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# Accurate Antenna Isolation Technique for Mitigation of CDMA Interference in a Co-Site Urban Environment

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**ABSTRACT***:* This Work developed an accurate and efficient Antenna Isolation model to minimize interference in co-habiting Networks that used co-site parameters in the formulation of the mathematical model. The Work determined the maximum radius of co-site cell as1200metres and equally deduced the width of side-lobes in the received radiation pattern, whose minimization, using the 7th order Chebyshev Polynomials, minimized interference effects in the signal propagation path. Comparison of the Isolation models showed that the Traditional Antenna Isolation Model used by most Researchers, yield isolation loss of less than 75dB at the far-field distance of the interfered with CDMA 2000 1X Base Station (BS) antenna Receiver footprint with dropped calls of 42 and Call Drop Rate (CDR) of 13.33%; which was above the 13% Standard (3GPP TR, 2002). The use of the Proposed Isolation Model has the advantage of isolation improvement at no extra cost. Isolation loss of more than 99dB was attained at the far-field distance of the interfered with BS antenna Receiver and at the footprint, dropped calls of 31 and CDR of 9.84% were recorded.

**KEYWORDS:** Antenna isolation, CDR, co-habiting

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## I. INTRODUCTION

Prior to 2001 in Nigeria, the Nigerian Telecommunications Limited (NITEL) was a monopoly and the only Operator and provider of telecommunications services in a coordinated manner in Nigeria. The deregulation of telecommunications industry in year 2001 saw the emergence of many Private Operators and introduction of different Systems in an un-coordinated manner making compatibility of Systems an issue. The installation of different Systems in close proximity to one another increased the interference levels that infected co-habiting Systems. Microwave and Base Transceiver Systems (BTS) at Ultra High Frequency (UHF), aside from radiating the main beam, also radiate a number of side-lobes (minor beams) and as the wave-length diminishes, the main (major) lobe becomes narrower and the aperture angle (beam width) of the radiation pattern becomes smaller with additional increase in number of side-lobes. These side-lobes are undesirable phenomenon since in a transmitting aerial, they mean that Power is radiated in unwanted directions (waste of Power) that interfere with other Systems; and in the case of receiving antennas they indicate a response to interference and noise arriving from unwanted directions. The manifestation of interference is poor Quality of Service (QoS) delivery that translate to increased rate of call drops, capacity degradation, delays, poor connectivity, and poor network reception (intermittent breaks or loss in signal) With attendant Customer dissatisfaction and complaints; hence the motivation for this Work on mitigation of CDMA interference in a co-site Urban Environment using an accurate Antenna Isolation Technique.

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## II. REVIEW OF RELATED LITERATURE

Shared or co-site Networks came about as a result of the rapid growth of cellular mobile radio, such that two or more different Systems or Generations are deployed in adjacent frequency bands in the same area. The growth of the Mobile Communications industry meant greater channel capacity and that more Systems are crowded in an area, with need for higher broadcast powers at the Base Stations. Deployment of higher broadcast power increases the interference level and the consequence is that as more new Operators emerge and more new Systems put into use, multiple different Systems are located at the same site generating higher interference levels that invade set RF environment, which translate to rise in the number of dropped calls or drop in the number of Mobiles that the interfered with System could have supported. **T**he far-field distance d, in the radiation zone given an approximate boundary condition for Co-site radius, is taken as $\frac{4}{5}$th the value, when the ratio of the magnitudes of the electric field excitation of the elemental dipole to a reference half-wave dipole is not more than 115 at the point of observation (Jingfei, 2009).

$$\left| \text{Co-site Radius d} \right| < 115 \quad \frac{E_{\theta \frac{\lambda}{2} \text{dipole}}}{E_{\theta \text{ elem .dipole}}} \qquad (1).$$

In the corollary, the approximate far-field condition for this distance which is $d_h \geq \frac{4}{5}$th d gives the radius of Co site cell (WG ST4 of CCSA, 2010). At the direction of the antenna axis, just as in the direction of the dipole axis, the width of the radiation pattern $x_o$ is given as:

$$x_o = \alpha_o = T_m(\alpha_o) = \frac{\cos\frac{\pi}{2m}}{\cos\left(\frac{\pi}{2}\sin\beta_o\right)} \qquad (2).$$

m and $\alpha_o$ should be chosen, taking into account that the larger the value of m, the smaller the level of the side-lobes of the dipole array and so, calculations are always done at m= 7, using the 7th order Chebyshev polynomials (Markov, 1976), given as:.

$$T_7(x) = 64x^7 - 112x^5 + 56x^3 - 7x \qquad (3)$$

### a). Analytical Antenna Isolation Technique

Under normal Systems deployment in Single-site Operations (coordinated operation), the BS transmitter and BS receiver antennas should be aligned towards each other at 0° direction of maximum gain if Systems belonged to same Operator (Jingfei, 2009).

