Mitigation of Intermodulation Effects Due to Co-Existence Of GSM 900 And CDMA 2ooo 1x Systems

Using Antenna Isolation Technique

By

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ABSTRACT

The major drawback of shared sites is the increased level of interference, analysis on intermodulation interference and the effect of noise on Receiver sensitivity of the CDMA System due to interference from GSM System in co-site cells showed that the Signal –to –Interference–plus–Noise Ratio (SINR) of Networks when operating separately in different sites is better than in co-site arrangement. This work adopted the Antenna Isolation technique as a viable option to minimize the interference level, in order to ensure harmony and co-existence of shared Networks based on a physical optimization of antenna systems that could be understood as a physical symmetry rotation in space, to vary the antenna tilt and azimuth. The approach independently reduces the interference effects on the distance between the base station antennas. This research analyzes the interference between co-site CDMA2000-800MHz (CDMA2000 1x/UMTS800) and GSM900MHz Base Station Systems due to spurious emission, intermodulation effects and blocking. Received Signal Strength (RSS) measurements were gathered in Enugu from Mobile Telecommunications of Nigeria (MTN) Network (GSM900) and Visafone Network (CDMA2000 1x) in sites where each Network operates alone and where both Networks shared sites (co-site or co-existence), while Antenna Isolation measurements were practically demonstrated in Huawei Laboratory so as not to disrupt traffic on Operators Networks, using token antennas and calibrated cables.

KEYWORDS: Antenna isolation, intermodulation interference, co-existence, co-location, interference reduction

I INTRODUCTION

The rapid growth of cellular mobile radio in the 800 MHz bands has stimulated the development of emerging wireless communications, such that two different Systems or Generations might be deployed in adjacent frequency bands in the same area (CDMA2000 1x/GSM900 or IS-95 CDMA/WCDMA). As more new Operators emerge and more new Mobile Communication Systems are put into use, multiple different Systems are more frequently located at the same site. This phenomenon is called co-site, shared or co-existence network, and due to the close distance between the Systems antennas such as CDMA2000 1x (UMTS800) in the RF environment of GSM900, results in increased Interference, which leads to capacity degradation of both Systems due to lack of RF isolation [1]. The major problem of co-site Systems as in this work is interference, mainly caused by the GSM900 transmitters that radiate spurious and intermodulation (IM) signals that affect the CDMA2000 1x (UMTS800) receiver.

Third Generation (3G) systems, such as CDMA2000 1x, IS-95 CDMA and WCDMA use CDMA as the multiple access technique, which is known to be resilient to narrow band interference and multipath fading. However, the degradation suffered as a result of co-existence can sometimes be notable. The primary applications of 3G Systems are interoperability, high throughput rates (up to 2Mbps), permanent connection support, transition to packet connection, providing multimedia services such as audio/video streaming applications and the internet [2].

GSM900 on its part utilizes hybrid FDMA and TDMA as the multiple access technique with 124 channels of 200 KHz bandwidth and 8 timeslots of 576.92ms each, using GMSK as the modulation method, which manages to serve 9.6kbps throughput. The main applications of GSM900 Systems are speech and short data messages (SMS) and the connection type is circuit connection. A typical design policy for GSM infrastructure is to maintain multiple transmission stations (BTS) in one transmitting antenna in order to increase the cell capacity. An average number is three BTS and the maximum is twelve. The signal from each transmitter (each transmitter operates in a single frequency with eight timeslots), is mixed in multiple adders and then fed into a Band Pass Filter (BPF) and finally into the antenna. Some of these adders are active so as to provide amplification to the input signals. Active devices tend to be extremely nonlinear [3]. Generation of IM Products is a direct result of nonlinearities which are multiples of the fundamental frequencies. Odd harmonics such as 3rd order, 5th order and 7th order harmonics show up in the receive bands of the interfered with System, causing IM Interference [1]. This output signal is in general not desirable, whether for the transmitters or for the receivers. for in-band Inter-modulation Product to occur, at least two different frequencies are required to be combined. In addition to that, Mobile Stations use much less power than Base Stations, and only one time slot out of eight in the GSM frame, hence reducing the imposed interference of any kind.

Finally, the signal reaches the UMTS800 receiver (MS or BTS) after travelling through the RF interface and suffering from propagation losses (L_P). This intermodulation (IM) interference generated at the transmitter end is called Active Interference, P_{active} which is the summation of all losses in the transmitter.

$$P_{active} = \sum_{f_i} L_{IM} L_T L_p P_{GSM} \qquad (1)$$

where

f_i is the frequency of the IM product, L_{IM} is the loss arising from IM interference, L_T is the antenna mismatch loss, L_P is the propagation loss in the path from

GSM900 transmitter to UMTS800 receiver while P_{GSM} is the GSM900 Base Station's transmit Power.

L_{IM} is a loss factor that indicates the difference in the level between the GSM signal and the intermodulation products.

$$P_{passive} = \sum_{f_i} L'_{IM} L_p P_{GSM} \qquad (2)$$

Hence, the sum of IM interference in the receiver end will be:

$$I_{IM} = P_{active} + P_{passive} \qquad (3)$$

Equipment manufacturers/vendors specify or provide information on the values of L_{IM}, L_T, Second Order and Third Order Intercept Points (SOI and TOI) [4].

