Effects of variation in Transmitter Power, Antenna Height and Antenna Tilt in a Wideband Code Division Multiple Access network.

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***Abstract*- Over the years, there has been an effort to improve the quality of services provided in the communication industry. Several measures like the use of adaptive modulation techniques, smart antennas and others have been employed. In this paper, variations in transmitter power, antenna height and antenna tilt will be extensively dealt with, with a view of understanding the effects such parameters will have in a Wide band Code Division Multiple Access (WCDMA) network. Here, WCDMA is evaluated on the basis of received signal level and the impact imposed on network coverage and capacity by varying the parameters mentioned above. It was found that by varying these parameters, optimum network performance in terms of received signal strength and better network coverage can be achieved.**

***Index Terms*— Antenna Height, Antenna Tilt, Transmitter Power, Wideband Code Division Multiple Access.**

I. INTRODUCTION.

With the rapid increasing demand by mobile phone users, wireless communication has become a very dynamic area of research due to the limited spectrum to accommodate many users. Communication without doubt is a major driver of any economy. Emerging trends in socio-economic growth shows a high premium being placed on information and communication technology (ICT) by homes, organizations and nations[1]. Multiple access schemes allow the network to maximize the number of users that occupy a channel [2]. For example, Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA). There are many wireless networks but this work is limited to wideband code division multiple access (W-CDMA) network. CDMA is a spread spectrum system and these systems have two categories: frequency hopping (FH), direct sequence (DS) etc. This work will base on DS-CDMA network. The two modulation techniques Quadrature Phase Shift Key (QPSK) and Quadrature Amplitude Modulation (QAM) techniques are chosen in this paper, because these are the primary techniques that will deliver higher data rate for High Speed Downlink Packet Access (HSDPA), an extension of 3G networks.

Wideband Code Division Multiple Access (WCDMA) is a spread spectrum technique that allows large number of users to share access to a single communication channel by encoding their data with a special pseudo noise (PN) code for each channel [3].WCDMA offer many advantages which include jam resistance, privacy and flexibility.

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II. PREVIEW OF RADIOWAVE PROPAGATION MODELS.

In this paper, the coverage of WCDMA network is evaluated on the basis of received signal level and the impact imposed on network coverage and capacity by varying the Base Station Antenna height, transmitter power and antenna tilt. The analysis of this work was done by comparing the information from the measured data with the analysis done using the European Cooperative for Scientific and Technical research (COST), Electronic and Communication Committee (ECC-33) and the Hata-Okumura models.

A. *HATA-OKUMURA MODEL.*

The Hata-Okumura model is an empirical formula for graphical path loss data provided by Yoshihisa Okumura. The Hata model is a set of equations based on measurements and extrapolations from curves derived by Okumura as shown in[4].

For urban area,

$$P_{L(URBAN)}\,(dB)=A+B\log(d) \quad (1)$$

Where;

$P_{L(URBAN)}$ (dB)=path loss for urban area in dB,

D=distance between Transmitter (Tx) and Receiver (Rx) in kilometer.

"A" represents a fixed loss that depends on frequency of the signal.

These parameters are given by the empirical formula:

ISSN: 2278 – 909X

$A=69.55+26.16\log(f)-13.82\log(h_b)-a(hm)$, where
$B=44.9-6.55\log(h_b)$
F=operating frequency measured in MHZ,
h_b=height of the base station antenna in metres,
hm=mobile antenna height in metres and
a(hm)=correction factor in dB.
For effective mobile antenna height, a(hm) is given by:

- For small and medium size cities,
  $a[hm]=[1.1\log(f)-0.7]hm-[1.56\log(f)-0.8]$
- For large cities,
  $a[hm]=8.29[\log 1.54hm]^2-11,\ f\leq 200MHZ$
  $a[hm]=3.2[\log 11.75]^2-4.97,\ f\geq 400MHZ.$