Figure 1: Antenna configurations for horizontal separation distance (Jingfei, 2009)

Free Space Propagation Model for predicting the Received Signal Strength (RSS) or Power ($P_r$) at any particular location, when the Transmitter and Receiver have a clear, unobstructed line-of-sight (LOS) path between them is:

$$P_r = \frac{P_t \lambda^2 C_t(\theta_t,\varphi_t) G_r(\theta_r,\varphi_r)}{(4\pi d)^2} \qquad (4)$$

However, in shared-sites, where different Systems and Operators are involved, consideration is given to Antenna orientation (alignment/shift) from the line of maximum gain of radiation, by introducing Antenna Isolation, $I_h$ (Jingfei, 2009) which yielded:

$$I_h = \frac{P_r}{P_t} = \frac{\lambda^2 C_t(\theta_t,\varphi_t) G_r(\theta_r,\varphi_r)}{(4\pi d)^2} \geq 75\text{dB} \qquad (5)$$ which when converted to decibel scale, yielded:

$$I_h = 22 + 20\text{Log}\left(\frac{d_h}{\lambda}\right) - (G_t, SL_t + G_r, SL_r) \geq 75\text{dB}$$

$$= 22 + 20\text{Log}\left(\frac{d_h}{\lambda}\right) - (G_t + G_r) - (SL_t + SL_r) \geq 75\text{dB} \qquad (6)$$

Where $d = d_h$ is the horizontal separation distance between the antenna masts which is fixed and satisfies the following approximate far-field condition: $d_h \geq \frac{4}{5}$th d (WG ST4 of CCSA, 2010). $G_t$ and $G_r$ are the respective gains of the transmit antenna and the receive antenna which could be used for arbitrarily rotated antennas with gain Figures in the Line-of-Sight (LOS) direction. The parameters involved are defined as follows:

$I_h$[dB]: isolation between horizontally separated transmitter and receiver antennas

$d_h$ [m]: the horizontal distance from the centre of interferer antenna to that of the interfered with receiver antenna

λ[m]: the wavelength of the interfered with system frequency band

$G_t$[dBi]: maximum gain of the transmitter antenna with respect to an isotropic antenna (dBi)

$G_r$[dBi]: maximum gain of the receiver antenna with respect to an isotropic antenna (dBi)

$SL_t$[dB]: gain of the side-lobe with respect to the main-lobe of the transmitter antenna (negative value),

$SL_r$[dB]: gain of the side-lobe with respect to the main-lobe of the receiver antenna (negative value).

This Work proved that the above Antenna Isolation Model (Eq.6) used by most Researchers is defective when deployed in co-site environment, where ground reflected, diffracted and scattered signals are involved, in the sense that the Model was developed based on parameters from only unobstructed or LOS environment (Free-Space) where the Path Loss Exponent of the Environment, n = 2 (ideal situation from literature). Normally in co-habiting Networks belonging to different Operators, the antennas are located and oriented such that they are in the side-lobe path of each other, away from the main lobe of the radiation, so the peak loss level in the side-lobe regions is:

$$S = 20 \text{ Log } \left(\frac{1}{T_m(\alpha_o)}\right) \qquad (7),$$

which is a dominant parameter in the analysis of Antenna Isolation in co-site environment (Rahnema, 2008).

### b) Propagation Path Loss Model

Propagation Path Loss models have been developed as tools in estimating radio wave propagations as accurately as possible. Path Loss Models have therefore been created for different environments to predict the signal Loss between the transmitter and receiver. The prediction of radio signal propagation in each of the specific radio environment was essential for the deployment of emerging Wireless Communications Systems to ensure QoS delivery, coverage, as well as for the upgrade and optimization of the existing cellular networks.

In general, Path Loss (Lp) is expressed as:

$$Lp = \frac{Transmitted\ \ power}{Received\ \ power} \qquad (8)$$

which in decibel (dB) is:

$$Lp\ [\text{dB}] = 10 \text{ Log } \left[\frac{P_t}{P_r}\right] \text{ dB} \qquad (9)$$

This Work was essentially Analytical and so, used Xia's Analytical Model for predicting Path Loss in Urban Environment. From Xia's formulation: In land mobile environments, buildings significantly influence radio signal propagation. For wireless subscribers, either walking or driving along a city street, they are generally located among buildings, so, the base station antennas are seldom visible (Non Line-of-Sight). The radio signal therefore, reached the Mobile Unit by traveling past rows of buildings. On one hand, buildings blockage caused shadowing. Diffraction at edges of buildings next to the Mobile Station or unit, on the other hand, allowed the signal to reach the mobile station behind the building. Xia identified three propagation processes as the most important components, which govern radio propagation in urban environments:

- Free Space propagation Loss
- Diffraction from rooftop down to street level (Diffraction Loss)
- Multiple forward diffraction past rows of buildings (Scatter Loss).

