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Measurement, Modeling and Analysis of Received Signal Strength at 800MHz and 1900MHz in Antenna Beam Tilt Cellular Mobile Environment

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ABSTRACT

In Code Division Multiple Access (CDMA) mobile environment, transmitter and receiver signals are heavily influenced by the effect of clutter surrounding both the transmitter and the receiver. Therefore the ability to optimize a CDMA system is dependent on the initial system configuration at the deployment stage. This includes the site location, antenna type, orientation, beam-tilt and the choice of propagation model which contributes greedily to a better optimization of the network. The proposed study provides an insight to two live CDMA2000 operators, on the sensitivity of received signals at the mobile terminal to adjustment of antenna beam-tilt angle to maintain good coverage. The operators transmit at 1900MHz and 800MHz frequency band respectively. The investigation was conducted in a series of field-tests. The result obtained from RSS coverage rate analysis, shows that the adjustment of beam-tilt angle to optimum value has great improvement on the coverage of the two CDMA operator networks.

Introduction

Code Division Multiple Access (*CDMA2000*) is a type of third-generation (*3G*) mobile system which provides wide-area wireless voice telephony and broadband wireless data communication to mobile phones. Services such as web browsing, audio streaming and video-streaming are significant examples of broadband data communications. However, these services might be limited due to attenuation and fluctuation of the received signal strength (RSS) at the mobile terminal, on which the installation of base station (*BS*) could have a big impact. RSS provides the information on how strong the signal is at the receiver front end. Low signal level can result in unwanted situations that could directly lower the network performance. Access failures can happen if signal level is below the required signal threshold in the target cell. Frequent call dropping has been link to low or bag signal quality. Carey, (2006) opined that RSS between BS and MS must be greater than the threshold value to maintain signal quality at the receiver. Simultaneously signal strength must not be too strong to create more co-channel interference with channels in another cell using the same frequency band). In cell planning, path loss prediction is used in order to minimize dead spots avoiding poor quality-of-service (*QoS*).

Hence, a good understanding and realistic prediction of the signal strength and propagation coverage area are vital aspects in the design mobile radio systems.

In this paper, the main aim is to examine the sensitivity of RSS to variation in antenna beam tilting situations in cell specific mobile environments in CDMA2000 network by using a Field-test Measurement.

Methodology

Measurement Configuration

A schematic diagram of the Field measurement set-up is shown in Figure 1. The testing tool used in the measurement was NOKIA 1265 CDMA test phone handset in the Net Monitor mode, in conjunction with a digital Global positioning System (MAP76CSX GPS) receiver antenna to determine distance (d) from the Base Station (BS). The software comprises a scale, which is calibrated in (dBm) (Emagbetere and Edeko, 2009; Rappoport, 2003).

In all the study locations, BS transmitting antenna were dual band with inbuilt features, which enables them to radiate at 1900MHz and 800MHz for operator A and Operator B respectively. Also their respective antenna heights are 45m and 40m above the sea level. The antennas were sectored 120^0. An approximate height of 1.5m was used as mobile receiver height.

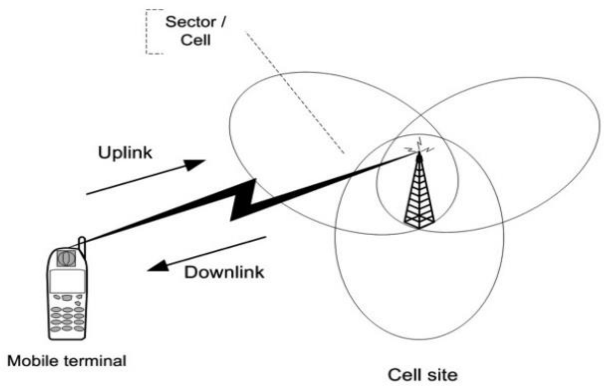

Figure 1: A set-up Field-test measurement

Measurement Environment

Past study reveals that determining the propagation of a city requires taking measurement at various high and low environment or taking exhaustive measurement round the city to cover all the possible terrain conditions (Emagbetere and Edeko,2009;Rautiainen,2001). In this study, the focus is on the first approach. A total of six base station sites; three for each of

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the two network operators were investigated and the choice of the number of sites in each environment was based on the availability of the network provider

Benin City was chosen to represent a typical urban region which consists of blocks densely built-up buildings of different heights and streets widths with small bushes and few trees. It lies within latitude 6.31760N and longitude 5.61450E (http:/en.wikipedia.org/wiki/Benin-City). It is situated 200 miles by road, east of Lagos with a population of about 1,147,188. Figure 2 shows the overall view of the measurement locations of Base Station sites in Benin City.