The main drawback of shared sites is the increased level of interference and in order to ensure harmony and co-existence of different Networks, the Radio-Communication Sector of ITU (ITU-R) published Recommendations and Reports. The publication is an aid to Operators to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all Services. The regulatory and policy functions of the ITU-R are performed by World and Regional Conferences and Assemblies, supported by Study Groups [5].

The key benefits of having co-site Systems however, are as follows:

- Encouraging equitable reasonable competition;
- Reducing the number of steel towers, for coordinated operations;
- Reducing infrastructural and network building expense;
- Reducing visual impact.

An important consideration when Base Station antennas share the same tower, rooftop, or other antenna sites (same Operator), and are consequently separated by small distances d, is the degree of isolation that can be obtained between the ports of two antennas. For distances more than 10meters, and up to 300meters, the propagation loss between the two antennas is small, so the channel may be described by Free Space Propagation model [6], though derived or calculated

Sun Jingfei [7] investigated the effects interference and floor noise levels have on deployed systems and receiver sensitivity. When the receiving intermediate frequency (i.f) band of the BTS is B_W (Hz) and its receiving noise coefficient is N_f (dB), the equivalent noise level of the BTS receiver is:

$$N_o = -174 + 10 \text{ Log } B_W + N_f \text{ (dBm)} \qquad (4)$$

If the unit of the bandwidth B_w is in MHz, then the equivalent noise level is:

$$N_o = -114 + 10 \text{ Log } (B_W) + N_f \text{ (dBm)} \qquad (5)$$

In theory, the receiver sensitivity of the BTS is:

$$S_o = N_o + \text{SIR (dBm)} \qquad (6)$$

where SIR in (dB), is the minimum demodulation Signal-to-Interference Ratio of the receiving system of the BTS. The noise floor level directly affects the Receiver Sensitivity that is, if the noise level increases by 1 dB, the receiver sensitivity of the BTS decreases by 1 dB accordingly [7]. He subsequently compared the typical values of the parameters in the current GSM900 and CDMA 2000 1x system (including IS 95, CDMA2000 and WCDMA).

In actual system implementation, the receiver bandwidth of the system and noise coefficient of the entire receiver usually fails to meet the theoretical value or optimal value as listed in [7] due to increased level of interference in shared-site System, so the theoretical receiver sensitivity are not always realized. It is therefore better to decrease the minimum demodulation Signal-to-Interference Ratio (SIR) by adopting the antenna isolation technique and other interference mitigation techniques in order to improve on system performance. If the intra-frequency spurious interference of the external receiving band is of white noise (AWGN), it is ultimately superimposed on the equivalent noise of the original system which raises the receiver noise level (dB) of the system.

In [8] the Receiver Sensitivity of -104dBm and using Equation (6), taking the GSM900 and UMTS800 Systems as examples, the equivalent receiver noise level of GSM900 system is -113dBm and UMTS800 is -91dBm. Now, if the external interference distributed similarly to white noise AWGN) is introduced at the entry to the BTS receiver and if the receiver sensitivity is allowed to deteriorate by 3dB, then the interference level is equal to the equivalent noise level of the original system, namely -113dBm and -91dBm for GSM900 and UMTS800 respectively. If the receiver sensitivity is only allowed to deteriorate by 0.5dB, the interference level must be lower than the noise level of the original BTS by 9dB, namely -122dBm/200kHz for GSM900 and -100dBm/1.28MHz for UMTS800. If the receiver sensitivity is only allowed to deteriorate by 0.1dB, the interference level must be lower than the noise level of the original BTS by16dB, namely; -129dBm/200kHz for GSM900 and -107dBm/1.28MHz for UMTS800.

2 INTERFERENCE REDUCTIONS AND ANTENNA ISOLATION

Generally speaking, interference can be divided into three categories - additive noise interference of the interference source, cross modulation and blocking interference of the receiver.

When two non-attenuating signals are input to the receiver, two new frequency components are generated due to non-linear effects. This phenomenon is called inter-modulation products.

The above categories of interferences generate intermodulation products (effects) in the non-linear device of the UMTS receiver. The following takes the CDMA and GSM BTS as example to calculate allowable external interference level. As specified in CDMA2000 1x and GSM 900 protocol, receiver sensitivity must be higher than -104dBm. The minimum demodulation SIR of the receiver is -13dB for CDMA2000 1x and 9dB for GSM900.

A way to model the transmission of intermodulation interference is to consider these coefficient signal losses (L_{IM}) with respect to a GSM signal (as a deviation from its original power).

$$L_{IM} = \frac{3P_{OP} - 2P_{TOI}}{P_{OP}} \qquad (7)$$

where

P_{op} is the operating power in the input of the nonlinear device and P_{TOI} is the given third order intercepts point.

The IM product created in the above adder, is then transmitted through the filter and the antenna and multiplied by $|H(f_i)|^2$ and by $1- |s_{11}(f_i)|^2$, as the filter characteristic function and the Signal Wave Ratio (SWR) of the antenna defined for certain frequency of the IM product (f_i), and by $D(\phi)$ as the directivity pattern designates. This mismatch of the antenna produces a loss denoted L_T.

$$L_T = |H(f_i)|^2 (1- |s_{11}(f_i)|^2) D(\phi) \qquad (8)$$

In order to calculate such losses, extensive measurements of the GSM antenna and transmitter are required, which again, no Operator would allow to be carried out in its active Networks. Hence this Work would resort to analytical deductions in evaluating these losses. The sum of IM interference in the receiver end as given in Equation (3) is:

$I_{IM} = P_{active} + P_{passive}$

In most work on IM interference, only those generated in the transmitter denoted as P_{active} are considered as that generated in the receiver denoted as $P_{passive}$ is so small that it is often ignored. From Equations (1) and (2), Lp is the Propagation Loss in the path from GSM900 transmitter to UMTS800 receiver and L'_{IM} is a loss factor that indicates the difference in the level between the GSM signal and the intermodulation products

In practice, single band antennas (vertical polarized antenna: co-polar and cross polar antenna, especially cross polar) are frequently used in mobile network deployments [8] to improve on antenna Isolation. Careful consideration of antenna Isolation is necessary for co-site base stations to avoid excessive interference, thereby reducing losses and improving on Link Quality. The amount of isolation that can be achieved between antennas depends on several factors, such as the physical horizontal separation distance, d_h between the antennas, polarization, radiation pattern of the antennas and whether the antennas are within the main beam of each other, and the conducting properties of the antenna tower. In practice, antenna isolation in excess of 80dB is very difficult to achieve due to secondary phenomena like reflections and scattering from the surrounding environment, mechanical or electrical antenna down-tilt, misalignments, etc. Antenna Isolation can most accurately be determined through on-site measurements though such measurement exercises are usually too costly, time-consuming and are bound to disrupt traffic in an active Network. Hence Network Operators disapprove of on-site Antenna Isolation measurements. As an alternative to on-site Antenna Isolation measurements, different methods of calculating same analytically is proposed as in [9].

The Antenna Isolation values $I_{isolation}$ obtained before and after optimization is then translated into Traffic Parameters (Key Performance Indicators).

2.1 Horizontal space isolation calculation:

The antenna isolation between spatially separated antennas is usually modeled based on measurements. An antenna isolation measurement configuration is illustrated in Figure 1, where two spatially separated antennas (antenna 1 and antenna 2) are connected to a network analyzer. A signal at GSM900 operating centre frequency is generated by the network analyzer and sent to the input of antenna 1; the output of the signal at antenna 2 is measured and recorded by the network analyzer. With calibrated connection cables, by taking into account the cable loss, the difference of signal power level at the output of antenna 2 and that at the antenna 1 input is taken as antenna isolation. High values (over 70dB) for horizontal separation, measured for different horizontal distances between the two antennas, at different angles of down tilt, and different bore-sight angle directions is an indication of good isolation, confirming reduced interference effects. The polarization of Antennas deployed by MTN and Visafone are cross-polar Antennas. The horizontal Space antenna isolation for a scenario as in Figure 1 can be computed analytically, using the following equation

$$I_H\,[dB] = 22 + 20\log(d_h/\lambda) - (G_{Tx} + G_{Rx}) - (SL_{Tx} + SL_{Rx}) \qquad (9)$$

where Equation (9) for horizontal space distance, d_h between two antennas satisfies the following approximate far-field condition: $d_h \geq 2D^2/\lambda$ [10].

However, the accuracy of this approximation decreases with decreasing antenna gain, but where polarizations differ, antenna isolation will increase.

The parameters involved are defined as follows:

D[m]: the maximum dimension of the largest of the transmitter or receiver Antenna

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_{Tx}[dBi]: maximum gain of the transmitter antenna with respect to an isotropic antenna (dBi)

G_{Rx}[dBi]: maximum gain of the receiver antenna with respect to an isotropic antenna (dBi)

SL_{Tx}[dB]: gain of the side-lobe with respect to the main-lobe of the transmitting antenna (negative value),

SL_{Rx}[dB]: gain of the side-lobe with respect to the main-lobe of the receiver antenna (negative value).

Equation (10) can be deduced from the Friis formula [10], which gives the following relation (in the linear domain) between the received Power (P_r) and transmitted Power (P_t) for line-of-sight conditions:

$$\frac{P_r}{P_t} = (G_{Tx} * SL_{Tx})(G_{Rx} * SL_{Rx})(\lambda/4\pi\ d_h)^2 \qquad (10)$$

By introducing the isolation $I_F = \frac{P_r}{P_t}$ and converting the Friis formula to dB scale, Equation (9) above is deduced. The Friis formula, and thus Equation (10) above, does not only apply to horizontal separation between antennas, but to any arbitrary separation. Furthermore, it can be used with arbitrarily rotated antennas, as indicated by the inclusion of the maximum and side-lobe antenna gains in the equation. Consequently, the equation can incorporate effects from both antenna tilt and variations in azimuthal angle. Information that may be helpful for obtaining estimates of the isolation between co-site base station antennas or between closely spaced base station antennas is whether one is dealing with coordinated or uncoordinated operations, assumptions that the antennas have the same polarization, and that influence from objects near the antennas can be disregarded. For this reason, antenna isolation is primarily a function of the wavelength, antenna types (Omni vs directional), antenna characteristics (down-tilt, gain, radiation patterns, etc.) and relative spatial configurations [10].