In summary, total propagation loss was: $L_p = L_{fs} + L_s + L_d$, which if expanded could be expressed as:

$$Lp = -10 \text{ Log } \left[\left(\frac{\lambda}{4\pi d}\right)^2\right] - 10 \text{ Log } \left[\frac{\lambda}{2\pi^2}\left(\frac{1}{(2\pi+\theta)}\right)^2\right] - 10 \text{ Log } \left[(2.35)^2\left(\frac{\Delta h_b}{d}\sqrt{\frac{D}{\lambda}}\right)^{1.8}\right] \qquad (10)$$

Total Loss:

$$Lp\ (\text{dB}) = 20\text{Log}_{10}\,[f\ (\text{MHZ})] + 20\text{Log}_{10}\,[d\ (\text{Km})] + 32.44 + 10\text{Log}_{10}\,[f\ (\text{MHz})] + 10\text{Log}_{10}[r\ (\text{m})] + 20\text{Log}_{10}\,[\theta\ (\text{degree})] - 20\text{ Log}_{10}\,[(2\pi+\theta)] + 18.18 + 18\text{Log}_{10}\,[d\ (\text{Km})] - 9\text{ Log}_{10}\,[f\ (\text{MHz})] - 9\text{Log}_{10}\,[D\ (\text{m})] - 18\text{ Log}_{10}\,\Delta h_2 - 12.13\text{ dB} \qquad (11)$$

In general terms therefore, co-site interference may be defined as: "The effect of unwanted energy due to one or a combination of emissions, radiation, or induction upon the reception of another radio system, manifested by the serious degradation, obstruction, or repeated interruption in communication" (Gavan, 1986).

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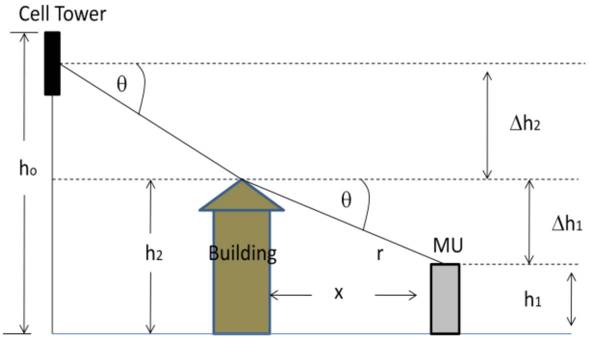

Figure 2: Diffraction Loss from Rooftop to Street level (Xia, 1999).

### c) Percentage (%) Capacity Degradation

Maintenance of the prescribed Quality of Service in the presence of interference source(s), means that the Power received by the interfered with system, must be less than the noise threshold ($P_{\text{min before}}$) as exceeding this lowers the QoS that manifests in drop in number of Users or Calls, previously supported (Heiska, 2004). From Literature: Cell

$$\text{capacity } k = 1 + \frac{G_p}{v * p * (1 + I_{UL})} \qquad (12).$$

$$P_{\text{min before}} = \frac{N_o * \rho}{G_p - v * \rho * (k-1) * (1 + I_{UL})} \qquad (13)$$

The interference power (IM3) that impinges on the desired UMTS800MHz RSSI is:

$$IM3 = P_{\text{min after}} \qquad (14).$$

$$\text{Dropped Calls } (K_d) = P_{\text{min after}} - P_{\text{min before}} \qquad (15).$$

Capacity when UMTS800MHz BS has been interfered with ($k_{int}$), was: $K_{int} = k - k_d$ (16).

$$\text{Percentage Capacity Loss (CDR)} = \left[1 - \frac{k_{int}}{k}\right] * 100\% \qquad (17).$$

For a good Quality Service offering, percentage capacity degradation or Call Drop Rate at the foot-print of the interfered System BS should not be more than 13% (3GPP TR, 2002).

## III. RESEARCH METHODOLOGY

This is the logical sequence or approach, adopted in verifying that field measurements (drive tests) were indeed gathered from co-site environment and that minimization of side-lobe losses, application of the Proposed Antenna Isolation Model mitigates interferences and ensures QoS delivery.