For Sub-urban area, the path loss is given as:
$P_{L\ (SUB-URBAN)}(dB)=P_{L(URBAN)}-2[\log f/28)^2-5.4]dB$ (2)
For Rural area, the path loss is given as:
$P_{L\ (RURAL)}(dB)=P_{L(URBAN)}-4.78\log(f)^2+18.33\log(f)-40.96dB.$ (3)
The range of value for validity of Hata model is
$150\leq f\leq 1500MHZ$
$30\leq h_b\leq 200m$
$1\leq hm\leq 10m$
$1\leq d\leq 20km.$

B. COST231 MODEL.

This model is derived from Hata model and depends upon 4 parameters for prediction of propagation loss:frequency, height of received antenna, height of base station and distance between base station and receiver.the formula is given below as shown in [4].
$P_L(dB)=46.33+33.9\log(f)-13.82\log(h_b)-a(hm)+[44.9-55\log(h_b)]\log(d)$ (4)
$A[hm]=[1.1\log(f)-0.7]hm-[1.56\log(f)-0.8].$

C. ECC-33 MODEL.

The ECC-33 Path loss model was developed by the Electronic Communication Committee(ECC). The Path loss is given below as shown in[4].

$$PL\ (dB)=A_{fs}+A_{bm}-Gt-Gr \quad (5)$$

Where;
A_{fs}=free space attenuation,
A_{bm}= Basic median path loss,
Gt=BS height gain factor,
Gr=received antenna height gain factor,
They are individually defined as:
$A_{fs}=92.4+20\log(d)+\log(f)$
$A_{bm}=20.41+9.83\log(d)+7.894\log(f)+9.56[\log(f)]^2$
$Gt=\log(h_b/200)[13.958+5.8\log d]^2$
$Gr=[42.57+13.7\log(f)][\log(hm)-0.585]$
Where,
F=operating frequency in GHZ.

III. METHOD OF DATA COLLECTION

Data collection for the WCDMA was achieved through study of network spectrum management such as: Total transmitted power, Received signal strength (RSS), antenna tilt, antenna height, total bandwidth, individual quality of service requirement, transmitted power control and adaptive modulation which is the goal of the study. Imo State was used for the real testing environment with the Mobile Telecommunication Network (MTN) Nigeria. An adopted or simplified approach for throughput and bit error rate problem is to assume continuous rate and power assignments, at the expense of an approximate solution [5]. This method is valid because throughput and bit error rate is continuously distributed over time and improves with continuous power assignments.

The benchmark of what a system is capable of doing or its maximum performance is what the user or designer is interested in. Bit error rate and throughput are the performance metrics and a key measure of the quality of wireless data link. Throughput is the average rate of successful message delivery over a communication channel and one will naturally like this quality to be as high as possible when browsing or downloading large files. This research will help to improve the quality of services in WCDMA network operators. Again theoretical analysis is a very important key to ensuring perfect implementation in any system.

This research will go a long way to ensure easy and perfect implementation of future generation systems (as WCDMA has been accepted as a key component of worldwide 3G systems).

The apparatus used in measurement include:

- GPS (Global positioning system) GERMIN
- Test mobile Sony K790 ERRICSON operated at 95% active mode
- Tilt Adjuster
- Binocular and Digital compass
- Classical node software
- Laptop
- Map info professional software
- Car

On start up, the software initializes the system by loading a configuration file which specifies the mode and frequency of operation. This allows operator independent operation.

The equipment used for the azimuths of the antenna was a digital and a set of binoculars. All binoculars were used in order to get a reasonable distance away from metal structure and still get an accurate azimuth.
The tilts were taken using an electronic tilt meter while the height of antenna was measured using tape. Each sector of the base station has Pseudonoise (PN) code and carrier identity (ID) that differentiates it from the other base stations, with the PN code we were able to know which base station sector we received from at each test point to be sure that the reference BTS was correct. Reading was taken at interval of 100m from the Base Transceiver Station (BTS) and stop at 1200m so that we cannot enter into another BTS. The centre
Frequency of the transmitter is 2116.4MHZ and the transmitter antenna gain of 16dB.