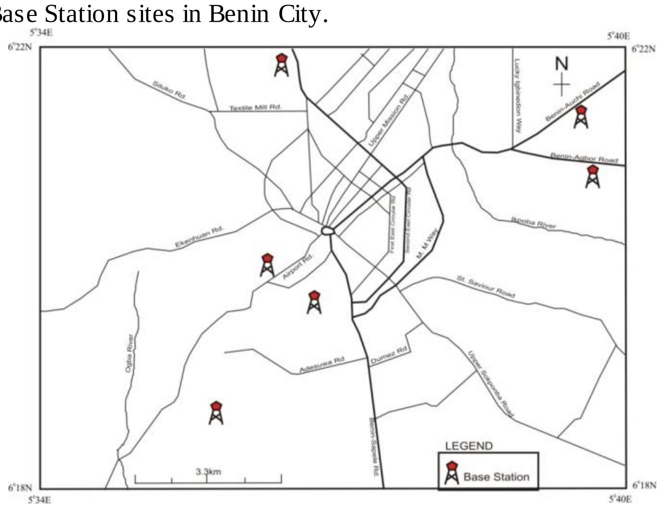

Figure 2: Map of BS site measurement locations

Measurement Procedure

With the aid of testing tool (i.e. NOKIA mobile handset) running on the software mode, calls were initiated at each test point until it is established and the signal strength information sent over the air interface between the base and the mobile station were read. For every site, received signal strength was measured at a reference distance of 100m from the base station and at subsequent interval of 100m up to 2000m. All measurements were taken in the mobile active mode and in three sectors of each base station. This was to ensure that the mobile phone was in constant touch with the base station. Also, measurements were taken on a uniform grid of outdoor static positions. This methodology is slightly different from the usual convectional drive-test procedure which may not cover certain inaccessible areas. At the same time, it presents some advantages because continuous measurement at the same point is captured, and this reduces systematic errors by properly windowing and averaging data.

Given in table 1 are the definition of the basic parameters/ specification of the CDMA networks of the two operators in the chosen area of study.

Parameter	Specification for Operator A	Specification for Operator B
Carrier Frequency in the Downlink	1900MHz	800MHz
Bandwidth	1.25MHz	1.25MHz
Modulation/Data Spreading	QPSK	QPSK
Antenna Height	45m	40m
Antenna Type	Directional (3-Sectored Antenna)	Directional (3-Sectored Antenna)
Antenna Gain	17dBi	17dBi
Transmit Power	43dBm	41.8dBm

Table 1: BS parameters

An approximate expression that describes the effect of BS transmitted power, P_T, gain of transmitting, G_T, gain of receiver, G_R, feeder losses of the transmitter and the receiver, L_T and L_R, BS antenna beam tilt angle, θ_{tilt}, BS height, h_{BS} and mobile station antenna height, h_{MS} on measured received signal strength, $RSS_{(measured)}$ in the downlink transmission of a CDMA cellular network is by equation (1) (Cerri et al, 2004):

$$RSS_{(measured)} = P_T + G_T + G_R - L_T - L_R - PL - X(\theta_{tilt}, d) \quad (1)$$

where X is the elevation angle difference between the antenna main lobe and line-of-sight (*LOS*) between the BS and MS (see Fig. 3) and is defined as:

$$X(\theta_{tilt}, d) = tan^{-1}(h_{BS}-h_{MS}/d) - \theta_{tilt} \quad (2)$$

where $tan^{-1}(h_{BS}-h_{MS}/d)$ represents the elevation angle looking from the MS. Parameter X was introduced to the RSS model because BS antenna gain depends on the parameter X and hence, it is expected that the effect of antenna gain in a path loss model can be expressed more precisely by adding the parameter X(Nagano,2008).