### (a)Verification and Determination Of Co-Site Radius

The effect of field intensities of the half-wave length dipole and an elemental dipole at the far-field distance d, when equal current is fed to the dipoles such that the ratio of the intensities is not more than 115 (Equation 1) the approximate boundary condition of Co-site radius as illustrated: The field intensity of a signal 1 mile distance from an elemental dipole ($\frac{\lambda}{360}$) long, carrying 1-A current is:

Elemental dipole: $E = E_o \frac{\eta I_o \sin\theta}{2d} \frac{dl}{\lambda}$ where: $\theta = 90^o$, $I_o$ = 1-A, $\eta = \frac{E_\theta}{H_\varphi} = 377\Omega$, $dl = \frac{\lambda}{360}$ and d = 1mile = 5280ft x 0.3048m/ft;

$$\text{hence: } E = \frac{377 \text{ x1 x1 } \sin 90^o}{2 \text{ x } 5280 \text{ x } 0{,}3048} \text{ x } \frac{\frac{\lambda}{360}}{\lambda} = 0.325 \text{ mV/m.}$$

For a half-wave length dipole, given the same magnitude of current, 1-A at a distance of 1 mile:

$$E = \eta I_o \frac{\cos\left(\frac{\pi}{2}\cos\theta\right)}{2\pi d \sin\theta} = \frac{377 \text{ x } 1 \cos\left(\frac{\pi}{2}\cos 90^o\right)}{2\pi \text{ x } 5280 \text{ x } 0.3048 \text{ x} \sin 90^o} = \frac{377 \text{ x } 1 \text{ x } \cos(0)}{2\pi \text{ x } 5280 \text{ x } 0.3048 \text{ x } 1} = 37.3 \text{ mV/m}$$

Hence Co-site radius boundary condition: $\frac{E_{\theta \frac{\lambda}{2\text{ dipole}}}}{E_{\theta \text{ elem },\text{dipole}}} = \frac{37.3 \text{ mV/m}}{0.325 \text{ mV/m}} = 114.77 < 115$. 1 mile = 5280ft x 0.3048 meters/ft = 1609 meters;

so the approximate far-field distance is $d_h \geq \frac{4}{5}$th d gives the radius of Co-site cell (WG ST4 of CCSA, 2010); $d < \frac{4}{5}$ x 1609metres $<$ 1280metres $\cong$ 1200metres.

**(b) Determination of Level Of Side-Lobes In Radiation Pattern**

From Equation (7) the level of side-lobe loss is:

$$S = 20 \text{ Log } \left(\frac{1}{T_m(\alpha_o)}\right)$$

where $\alpha_o$ is the width of the main lobe, chosen so as to correspond to the coefficients of the Chebyshev polynomials $T_m(\alpha_o)$ of the same order m = 7. The first zero of radiation pattern, which determines the width of the main lobe of antenna, $\alpha_o$ is (Eq 2):

$$x_o = \alpha_o = T_m(\alpha_o) = \frac{\cos\frac{\pi}{2m}}{\cos\left(\frac{\pi}{2}\sin\beta_o\right)},$$

given Beam-width = $2\alpha_{\frac{1}{2}} = 2\beta_o = 2\sqrt{0.28\frac{\lambda}{L}}$

which yielded 38° when $L = \frac{5\lambda}{8}$.

The level of side-lobe loss could be deduced by first determining the coefficients of the Chebyshev polynomials $T_m(\alpha_o)$ of the 7th order.

$$\alpha_o = T_m(\alpha_o) = \frac{\cos\frac{\pi}{2m}}{\cos\left(\frac{\pi}{2}\sin\beta_o\right)} = \frac{\cos\left(\frac{\pi}{14}\right)}{\cos\left(\frac{\pi}{2}\sin 19\right)} = \frac{0.99999233}{0.999960166} = 1.00003.$$

Therefore, Equation (3):

$T_7(1.00003) = 1.0015$. Consequently, from Equation (7) the level of side-lobe loss is:

$$S = 20 \text{ Log } \left(\frac{1}{T_m(\alpha_o)}\right) = 20 \text{ Log } \left(\frac{1}{1.0015}\right) = -0.013 \text{ dB}.$$

Recall that the higher the value of the beam-width of the radiation main lobe, the higher the side-lobe losses. So if $2\beta_o = 60^o$, then $\beta_o = 30^o$ and if substituted into Equation (2);

$$\alpha_o = T_m(\alpha_o) = \frac{\cos\frac{\pi}{2m}}{\cos\left(\frac{\pi}{2}\sin\beta_o\right)} = \frac{\cos\left(\frac{\pi}{14}\right)}{\cos\left(\frac{\pi}{2}\sin 30\right)} = \frac{0.99999233}{0.999906049} = 1.0000863.$$

Therefore, Equation (2):

$T_7(1.0000863) = 1.004$. Consequently, from Equation (3) the level of side-lobe loss is:

$S = 20 \text{ Log } \left(\frac{1}{T_m(\alpha_o)}\right) = 20 \text{ Log } \left(\frac{1}{1.004}\right) = -0.035$ dB. Above procedure was used to build the Table of relative side-lobe gains of Antenna at various down-tilt angles as in Table 1; sourced from Huawei Technologies. The gain values are suitable for all BTS antennas at bands from 824MHz to 960MHz and indicate losses (minus signs).