IV. RESULT PRESENTATION.

The following are measured data from a 2G & 3G Base Transceiver station BTS in Imo State, Nigeria, with Site ID IMO 323 operating at a frequency of 2116.4MHZ and Antenna height of 30m. Measurements were taken for QAM and QSPK modulation with antenna till of 4^0 .

ISSN: 2278 – 909X

TABLE 1: MEASUREMENT FROM BTS 1

Distance (m)	Tx power (dBm)	QAM mod. RxAv. (dBm)	QPSK mod. Rxav(dBm)
100	44.1	-52	-50
200	44.1	-50	-48
300	44.1	-53	-51
400	44.1	-57	-55
500	44.1	-55	-53
600	44.1	-58	-56
700	44.1	-57	-55
800	44.1	-62	-60
900	44.1	-72	-70
1000	44.1	-74	-72
1100	44.1	-79	-77
1200	44.1	-82	-80

The following data was gotten from another 2G and 3G BTS operating at a frequency of 2116.4MHZ with ID IMO 326 with antenna height of 30m. Measurements were taken for QAM and QPSK modulation with antenna tilt of 2^0.

TABLE II: MEASUREMENT FROM BTS 2.

Distance (m)	Tx power (dBm)	QAM mod. RxAv. (dBm)	QPSK mod. RxAv.(dBm)
100	44.1	-63	-60
200	44.1	-65	-62
300	44.1	-67	-65
400	44.1	-70	-68
500	44.1	-72	-70
600	44.1	-74	-68
700	44.1	-75	-72
800	44.1	-77	-73
900	44.1	-78	-74
1000	44.1	-80	-75
1100	44.1	-82	-75
1200	44.1	-83	-78

V. IMPACT OF BS ANTENNA HEIGHT ON COVERAGE

Tall antenna tower are costly and might be perceived as having a negative aesthetic impact. However, in extremely rural areas, such as desert environment and emerging markets, tall, low-cost towers can be used to efficiently reduce site costs and significantly improve coverage.
Increasing the height from 30m to 50m can give an improvement of cell range of as much as 40% in open rural areas [6].
The base station coverage area is primarily dependent on the antenna height. If the antenna height is increased path loss is lessened and on decreasing the antenna height path loss increases [7].
The relation of path loss with antenna height is given in table 3 as gotten from equations (1),(4) and(5) for the propagation models discussed above.

TABLE III: EFFECT OF VARYING BS ANTENNA HEIGHT ON PATH LOSS.

Also path loss is related to received power as

$$Rxd\ (dBm) = EiRPTx - L_{MASK} - Lp: \quad (6)$$

Where Rxd (dBm) is the received power in dBm.
EiRPTx is the maximum Effective Isotropic Radiated Power of the cell in dBm (that is, at the peak gain point of the antenna).
L_{MASK} is the antenna mask loss value for azimuth and elevation angles respectively in the direction of the path being calculated in dB. When the received signal is directly on the main beam of the antenna, this value will be zero. Lp is the path loss in dB.

$$EiRP = P_A Power + antenna\ G \quad (7)$$

Where,
Antenna G = antenna Gain + 2.14 (if the gain is in dB)
So, if path loss increases then received power will decrease. If path loss decreases then received power will increase so the signal from the BTS will cover more distance.

BS Antenna height (m)	*Hata L_p (dB)*	*COST231 L_p (dB)*	*ECC-33 L_p (dB)*
20	165.23	164.86	549.78
22	164.37	164.02	533.62
24	163.60	163.25	518.87
26	162.89	162.54	505.30
28	162.23	161.88	492.74
30	161.63	161.27	481.04
32	161.06	160.70	470.10
34	160.52	160.17	459.82
36	160.02	159.66	450.13
38	159.54	159.18	440.96

Having known the values for path losses for the various models (Hata, COST 231, and ECC-33) at BS antenna height, we can also determine their various values for the received power (Rxd) using equation (6). This was determined and shown in table 4 below.

TABLE IV: EFFECT ON RECEIVED SIGNAL STRENGTH BY VARYING BS ANTENNA HEIGHT.