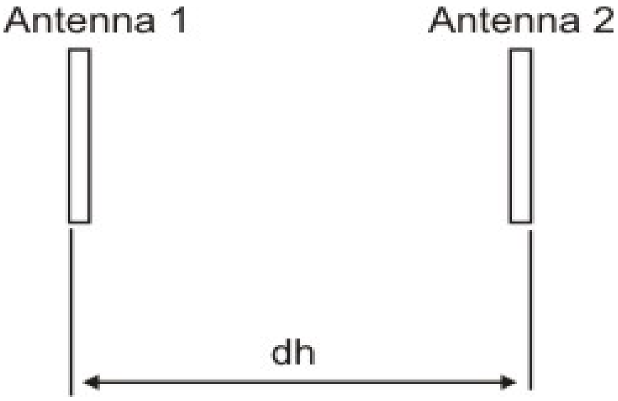

Figure 1: Antenna configuration for horizontal separation distance

2.2 Vertical space isolation calculation

Vertical separation can be employed to isolate two antennas in a co-site situation. However, this basic configuration is relevant to co-location arrangement and is depicted in Figure 2, while a combination of horizontal and vertical separation is the option more relevant for co-site arrangement as depicted in Figure 3. Vertical separation is fixed at 1m while the horizontal separation was varied for the measurement process. Cross polar operation is assumed to be employed.

Vertical isolation can be computed by the following equation [9]:

$$I_V\ [dB] = 28 + 40*\log(d_V / \lambda) - (G_{Tx} + G_{Rx}) \qquad (11).$$

Usually, gains of BTS antennas take approximations, $G_{Tx} = G_{Rx} = 0$dBi. Hence Equation (11) becomes:

$$I_V\ [dB] = 28 + 40*\log(d_v / \lambda) \qquad (12)$$

where

I_V[dB]: isolation between vertically separated transmitter and receiver antennas

d_V[m]: the vertical distance from the interferer antenna to the interfered with receiver antenna, measured from radiation centre-to-radiation centre

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

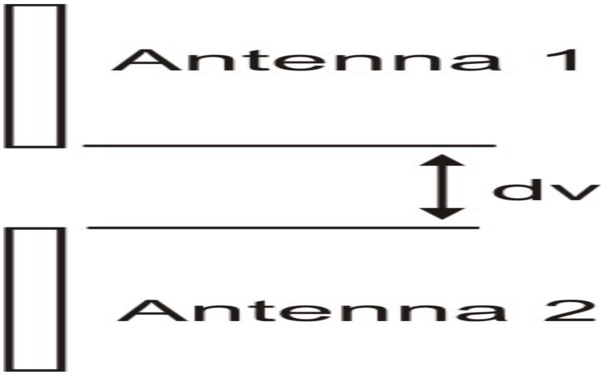

Figure 2: Antenna configuration for vertical separation (co-location)

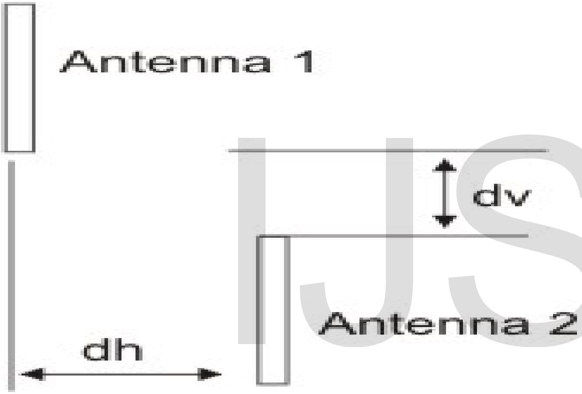

Figure 3 :Antenna configuration for vertical separation (co-site)

2.3 Slant space isolation calculation

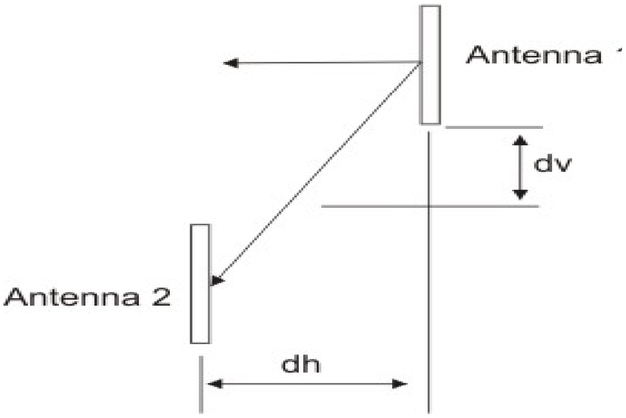

Figure 4: Antenna configuration of slant separation

When one of the antennas of Figure 3 above is down-tilted, Antenna configuration of slant separation, Figure 4 is unwittingly configured [11]. Slant isolation can be computed by the following equation:

$$I_S[dB] = (I_V - I_H) * (\alpha/90°) + I_H \qquad (13)$$

where

I_S[dB]: when antennas slantingly configured, the isolation between the transmitter antenna and receiver antenna

I_H[dB]: when antennas horizontally configured, the isolation between the transmitter antenna and receiver antenna

I_V[dB]: when antennas vertically configured, the isolation between the transmitter antenna and receiver antenna

α[°]: the vertical angle between the transmitter antenna and receiver antenna.

Equation (13) is the linear interpolation of the equations for horizontal and vertical separation. [11] noted that the actual slant isolation is dependent on factors such as actual shape and taper of the antenna beams and that the linear interpolation might not provide a realistic estimation of the isolation. It equally noted the uncertainty regarding the factor representing the vertical isolation if Equation (12) is used. Equation (13) is however, applicable when $d_h \geq 2D^2/\lambda$ and $d_V > 10*\lambda$, as for the horizontal and vertical cases. [11] Proposed 10λ as the required horizontal separation for Equation (13) to be valid.