Table 1: Relative Side-Lobe gains of Antenna at various down-tilt angles

| Angle (θ°) | φ 65° antenna a1 | φ 90° antenna a2 | φ 120° antenna a3 |
|---|---|---|---|
| 0° | 0 (dB) | 0 (dB) | 0 (dB) |
| ±5° | -0.1 | 0 | 0 |
| ±10° | -0.3 | -0.2 | -0.1 |
| ±15° | -0.7 | -04 | -0.2 |
| ±20° | -1.2 | -0.7 | -0.3 |
| ±25° | -1.9 | -1.1 | -0.5 |
| ±30° | -2.7 | -1.5 | -0.7 |
| ±35° | -3.6 | -2 | -0.9 |
| ±40° | -4.6 | -2.6 | -1.2 |
| ±45° | -5.8 | -3.3 | -1.6 |
| ±50° | -7 | -4 | -2.0 |
| ±55° | -8.3 | -4.8 | -2.4 |
| ±60° | -9.7 | -5.7 | -2.9 |
| ±65° | -11.2 | -6.6 | -3.5 |
| ±70° | -12.6 | -7.6 | -4.1 |
| ±75° | -14 | -8.6 | -4.7 |
| ±80° | -15.4 | -9.7 | -5.5 |

| | | | |
|---|---|---|---|
| ±90° | -17 | -11.9 | -7.1 |
| ±95° | -18.5 | -12.9 | -7.8 |
| ±100° | -19.5 | -14 | -8.5 |
| ±105° | -20.5 | -15.3 | -10.1 |
| ±110° | -21.5 | -16.7 | -11.7 |
| ±115° | -22.4 | -18.3 | -14.2 |
| ±120° | -23.5 | -20 | -16.5 |
| ±125° | -24.7 | -21.8 | -18.6 |
| ±130° | -26.8 | -23.4 | -20 |
| ±135° | -27.7 | -25 | -21.6 |
| ±140° | -29.2 | -26.6 | -22.9 |
| ±145° | -30.1 | -26.6 | -22.9 |
| ±150° | -31.6 | -26.4 | -22.7 |
| ±155° | -30..5 | -26.1 | -22.5 |
| ±160° | -30.8 | -26 | -22.4 |
| ±165° | -29.9 | -26.3 | -22.7 |
| ±170° | -28.8 | -26.4 | -22.9 |
| ±175° | -27.9 | -26.4 | -23.0 |
| ±180° | -27.0 | -26.4 | -23.1 |

## IV. DATA COLLECTION, ANALYSIS AND RESULT PRESENTATION

### (a) Data Collection

With the collaboration of Huawei Technologies, field measurements (test drive) were carried out in Visafone Network (CDMA2000 1x) in ten (10) sites co-habiting with GSM900MHz Network, whose radius range from 500meters to 1200meters, though only the data of one site was collected and shown in this Work.

Table 2: Average Measured RSSI – Co-site Cell

| Distance (m) | Site Name | CDMA Rx (dBm) |
|---|---|---|
| 100 | Uwani Divisional Police Hqtrs. | -92 |
| 200 | Uwani Divisional Police Hqtrs.. | -93 |
| 300 | Uwani Divisional Police Hqtrs. | -94 |
| 400 | Uwani Divisional Police Hqtrs. | -96 |
| 500 | Uwani Divisional Police Hqtrs. | -97 |
| 600 | Uwani Divisional Police Hqtrs. | -99 |
| 700 | Uwani Divisional Police Hqtrs. | -101 |
| 800 | Uwani Divisional Police Hqtrs. | -102 |
| 900 | Uwani Divisional Police Hqtrs. | -104 |
| 1000 | Uwani Divisional Police Hqtrs. | -105 |
| 1100 | Uwani Divisional Police Hqtrs. | -107 |
| 1200 | Uwani Divisional Police Hqtrs. | -109 |
| 1300 | Uwani Divisional Police Hqtrs. | -110 |
| 1400 | Uwani Divisional Police Hqtrs. | -113 |
| 1500 | Uwani Divisional Police Hqtrs. | -115 |
| 1600 | Uwani Divisional Police Hqtrs. | -117 |
| 1700 | Uwani Divisional Police Hqtrs. | -118 |
| 1800 | Uwani Divisional Police Hqtrs. | -120 |
| 1900 | Uwani Divisional Police Hqtrs. | -123 |
| 2000 | Uwani Divisional Police Hqtrs. | -125 |

Table 3: Analytical Traditional Isolation Measurement

| Distance (m) | Antenna Isolation (dB) |
|---|---|
| 100 | 56.12 |
| 200 | 62.14 |
| 300 | 65.66 |
| 400 | 68.16 |
| 500 | 70.09 |
| 600 | 71.68 |
| 700 | 73.02 |
| 800 | 74.18 |
| 900 | 75.20 |
| 1000 | 76.12 |
| 1100 | 76.95 |
| 1200 | 77.70 |
| 1300 | 78.40 |
| 1400 | 79.04 |
| 1500 | 79.64 |
| 1600 | 80.20 |
| 1700 | 80.73 |
| 1800 | 81.22 |
| 1900 | 81.69 |
| 2000 | 82.14 |

### (b). Analytical Traditional Antenna Isolation Model using installed parameters

Installed MTN directional GSM900 antenna type is APX15GV-DV-0915.02dpa (900MHz, 90°, 90°, 15dBi) and VISAFONE directional UMTS800 antenna type is 742266-0902-X- 02T.dpa (800MHz, 60°, 120°, 15dBi). (Source: Huawei Technologies).

