for Portharcout.

Therefore, in order to completely characterize a propagation environment under study, the following parameters must be known:

1. Received signal strength obtained from field measurement
2. The pathloss exponent, n,of the characterized environment
3. An empirical propagation path loss model for the test bed environment.

(I) Determination of Pathloss Exponent (n) of UltraTest Bed Environment

Equation (1) predicts that the mean path loss $P_L(d_i)$ [dB] at a transmitter receiver separation d_i is (Feher,2006):

$$P_L(d_i)\ [\text{dB}] = P_L(d_0)\ [\text{dB}] + 10n \log_{10}\left(\frac{d_i}{d_0}\right) \qquad (2)$$

Where n = pathloss exponent

$P_L(d_0)$ = pathloss at known reference distance d_0. That is:

$$n = \frac{\{P_L(d_i) - P_L(d_0)\}}{10\log_{10}\left(\frac{d_i}{d_0}\right)} \qquad (3)$$

(II) Empirical Path Loss Model For Mobile Radio Propagation Environment.

The path loss model for free space is given by equation (3) (Gupta, *et al*, 2009) LP_{fs} (dB) = $32.44 + 20\log_{10}(f_c) + 20\log_{10}(d_i)$ (4)

Where LP_{fs} is the free space path loss

f_c is the carrier frequency in (MHz)

d_i is the distance between the base station (BS) and mobile station (MS) in (Km).

The Hata path loss model for urban and suburban environment is given in equation (5) and (6) respectively.

$$L_{Pu}\,(\text{dB}) = 69.55 + 26.16\log_{10}(f_c) + (44.9 - 6.55\log_{10}h_b)\log(d_i) - 13.82\log_{10}(h_b) - \alpha(h_m) \qquad (5)$$

$$L_{Ps} = Lp_u - 2\left[\log_{10}\left(\frac{fc}{28}\right)\right]^2 - 5.4 \qquad (6)$$

Where; LP_u is the pathloss prediction for urban area in dB, L_{ps} is the pathloss prediction for suburban area in dB, $\alpha(h_m)$ is the correlation factor for mobile station antenna height in dB, h_b is the height of BS (km). h_m is the height of MS.The correlation factor $\alpha(h_m)$ for suburban is given as:

$$\alpha(h_m) = [1.1\log_{10}f_c - 0.7]h_m - [1.56\log f_c - 0.8] \qquad (7)$$

(III) Computation of Pathloss Exponent

Using equation (3) to obtain the pathloss, n, of the test bed environment where, P_r ,is the received signal strength values in dBm , P_t is the transmitting power in dB, Pathloss P_L is the difference between P_t and P_r.

Let N, denote the numerator values and D denote denominator values, we computed the pathloss exponent of the test bed area as follows:

d=[100,200,300,400,500,600,700]

P_t=44.4dB

P_r=[-67.94 -74.16 -86.84 -87.04 -91.64 -99.33 -103.13]

$P_L(d)=P_t-P_r$=44.4 -[-67.94 -74.16 -86.84 -87.04 -91.64 -99.33 -103.13]

$P_L(d)$=[112.34 118.56 131.25 131.44 136.04 143.73 147.53]

=[112.34 118.56 131.25 131.44 136.04 143.73 147.53]-[112.34]

=[0 6.22 18.91 19.10 23.70 31.39 35.19]

N =134.51

$D=\sum [10\log_{10} [1\ 2\ 3\ 4\ 5\ 6\ 7\ ]]$

D=0+3.01+4.77+6.02+6.99+7.78+8.45

=37.02

Therefore, n= N/D

Pathloss exponent, n =3.63

The pathloss exponent, n, which characterizes the propagation environment under study (test bed area/environment) is obtained from the measured data and is 3.63.

(IV) Developed Ultramobile broadband Propagation Pathloss Model For Test bed area.

Using equation (8) and equation (9) and substituting f_c =878.87MHz,

h_b= 0.036,h_m=0.0018, α (h_m)=3.99,we obtain the value for the pathloss model for Portharcourt as:

$L_{Pu}(dB) = 69.55 + 26.16\log_{10}(878.87)+(44.9-6.55\log_{10}(0.036))\log(d_i)-13.82\log_{10}(0.0018) - 3.99$ (8)

$L_{Pu}(dB) = 104.63+54.36\mathrm{Log}(d_i)$ (9)

From equation 6, we obtain:

$L_{Ps} = 104.63+54.36\mathrm{Log}(d_i) - 2[\log_{10}(\frac{878.87}{28})]^2 - 5.4$ (10)

$L_{Ps}(d_o)$=94.74dB.

But, re-arranging equation (3.1), so that:

$P_L(d_i)$ [dB]=$L_p(d_i)$=empirical pathloss model for Portharcourt

$P_L(d_0) = L_{Ps}(d_o)$ = pathloss for Portharcourt at known reference distance d_0

n = 3.63 =pathloss exponent.