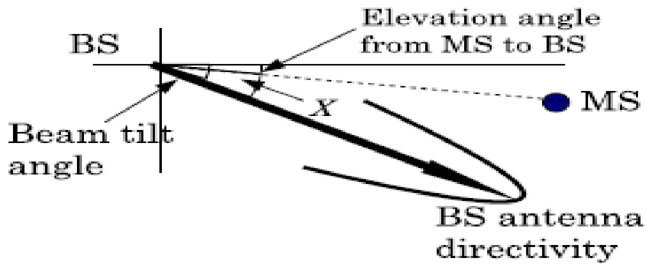

Figure 3: Definition of X as the elevation angle difference between the antenna main lobe and the Line of Sight (LOS) between the BS and MS

There is always an optimum value for the tilting, which depends on the cell size, the height of the BS antenna and the antenna radiation pattern. The optimum adjustment of the antenna downtilt would be to achieve maximum antenna gain for the mobile stations in the own cell and at the same time having maximum loss in the far end interference area, that means in the neighboring cells. The empirical formula in equation (3) was used to compute the optimum beam tilt angle, θ_{opt} and is given by (Niemelä, et al., 2005):

$$\theta_{opt} = 2.52(ln h_{BS} - d^{0.8}) \quad (3)$$

With an optimum beam tilt angle, network coverage is guaranteed, and simultaneously, other-cell interference is mitigated as efficiently as possible. More detailed description of the definition method of ODA can be found from (Isotalo et al, 2004)

Results and Discussions

Linear Regression

Regression is a method to describe the relationship between the dependent variable (RSS in this study) and the independent variables (BS-MS distance, antenna beam tilt, etc. in this study).

In the specific case of propagation analysis, it helps to explain the RSS dependence as a function of the logarithmic distance between the transmitter and receiver. Here, simple regression was fitted to the set of measured signal data, using least square curve fitting procedure. The mean RSS dBm at MS as a function of distance d from BS is modeled as:

$$RSS_{(measured)} = P_T + G_T + G_R - L_T - L_R - PL - X(\theta_{tilt}, d) = \alpha - 10\gamma \log_{10}(d) \quad (4)$$

where α is the intercept determined by the transmitter power, operating frequency and antenna characteristics and γ , the path loss exponent which defines the rate of RSS attenuation in each cell. The mean value of received signal levels for each location was calculated by averaging the total number of samples within that particular measurement cell. The graphs of figure 4 and 5 are plotted to determine the mean rate decay of the received signal (i.e. the path loss exponent) with respect to MS and BS separation at various locations of study for the two operators. In the analysis simple regression were fitted to the set of data, using least square curve fitting procedure and this allowed us to determine the values γ and the α for each cell sites. It is clearly evident from plotted graphs that as the signal strength decrease as the separation between BS and MS increases. It can also be observed from the graphs that the MSs closer to the BS experiences more rapid attenuation than those far away from the BS. The signal attenuation experienced in the various cells may be attributed to reflection, refraction and diffraction from the surrounding objects that influence transmitted signals. These objects can be either static (man-made or natural obstacles such as tall building) or time varying (moving vehicles, wind-blown trees or atmosphere variations) considered to be a part of the propagation channel. This mainly due to the fact that the MS close to the BS is more frequently under non line of sight (NLOS) conditions than the MS farther away from the BS.

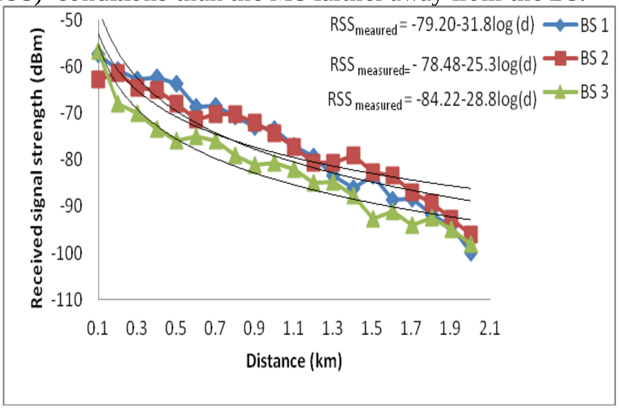

Fig.4: Measured received signal strength against distance for, operator A.