Recall Equation (4):

$$P_r = \frac{P_t\lambda^2 G_t(\theta_t,\varphi_t)G_r(\theta_r,\varphi_r)}{(4\pi d)^2},$$

Hence, Gains of both directional antennas are 15dBi.

GSM900MHz antenna, $\theta_t = 90^o$ and $\varphi_t = 90^o$ in the direction of the receiver, while the UMTS800MHz antenna, $\theta_r = 60^o$ and $\varphi_r = 120^o$, in the direction of transmitter.

**Parameters**

Hence $G_t = 15$, $SL_t$ ($\theta = 90^o$ and $\varphi = 90^o$) = – 11.9 (obtained from Table1),

$d_h = 500$m (fixed), $G_r = 15$, $SL_r$ ($\theta = 60^o$ and $\varphi = 120^o$) = – 2.9 (obtained from Table1).

Recall wavelength

$$(\lambda) = \frac{\text{Speed of Light (c)}}{\text{Frequency (f)}} \quad \text{or} \quad \lambda\text{ (km)} = \frac{0.3\text{(km)}}{\text{f (MHz)}}$$

For Visafone interfered with UMTS800MHz System, the wave length, $\lambda$ (meters) = $\frac{300}{876.87}$ = 0.342.

Applying Traditional Antenna Isolation technique, Equation (6) and varying measurement sample points along the horizontal separation distance $d_h$ yielded results as depicted in Table 3

### (c) Development of an enhanced (Proposed) Antenna Isolation Model for Co-site Networks

This Work thus filled a gap left by other Researchers that used Antenna Isolation Technique (Traditional), modeled in Free-Space environment. Applying Equation (18), the Xia’s simplified model for predicting the Path Loss of the Received Power ($P_r$) in a co-site environment was modified in this Work, using peculiar Nigerian environmental factors which are very much relevant in a shared-site Network.

$$I_h = -10\text{Log}\left(\frac{\lambda}{4\pi d_h}\right)^2 G_t(\theta_t\varphi_t)G_r(\theta_r\varphi_r) - 10\text{Log}\left[\frac{\lambda}{2\pi^2 r}\left(\frac{1}{\theta} - \frac{1}{(2\pi+\theta)}\right)^2\right] - 10\text{Log}\left[(2.35)^2\left(\frac{\Delta h_2}{d_h}\sqrt{\frac{D}{\lambda}}\right)^{1.8}\right] \geq 75\text{ dB} \qquad (18)$$

where d is the horizontal distance, $d_h$ from the center of interferer antenna to that of interfered with receiver antenna = 500meters, $\Delta h_2$ is the base station antenna height with respect to the average rooftop level which is 15meters since average antenna height is 30meters, and building height (3 storey) is 15meters. In-between building distance D (displacement) is 10meters in Nigeria, whereas in Advanced Countries, D is 80meters and r, the radial distance of the Mobile Unit on the street is 16.8meters and θ, the radiation angle is 53.5° (see Figure 2). Therefore Proposed Antenna Isolation formula, I is:

$$I_h = 22 + 20\text{Log}\left(\frac{d_h}{\lambda}\right) - (G_t, SL_t + G_r, SL_r) + 10\text{Log}\frac{2\pi^2 r}{\lambda} + 10\text{Log}\,\theta - 20\text{Log}\,(2\pi + \theta) + 20\text{Log}\,2.35 + 18\text{Log}\left(\frac{d_h}{\Delta h_2}\right) + 9\text{Log}\frac{\lambda}{D} \geq 75\text{dB} \qquad (19)$$

which yielded:

$$I_h = 22 + 20\text{Log}\left(\frac{d_h}{\lambda}\right) - (G_t + G_r) - (SL_t + SL_r) + 29.23 + 16.67 - 34.43 + 7.42 + 18\text{Log}\left(\frac{d_h}{\Delta h_2}\right) - 13.2 \geq 75\text{dB} = 28 + 20\text{Log}\left(\frac{d_h}{\lambda}\right) + 18\text{Log}\left(\frac{d_h}{\Delta h_2}\right) - (G_t + G_r) - (SL_t + SL_r) \geq 75\text{dB} \qquad (20)$$