Therefore, the empirical path loss model for Portharcourt is:

$L_p(d_i)=94.74 + 36.3\mathrm{Log}(d_i)$ (11)

3.4 The Propose Developed Mathematical Signal Model.

A possible method of predicting the received signal power (RSS) for the test-bed environment is propose by (Chipcon,2007) as shown in equation

$\mathrm{RSSI} = -10n\log_{10}(\frac{d_i}{d_0}) + A$ (12)

Where;

RSSI = the signal power at the receiver

n= pathloss exponent

d_i = distance between the transmitter and receiver

d_o= reference distance from the transmitting base station i.e.100m

A = the RSS at a hundred meter distancefrom transmitting base station

The value for the pathloss ,n, exponent was computed to be 3.63. The value for *A;* which is the received signal power at 100 meter from the transmitter, and is found to be -67.94 dBm. Putting these values back to the model represented by equation (12).and re-arranging equation (12), so that y denotes RSSI and x denote$\frac{di}{do}$, our propose model which can be used in predicting received signal strength is:

$y = -36.3\log_{10} x - 67.94$ (13)

Equation (13) was used in predicting the received signal strength of the test bed environment.

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4.0 RESULTS AND DISCUSSIONS

Comparison of Bit Error Rate Performance of Ultra-Broadband Network Using Adaptive Interference and cancelling technique Algorithm and Conventional Beam forming Algorithm

Figure 2 show the comparison of the receiver average BER performance of ultra-mobile broadband network with LMS adaptive beam forming algorithm and conventional beam forming algorithm. The mean BER is improved with the LMS adaptive beam forming compared to the conventional beam forming algorithm. The BER of the LMS is of order 10^{-2} at $E_b/N_o \leq 10$dB

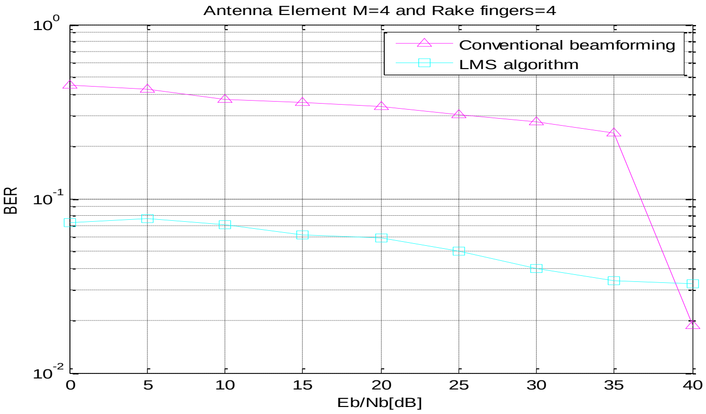

Figure 2; BER Vs. E_b/N_o Performance of ultra-mobile broadband network using LMS Adaptive Beam forming Algorithm compared with Conventional Beam forming Algorithm.

5.0 CONCLUSION

The improvement of ultra mobile broadband network using adaptive interference and noise cancellation technique was investigated for a conventional narrow band beam former by varying the array elements and the number of interferers which revealed significant improvement as these numbers increase for odd numbered arrays. Hence, interference is greatly suppressed as the odd numbered array elements increases. From the charts, it was observed that the signal-to-interference and noise ratio depends on the number of antenna element, the inter-element spacing between the arrays and the number of interferers. There was great improvement in the SINR when odd numbered elements were used with inter-element spacing of $d=0.5\lambda$ in the presence of large interferers. Adaptive antenna as observed from our analysis showed greater improvement in the SINR over sectorized antenna in the presence of large interferers. Finally, improving the interference suppression and noise reduction capabilities of any antenna system in the presence of large interferers, increases the capacity of that system deploying such an antenna. Therefore, adaptive antenna proposed here will increase capacity of the ultra mobile broadband , thus making the network to accommodate more subscribers per base station.

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REFERENCES

Lee W.Y.C., (2011), "Effects of correlation between two mobile radio base Station antennas", IEEE Transactions on Communications, vol. 21, no. 11, pp.1214-1224.

Cox, D.C., (2012), "Delay Doppler characteristics of multipath Delay spread and Average Excess Delay for 910MHz urban mobile Radio paths", IEEE Transactions on Antennas and propagation Vol. 20, No. 5, pp. 625-635.

Ellingson, S., (2001), "Smart Antenna Technologies", IEEE Workshop, Vol 3,pp. 106-110.

Rappaport, T.S., (2010), "Smart Antennas: Adaptive Arrays, Algorithms and Wireless Position Location", IEEE Press. Pg 800-805.

Wells, M.C., (2006), "Increasing the capacity of GSM cellular radio using adaptive antennas", IEEE proceedings, vol.55, No. 12., pp 2143-2159.

Abdullah Aburomeh, (2009) "Capacity Analysis of Cellular CDMA Systems" (ECE 559 Project)

A. M. Viterbi, A. J. Viterbi (2008) "Erlang Capacity of a power Controoled CDMA system"

Darren D. Chang and Olivier L. de Weck, 2005'Basic capacity calculation methods and benchmarking for MF-TDMA and MF-CDMA communication satellites. INTERNATIONAL JOURNAL OF SATELLITE COMMUNICATIONS AND NETWORKING; 23:153–171.

K. S. Gilhousen *et al.*, 1991 "*On the capacity of a cellular CDMA system*," *IEEE Trans. Veh. Technol.*, vol. 40, pp. 303–312,