3 RESEARCH METHODOLOGY

This Work presents analytical methods on measured Antenna Isolation values for horizontal, vertical and slant separation of antennas, obtainable by variable space separation with a view to minimizing the degradation suffered by UMTS800. The problem of this Work is the effect of intermodulation (IM) products and how to avoid or mitigate its effects in co-site cells deploying GSM900 and UMTS800 (CDMA2000 1x) Networks, by providing sufficient physical separation and proper orientation, between antennas (Antenna

Isolation) without the need to supplement cost. Since no Operator would allow real-time Antenna Isolation measurements that are bound to disrupt traffic in active Networks. Site measurements of signals (RSS) are restricted to Mobile Telecommunications (Nigeria) Limited (MTN) Network, a notable GSM900 and GSM1800 Operator, and Visafone Network, a UMTS800 (CDMA 2000 1x) Service Provider, co-existing in the same site (area). The Research is conducted in Enugu Urban(South-East Nigeria) Environment (test bed) and data were gathered from three (3) locations, where the systems of both Operators share the same site. GSM900 transmit Power is 20W (43dBm), while CDMA2000 1x transmit Power is 30W (44.77dBm). Average tower height of both Systems is 30meter (ranging from 22m to 45m). A distance of 1250meters was covered in gathering RSS. MTN deploys a transmitting centre Frequency (Down Link - D_L) of 947.5MHz, while Visafone deploys 876.87MHz. Measurement Tools used in this Work for RSS gathering is the Transverse Electromagnetic waves (TEMS) Investigation software package, loaded in a Note Book (Laptop), while the RF Network Analyzer was used for practical demonstrations in the Laboratory with token antennas and calibrated cables in determining optimal Antenna Isolation value. Both measurement tools were sourced from Huawei Technologies. The RSS values gathered were used to determine the Propagation Path Loss and Path Loss Exponent for Enugu Urban Environment and Signal to Interference plus Noise Ratio (SINR).

The Research design adopted, is the already existing design, and does not require any extra hardware installation. To simplify the shared-site problems, only the 1st tier interferers of the hexagonal cellular symmetry, is considered; as the role of the rest interferers are rather small [6, 9]. Note that the position of the UMTS800 (CDMA2000 1x) Mobile Station can be anywhere within the footprint of a GSM900 BTS, while the UMTS800 Base Station can be exactly on one GSM Base Station (when the Provider is the same, that is, coordinated operation), or in a random position (when Systems belong to different Service Providers that is, un-coordinated operation, as in this Research. This scenario is shown in Figure 5 and figure 6, where a UMTS800 Base Station and a UMTS800 Mobile Station suffer from IM effects caused by the adjacent GSM900 transmitters. The design was same as that for gathering RSS measurements. For Antenna Isolation measurements conducted in the Laboratory, the design is depicted in Figure 7

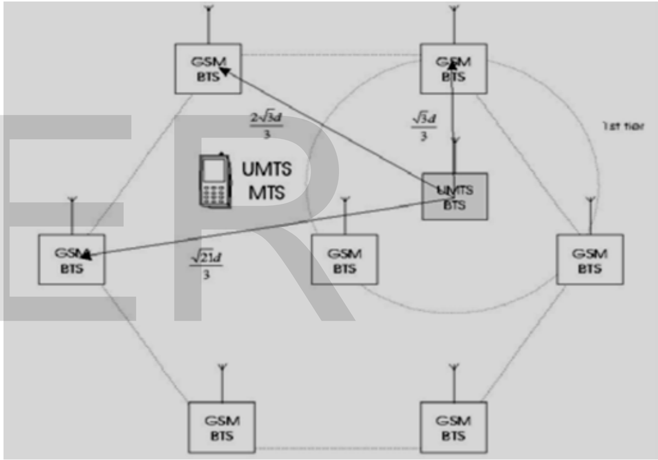

Figure 5: Multiple GSM900 Base Stations causes IM interference to UMTS800 Base Stations or Mobile Stations (uncoordinated Operations)