Using the same Uwani Police Station site parameters and Table 1 and applying the Developed (Proposed) Model;

Substituting values of parameters into Equation 20 and varying the sample point distance $d_h$ along the propagation distance:

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Table 4: Isolation Measurement of Developed (Proposed) Model

| Distance (m) | Antenna Isolation (dB) |
|---|---|
| 100 | 76.95 |
| 200 | 88.39 |
| 300 | 95.08 |
| 400 | 99.83 |
| 500 | 103.31 |
| 600 | 106.52 |
| 700 | 109.06 |
| 800 | 111.27 |
| 900 | 113.21 |
| 1000 | 114.95 |
| 1100 | 116.52 |
| 1200 | 117.96 |
| 1300 | 119.28 |
| 1400 | 120.50 |
| 1500 | 121.64 |
| 1600 | 122.71 |
| 1700 | 124.15 |
| 1800 | 124.65 |
| 1900 | 125.54 |
| 2000 | 126.39 |

**(d) Determination of % Capacity Degradation due to Interference signal**

The pole capacity, that is, maximum number of Mobiles which the UMTS800MHz BS could possibly support from Equation (17) is: Cell capacity

$$k = 1 + \frac{G_p}{v*p*(1+I_{UL})}.$$

From Literature, User bit-rate, (R) is 12.2 kbps, Chip rate, (W) is 38.4 Mcps and

Transmitted Energy per Interference-plus-Noise spectral density ($\frac{E_b}{I_o}$) = ρ = 4.9dB, while other-to-own-cell interference, ($I_{UL}$) is 3.085 and Orthogonality factor, ($\alpha$) is 0.4.

Voice activity factor, v = 0.5, Thermal Noise, $N_o$ = – 91dBm, hence $G_p = \frac{W}{R} = \frac{38.4Mcps}{12.2\ Kbps} = 3147.54$

$$k = 1 + \frac{\frac{38400}{12.2}}{0.5*4.9*(1+3.085)} \cong \frac{3174.54}{0.5*4.9*4.085} = 1 + \frac{3147.5}{10.008} = 1 + 314.49 \cong 1 + 314 = 315$$

Hence, a maximum of 315 Mobile Users or simultaneous calls could be supported in the UMTS800MHz Network, depending on the desired QoS, and the amount of interference suffered.

$$P_{min\ before} = \frac{-445.9}{3147.54-3142.59} = \frac{-445.9}{4.91} = -90.81dBm \cong -91dBm$$

Hence number of dropped calls or Mobiles was: $K_d = P_{min\ after} - P_{min\ before}$ as in Table 5.

Table 5: Call Drop ($K_d$) in the presence of interference

| Distance (m) | UMTS800MHz RSSI (dBm) | $P_{min\ before}$ (dBm) | Analytical $P_{min\ after}$ (dBm) | KPI $K_d$ |
|---|---|---|---|---|
| 100 | -92 | -91 | -49.38 | 42 |
| 200 | -93 | -91 | -55.40 | 36 |
| 300 | -94 | -91 | -58.92 | 32 |
| 400 | -96 | -91 | -61.12 | 30 |
| 500 | -97 | -91 | -63.36 | 28 |
| 600 | -99 | -91 | -64.94 | 26 |
| 700 | -101 | -91 | -66.28 | 25 |
| 800 | -102 | -91 | -67.44 | 24 |
| 900 | -104 | -91 | -68.46 | 23 |
| 1000 | -105 | -91 | -69.38 | 22 |
| 1100 | -107 | -91 | -70.21 | 21 |
| 1200 | -109 | -91 | 70.96 | 20 |
| 1300 | -110 | -91 | -71.66 | 19 |
| 1400 | -113 | -91 | -72.30 | 19 |
| 1500 | -115 | -91 | -72.52 | 18 |
| 1600 | -117 | -91 | -73.08 | 18 |

| | | | | |
|---|---|---|---|---|
| 1700 | -118 | -91 | -73.61 | 17 |
| 1800 | -120 | -91 | -74.11 | 17 |
| 1900 | -123 | -91 | -74.58 | 16 |
| 2000 | -125 | -91 | -75.02 | 16 |