ISSN: 2278 – 909X

BS Antenna height (m)	*Hata R_{xd} (dBm)*	*COST231 R_{xd} (dBm)*	*ECC-33 R_{xd} (dBm)*
20	-533.24	-532.89	-917.81
22	-516.24	-515.89	-885.49
24	-500.72	-500.37	-855.99
26	-486.44	-486.09	-828.85
28	-473.22	-472.87	-803.72
30	-460.91	-460.56	-780.33
32	-449.40	-449.05	-758.44
34	-438.59	-438.23	-737.89
36	-428.39	-428.04	-718.51
38	-418.75	-418.39	-700.17

VI. IMPACT OF TRANSMITTER POWER ON COVERAGE.

Controlling the transmit power of the mobile and base station reduces the system interference and thus can be used to reduce the cluster size if implemented properly [8]. The essence of this is to ensure that each mobile transmits the smallest power necessary to maintain a good quality link on the reverse channel [9].

It should be noted that the received signal strength for various path loss models like Hata-okumura, COST231 andECC-33 are calculated using the equation below:

$$Pr = Pt+Gt+Gr-P_L-A \quad (8)$$

Where:

Pr= Received power,

Pt= Transmitted power,

Gt= Transmitted antenna gain,

Gr= Received antenna gain,

P_L=Path loss,

A= Connector and cable loss.

The impact on received signal level (coverage area) by varying the transmitted power from 30dB to 46dB using a step size of 2dB for the various models were gotten and shown below.

As the BTS power increases, the received power also increases.

TABLE V: EFFECTS ON RECEIVED SIGNAL STRENGTH BY VARYING TRANSMITTED POWER..

Txd power (dBm)	Hata R_{xd} (dBm)	COST231 R_{xd} (dBm)	ECC-33 R_{xd} (dBm)
30	-135.50	-135.14	-150.05
32	-133.50	-133.14	-148.05
34	-131.50	-131.14	-146.05
36	-129.50	-129.14	-144.05
38	-127.50	-127.14	-142.05
40	-125.50	-125.14	-140.05
42	-123.50	-123.14	-138.05
44	-121.50	-121.14	-136.05
46	-119.50	-119.14	-134.05

VII. IMPACT OF ANTENNA TILT ON COVERAGE.

The efficiency of a cellular network depends on its correct configuration and adjustment of radiant systems; the transmitting and the receiving antennas. And one of the more important system optimizations task is based on correct adjusting tilts, or the inclination of the antenna in relation to an axis. With the tilt, we direct irradiation further down (or higher), concentrating the energy in the new desired direction. When the antenna is tilted down, it is called down tilt, which is the most common use. If the inclination is up (very rare and extreme cases), we call up tilt. The tilt is used when we want to reduce interference and/or coverage in some specific areas, having each cell to meet only its designed area [8].

When selecting the optimum tilt angle, the goal is to have as high signal strength as possible in the area where the cell should be serving traffic. Beyond the serving area of the cell, the signal strength should be as low as possible.

When the cell site uses a high-gain antenna, downward tilting can direct the nulls in the antenna pattern towards the horizon to prevent energy from propagating into other cells [10]. A too aggressive down tilting strategy will however lead to an overall loss of coverage. Down tilting the antenna limits the range by reducing the field strength in the horizon and increases the radiated power in the cell that is actually to be covered.

Down tilting can be done in two ways: Electrical down tilt and Mechanical down tilt. Total tilt effect is the sum of both electrical tilt and mechanical tilt. Electrical tilt is constant at 2° as it is manufacturer specific and mechanical tilt is varied from 0° to 5°. So the total tilt is varied from 0° to 7°. The table 6 summarized the impact on received signal level (coverage area) by varying the Antenna Tilt.

The tilt angle can be estimated through simple calculation of the vertical angle between the antenna and the area of interest this can be achieved using the basic formula of Pythagoras: we have that, tan θ=opposite/adjacent

Where,

Opposite=Height of the antenna,

Adjacent =Distance,

Angle=ArcTan(Height/Distance). (9)

The height and distance must be in the same measurement units.

Using measurements, we can obtain the value of the tilt angle, the antenna height. For $\theta=0^0$-5^0,values were obtained as follows for the received signal strength for the various models as shown below.