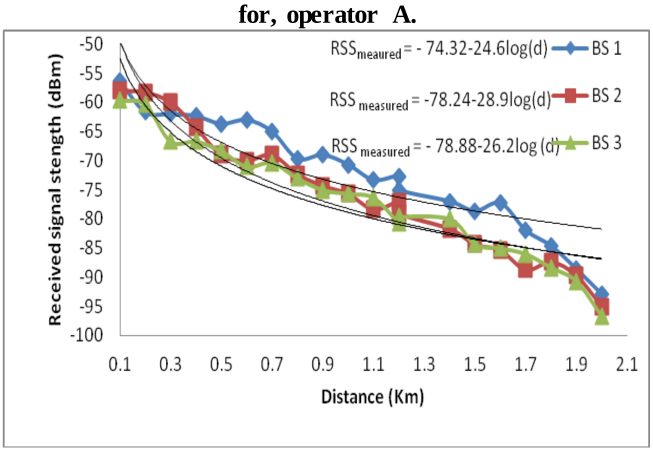

Fig.5: Measured received signal strength against distance for, operator B.

The following range in received signal strength classification Threshold as depicted in table 2 below is used to decide on the quality of the signal (Dotche, 2010)

Subjective score	Signal Threshold Level	Grade	Some Explanation	User Satisfaction
1	-105≤x≤-95	Poor	a higher interference area	Many dissatisfied
2	-95≤x≤-85	Fair	the interference area	Some dissatisfied
3	-85≤x≤-75	Good	a good signal coverage level	Satisfied
4	- 7 5 ≤x≤-65	Very good	very good signal coverage	Very satisfied
5	-65≤x≤max	Excellent	strongest signal coverage	remarkably satisfied

Table 2: Received Signal Strength (dBm) Classification Legend

Coverage Rate Analysis

One of the well known key performance indicator (KPI) that is used for assessing the quality of service (QoS) in wireless cellular networks is Coverage Rate.

Here, an analysis of RSS in terms of coverage rate is given to further assess the quality coverage of the two operators. The formula is given by (Ali, Shehzad and Akram,2010):

$$\text{Coverage Rate} = \frac{\text{No of samples having Signal strength (dBm)} \geq \text{signal strength threshold}}{\text{Total Samples}} * 100 \quad (5)$$

The bar chart in Figure 6 and 7 illustrates the cell servicing coverage rate of the received signal level of operator A and B