Table 6: Capacity in the presence of interference ($K_{int}$) and CDR

| Distance (m) | UMTS 800MHz RSSI (dBm) | KPI K | KPI $K_d$ | KPI $K_{int}$ | % Capacity Loss (CDR) |
|---|---|---|---|---|---|
| 100 | -92 | 315 | 42 | 273 | 13.33 |
| 200 | -93 | 315 | 36 | 279 | 11.43 |
| 300 | -94 | 315 | 32 | 283 | 10.16 |
| 400 | -96 | 315 | 30 | 285 | 9.50 |
| 500 | -97 | 315 | 28 | 287 | 8.89 |
| 600 | -99 | 315 | 26 | 289 | 8.30 |
| 700 | -101 | 315 | 25 | 290 | 8.00 |
| 800 | -102 | 315 | 24 | 291 | 7.60 |
| 900 | -104 | 315 | 23 | 292 | 7.30 |
| 1000 | -105 | 315 | 22 | 293 | 7.00 |
| 1100 | -107 | 315 | 21 | 294 | 6.67 |
| 1200 | -109 | 315 | 20 | 295 | 6.35 |
| 1300 | -110 | 315 | 19 | 296 | 6.03 |
| 1400 | -113 | 315 | 19 | 296 | 6.03 |
| 1500 | -115 | 315 | 18 | 297 | 5.71 |
| 1600 | -117 | 315 | 18 | 297 | 5.71 |
| 1700 | -118 | 315 | 17 | 298 | 5.40 |
| 1800 | -120 | 315 | 17 | 298 | 5.40 |
| 1900 | -123 | 315 | 16 | 299 | 5.10 |
| 2000 | -125 | 315 | 16 | 299 | 5.10 |

Capacity when interfered was: $k_{int} = k - k_{d.}$ Therefore % capacity loss (CDR) = $[1 - \frac{k_{int}}{k}]$* 100% is shown.

## V. RESULT PRESENTATION

**Percentage (%) Capacity Degradation due to GSM900MHz IM3 Interference:**

The Minimum Received Signal Strength Indicator (RSSI) at UMTS800MHz BS before the presence of interference from GSM900MHz System presupposes that QoS offered was maintained. In the presence of interference, higher numbers of dropped calls at the BS footprint that exceeds 13% confirmed that QoS was impaired (Figures 3 and 4).

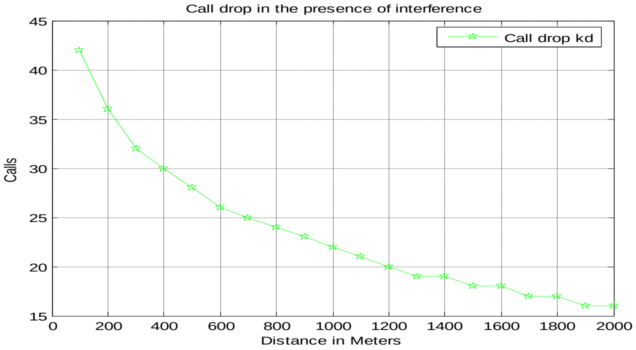

Figure 3: Call Drop ($K_d$) in the presence of interference

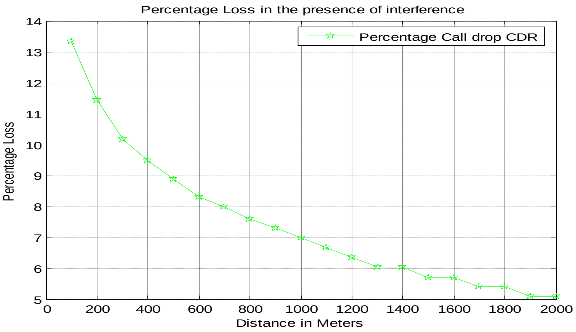

Figure 4: Percentage Call Drop in the presence of interference

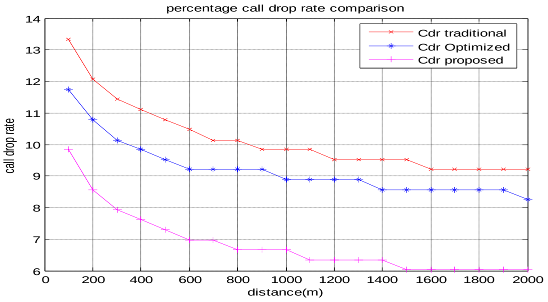

Figure 5: Comparison of percentage Call Drop Rate (CDR)

Figure 4, confirmed that QoS was impaired as the Call Drop Rate (CDR) exceeded 13% at the BS footprint. Comparison of the Call Drop Rate (CDR) of Traditional, Optimized and Proposed Isolation Models, showed CDR of 13.33%, 11.75% and 9.84% respectively, as in shown in figure 5

## VI. CONCLUSION

The rapid growth of Cellular Radio led to the deployment of Systems in close proximity to one another that resulted in increased interference level for shared-site Networks. This Report therefore, contained interference analysis and techniques to mitigate their effects in shared-site Systems, using Antenna Isolation (Antenna coupling loss) Technique that is cost effective. The Developed (Proposed) Model obviates the need to arbitrarily rotate or adjust the antenna of the interfered with System. One advantage of the Model as a mitigation tool was that Isolation improvement was attained in terms of coupling loss efficiency and less number of dropped calls and Call Drop Rates at the interfered with BS Receiver System footprint.

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