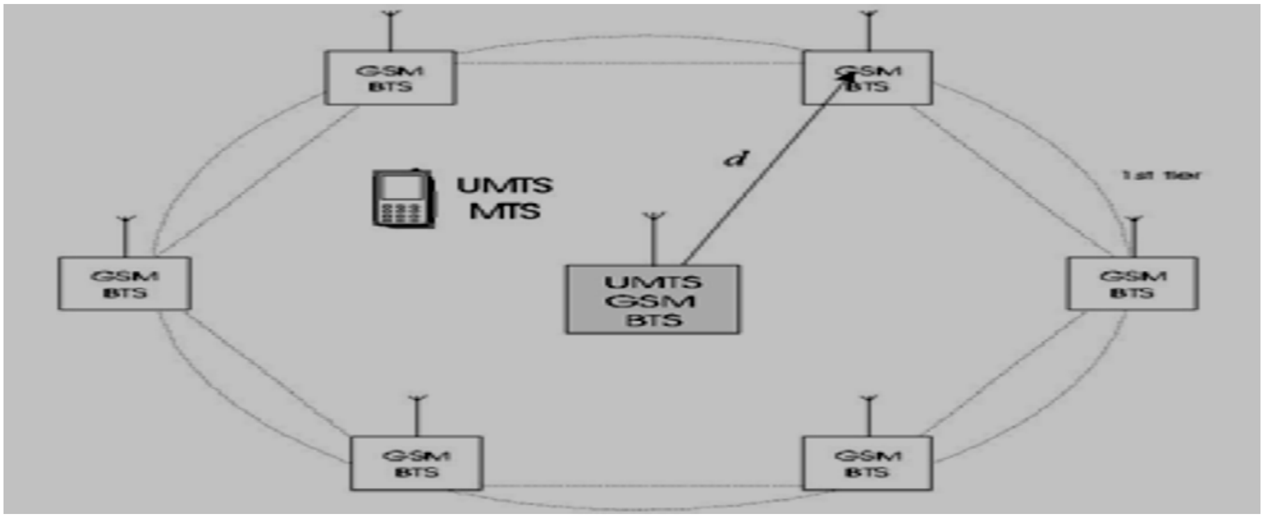

Figure 6: Multiple GSM900 Base Stations causes IM interference to UMTS800 Base Stations or Mobile Stations (coordinated Operations

The following takes the CDMA and GSM BTS as example to calculate allowable external interference level. As specified in CDMA2000 1x and GSM 900 protocol, receiver sensitivity must be higher than -104dBm. The minimum demodulation SIR of the receiver is -13dB for CDMA2000 1x and 9dB for GSM900.

Table 1: Comparison of typical parameters in various systems [7]

Systems	bandwidth B_w in MHz	Noise Coefficient of the BTS N_f (dB)	Equivalent Noise level of the BTS N_o (dBm)	Minimum Demodulation SIR (dB)	Theoretical Receiver sensitivity (dBm)
GSM900	0.2	4	-117	9	-108
IS 95	1.25	4	-109	-14	-123
CDMA2000	1.25	4	-109	-16	-125
CDMA2000 1x	1.28	4	-109	-13	-122
WCDMA	5	4	-10 3	-19	-122

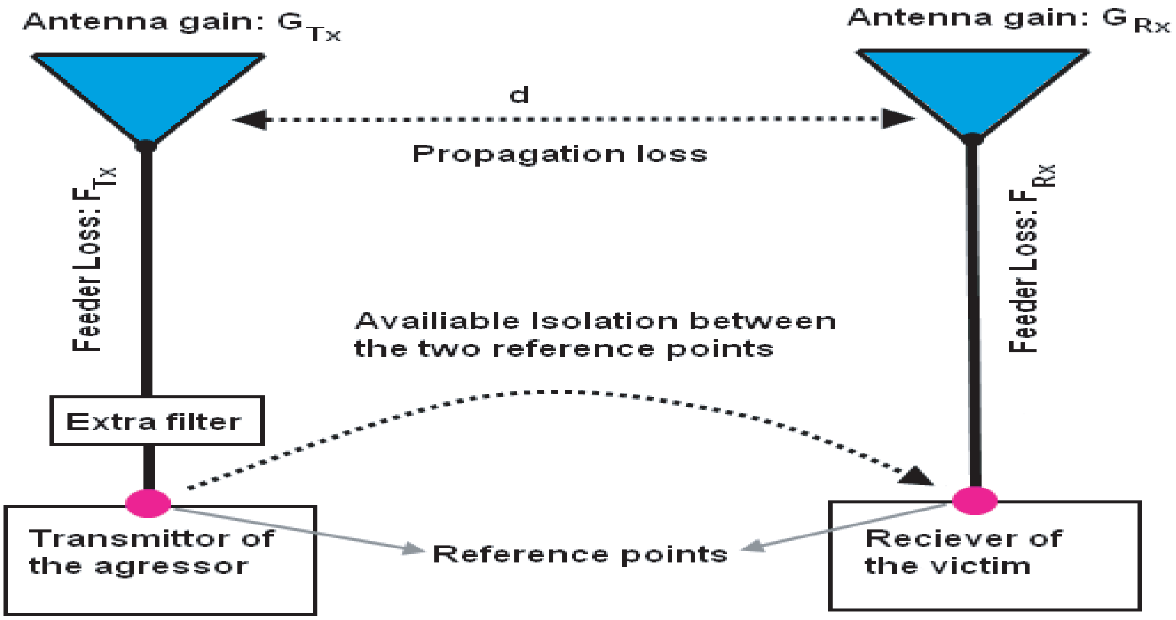

Figure 7: Design for Antenna Isolation Measurements

For distance d, more than 10m, the Propagation Loss between two antennas is small, so the channel may be described by a Free Space propagation model with higher isolation values. The Radio Propagation Simulator (TEMS) which serves as the Mobile Unit, in this instance, records the base station and each test point coordinates (latitudes and longitudes), together with the Received Signal Strength (RSS).

The Base Station Antennas are sectored, and each Base Trans-Receive Station (BTS) or sector has a Pseudo-random Noise (PN) code and carrier ID that distinguishes it from the others. With the marker highlighted, one is able to identify and differentiate the Base Station, or Sector, one is receiving from, at each point in time at any designated test point so as to ensure that the reference Base Station was correct.