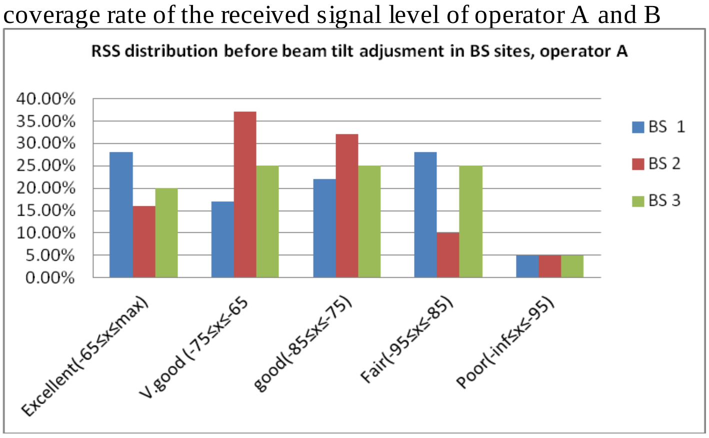

Figure 6: Cell Sites Coverage Analysis, Operator A

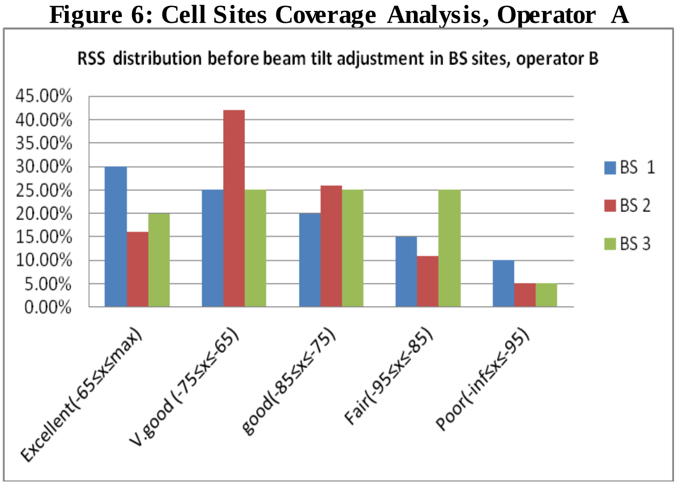

Figure 7: Cell Sites Coverage Analysis, Operator B

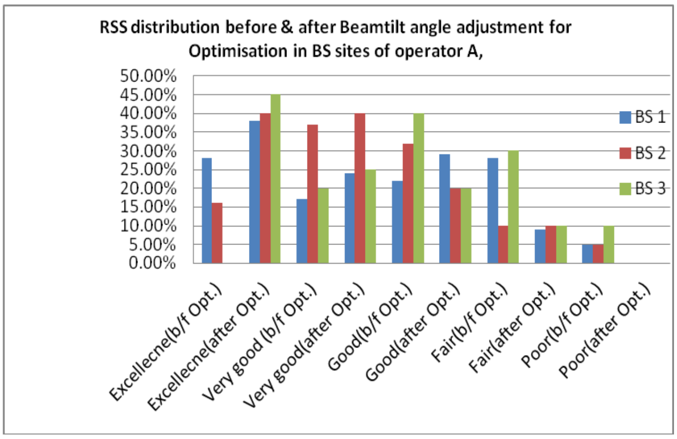

Figure 8: Statistics of RSS distribution in BS Cell Sites of Operator A

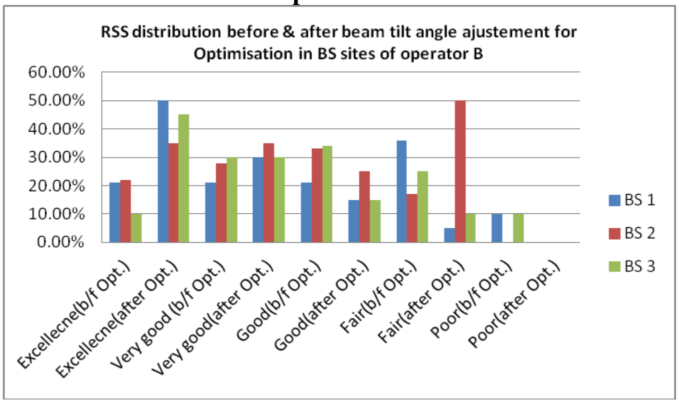

Figure 9: Statistics of RSS distribution in BS Cell Sites of Operator B

The chart in figure 6 and 7 above shows the distribution of RSS coverage rate and from the charts we can see that the RSS value above -85 dBm are 67%,65% 60% for operator A and 63%, 84%, 74% for operator B respectively. Similarly the low RSS value below -85dBm are 33%, 35%, 40% and 37%, 26%, 34% for the two operators. In terms of good RSS level, the above results shows the coverage standard of 95% for a cell-site to be said to be fully covered is not met by the operators. The reasons for low value of coverage rate may be attributed to distance from serving sector, poor beam tilt configuration and topographical terrain of the concerned areas.

To improve on the coverage, the beam tilt parameter was adjusted to optimum value using the expression in equation (1) to (3); and the results are depicted in figure 8 and 9. From the charts we can see that the RSS value above -85 dBm has improved from 67%, 65% 60% to 93.50%, 91.55%, 90% to 99.58% for operator A and from 63%, 84%, 74% to 92.0%, 97.7%, 83% operator B. Also the low RSS value below -85dBm has reduced from 33%, 35%, 40% to 6.5%, 8.45%, and 10% for operator A and from 37%, 26%, 34% to 8%, and 2.75% 27% for operator B.

Conclusion

The proposed study provides an insight to two CDMA operators on the sensitivity of received signal strength to variations in antenna beam-tilt with at the mobile terminal with optimisation of their network coverage in mind. Field test was carried out on 6 (six) sites (i.e. three sites for each operator) located at Benin, Edo State, South-South Nigeria to attain a desirable network coverage performance threshold. The result obtained from the field test, shows that the adjustment of beam-tilt angle to optimum value has greatly improved on the network coverage performances. The receive signal strength level which was above -85 dBm has improved from 67%, 65% 60% to 93.50%, 91.55%, 90% to 99.58% for operator A and from 63%, 84%, 74% to 92.0%, 97.7%, 83% for operator B. Also the low RSS value below -85dBm has reduced from 33%, 35%, 40% to 6.5%, 8.45%, 10% for operator A and from 37%, 26%, 34% to 8%, 2.75% 27% for operator B. The coverage optimization technique carried out in this study may be used by telecommunication operators to improve their service.

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