4 RESULTS AND ANALYSIS

The reference or target Base Station was assigned zero meter distance, and measurements were taken at intervals of 50meters, with initial one at 100m meters, moving away from the Base Station, up to a distance of 1250meters as shown in table 2. Figure 8 shows a plot of the average RSS against the distance. TEMS was placed on a platform in a vehicle, measured 1.5meters above the ground whereas, Isolation determination for spatial separations was conducted in the Laboratory by generating GSM centre frequency, using the network analyzer; which is sent to the input of antenna 1 at GSM frequency band, while varying the spatial separations between the two antenna ports. The output of the signal at antenna 2 at CDMA frequency band is measured and recorded by the network analyzer. A token antenna, type AM-X-WM-17-65-00T-RB was used for the test and both were mounted on different poles at the same height. With calibrated connection cables, and taking into account the cable losses, the difference of signal power level at the output of antenna 2 and that at the antenna 1 input (56dB) is noted as the antenna isolation. The tilt of one of the antennas (receive), is gradually shifted from the position of maximum gain (0^o) and the tilt, at which the highest value is attained is noted. This tilt was observed to be 4^o and the highest value attained for the horizontal antenna separation distance is the optimized value at 75dB.

Table 2: Average RSS (Data Collected) – Co-site

Distance (m)	GSM Rx	CDMA Rx
100	-50	-48
150	-48	-46
200	-51	-49
250	-55	-53
300	-53	-51
350	-56	-54
400	-55	-53
450	-60	-58
500	-63	-63
550	-65	-64
600	-69	-67
650	-71	-69
700	-72	-71
750	-75	-74
800	-78	-78
850	-80	-80
900	-84	-82
950	-87	-83
1000	-89	-85
1050	-90	-87
1100	-94	-89
1150	-91	-90
1200	-92	-91
1250	-93	-93

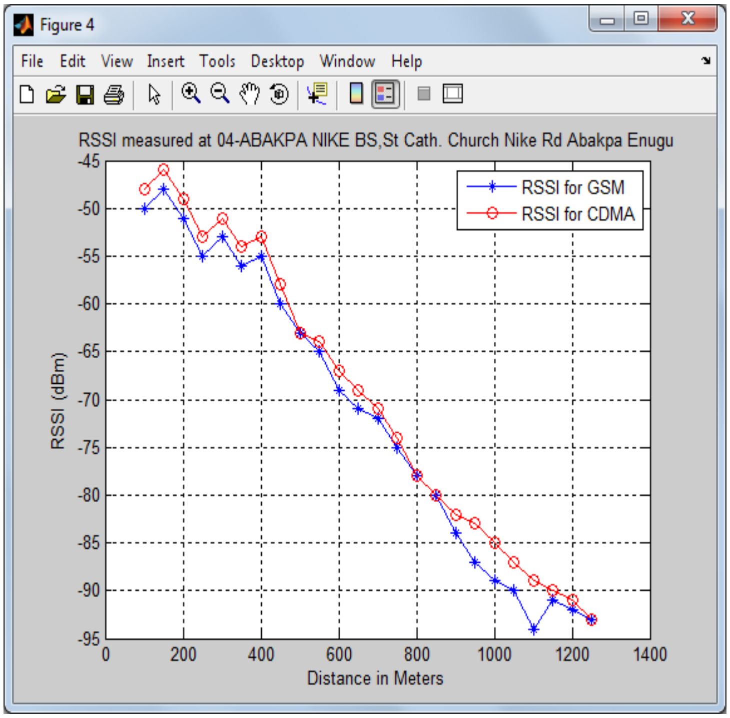

Figure 8: Average RSS (Data Collected from Table 1) – Co-site

In this work, SINR was generated to evaluate the Link performance of co-site operation in comparison to Single Network operation in a site using Equation below

$$\mathrm{SINR} = \frac{S}{1+N_0}, \qquad (14)$$

Where S is the resulting RSS (P_r) values gathered from field measurements (Table 1) and N_o is a constant (-109dBm)[12]. Figure 9 shows the link performance of co-site in comparison with that of a single site.

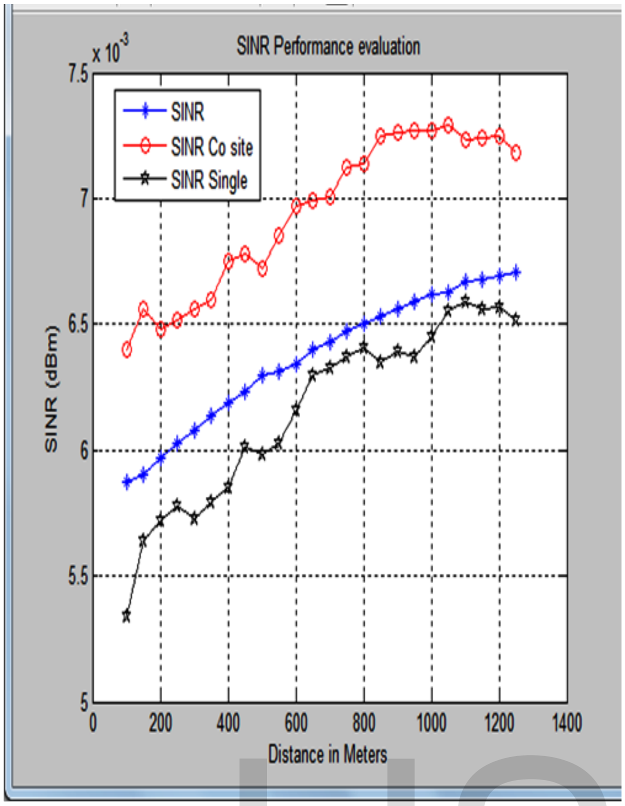

Figure 9: Simulation of SINR performance evaluation

Table 3: Result of Laboratory demonstration of Measured Isolation Values

Antenna configuration	Measured Isolation
Horizontal separation 3 m/8 m	56 dB/61 dB
Horizontal separation 3 m with 0°/+15°boresight angle rotation	56 dB/60 dB
Horizontal separation 3 m with 0°/4°electrical down-tilt	56 dB/75 dB
Vertical separation 0 m	70 dB
Vertical separation 1 m with different antenna pole (horizontal separation 1m)	75 dB
Vertical separation 0.5 m with 0°/4°electrical down-tilt	75 dB/83 dB

Careful analysis of Table 3 shows mitigation or reduction of interferences and IM effects as the separation distances (both horizontal and vertical) increases. Same goes for the electrical down tilt, as the azimuth (angle) of one of the Antennas changes from 0º to 4º. SIR for the interfered with System (UMTS800) is evaluated using Equation (15)

$$\mathrm{SIR} = \frac{G_p * S_i}{N_o + I_{GSM} + I_{IM}} \qquad (15)$$

$G_p = \frac{W}{R}$ = Processing gain = 3174.5

S_i = Power of one UMTS800 channel = 1mW ≅ -0.09dBm.

N_o = -109dBm

I_{GSM} = 10dB [4]

I_{IM} = 60dB [4]

Converting dB values to dBm and evaluating Equation (15) yields:

$$\mathrm{SIR} = \frac{3174.5*(-0.09)}{-109+40+90} = \frac{-285.71}{21} = -13.60$$

Literature value for SIR (UMTS800) is -12 to – 16

From literature, Capacity in a CDMA system is extracted, as

$$\text{Cell capacity } k = 1 + \frac{G_p}{v*p*(1+I_{UL})} \qquad (16)$$

if we solve for k (Eq. 16)

$$k = 1 + \frac{G_p}{v*p*(1+I_{UL})} = 1+\frac{3174.5}{0.5*4.9*1.55} = 837$$

Hence, 837 Mobile Users can be supported in the Network, if System is not interfered with by GSM900 System. When UMTS800 System is interfered with, Capacity degradation can be evaluated by noting the minimum allowed received power at the UMTS800 BS before and after being interfered with, by Signal GSM900 Base Station.

$$P_{\min} \text{ before} = \frac{N_o * \mathrm{SIR}}{G_{p\_}\alpha * \mathrm{SIR} * (k-1) * (1+I_{UL})} \qquad (17)$$

$$= \frac{(-109)(-13.6)}{3174.5-0.5\,(-13.6)(836)(1.55)}$$

$$= \frac{1482.4}{11985.94} = 0.1237 \text{ W}$$

Calculating the minimum allowed received power at UMTS800 BS after the presence of the GSM900 signal by judging I_{GSM900}, is as shown in Equation (18).

$$P_{min}\text{ after} = \frac{(N_o+I_{GSM900})*SIR}{G_p-\alpha*SIR*(k-1)*(1+I_{UL})} \quad (18)$$

$$= \frac{(-109)(-13.6)}{3174.5-0.5\,(-13.6)(836)(1.55)}$$

$$= \frac{938.4}{11985.94} = 0.0783\text{ W}$$

UMTS800 Capacity when interfered with, by GSM900 MS could be adduced, using Equation below.

$$K_{int} = 1 + \left[\frac{G_P P_{min}\text{before}}{v*\rho*I_{UL}}\right] \quad (19)$$

$$= 1 + \left[\frac{3174.4*0.1237}{0.5*4.9*1.55}\right] = 1 + \frac{392.68}{3.7975} =$$

$$1 + 103 = 104$$

Percentage of capacity loss can be calculated as

$$\%\text{ capacity loss} = \left[1 - \frac{k_{int}}{k}\right]*\,100\% \quad (20)$$

$$= \left[\,1 - \frac{104}{837}\,\right]*100\% = 87.6\%$$

% Capacity loss above indicates that the UMTS800 System is seriously impaired by the Intermodulation effects, arising from the Signal of GSM900 System.

This would result to serious Call dropping (over 80%), blocking and unavailability of service as only 104 Users can be supported bt the System that would have hither to, supported 837 Users.

Antenna isolation is therefore necessary in co-site Base Stations in order to avoid excessive interference, thereby reducing losses and improving on Link quality.

Before optimization, Antenna Isolation was 65.66 dB.

After optimization, Antenna Isolation was 71.26dB.

$$\%\text{ improvement} = \left[\frac{71.21-65.66}{65.66}\right] *\,100\% = 8.5\%$$

5 CONCLUSION

The rapid growth of Cellular Radio in the 800MHz band (3G) and its deployment in the RF environment of existing 2G Networks (GSM900) results in increased Interference level for co-site or shared-site Systems, since Signals generated is an interference source to all other Systems in the crowded RF environment. A typical design policy for GSM infrastructure is to maintain multiple transmission stations (BTS) in one transmitting Antenna in order to increase the Cell capacity. Generation of IM Products is a direct result of nonlinearities of the Adders in the transmitting Antenna that adds two or more frequencies.

This Report therefore, contains IM interference analysis and techniques to mitigate the effects of IM in shared-site Systems, using Antenna Isolation Method. The Link quality assessment showed better Quality Service when Systems are operating alone than in Co-Site arrangement due to increased level of Interference in relation to SINR parameter.

In terms of diversity techniques, Antenna Isolation technique was adopted as the most feasible and most cost effective solution to mitigate cross-modulation and intermodulation products, produced by strong un-attenuating GSM900 Signals that mix with the Local oscillator of the LNA of the UMTS800 BS Receivers.

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