TABLE VI: .EFFECT ON RECEIVED SIGNAL STRENGTH BY VARYING THE BS ANTENNA TILT.

Tilt angle (degree)	0^o	1^o	2^o	3^o	4^o	5^o
Hata Okumura R_{xd} (dBm)	-248.11	-249.02	-225.13	-301.50	-250.01	-228.30
COST-231 R_{xd} (dBm)	-249.00	-249.16	-225.20	-302.03	-250.50	-229.00
ECC-33 R_{xd} (dBm)	-350.72	-340.25	-302.00	-441.15	-350.00	-290.20

VIII. ANALYZING THE IMPACT ON COVERAGE AND CAPACITY BY VARYING THE BS ANTENNA HEIGHT, TILT AND POWER USING STATISTICAL PLOTS BY MATLAB.

The target of radio network topology planning is to provide a configuration that offers the required coverage

ISSN: 2278 – 909X

for different services, and simultaneously maximizes the system capacity. This section addresses the impact of antenna height, tilt and power on network coverage and system capacity.

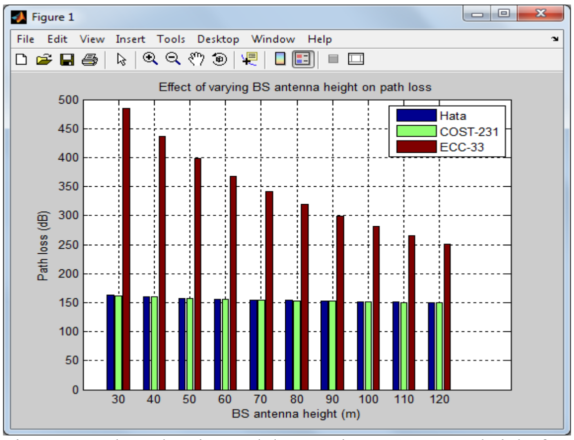

Fig. 1, Bar chart showing path loss against BS antenna height for the various empirical propagation models.

The plot above shows that as the antenna height increases, the path loss decreases for all the propagation models.

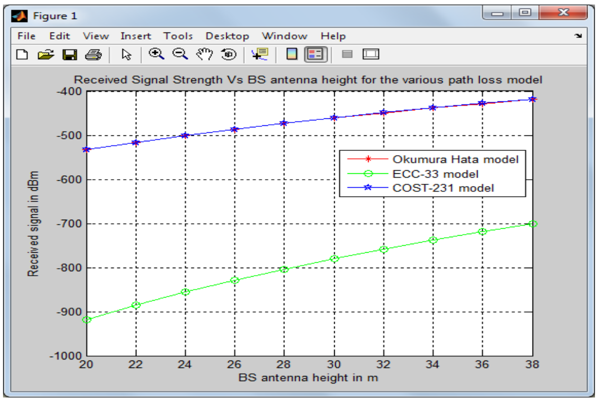

Fig .2, Plot showing received signal strength against BS antenna height for the various empirical propagation models.

Figure 2 above shows that as the BS antenna height is increased, the received signal strength also increases for all the models.

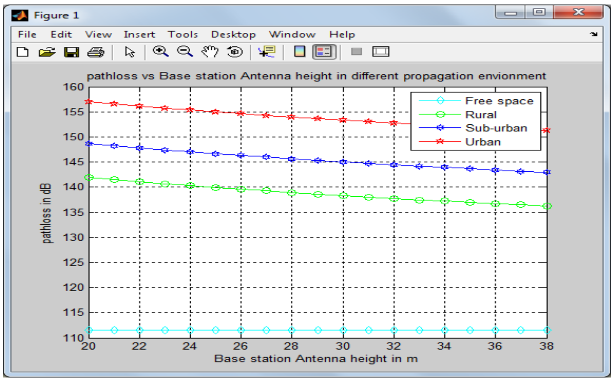

Fig. 3,Plot showing path loss against BS antenna height in different propagation environment.

Figure 3 above shows that no matter the propagation environment, the path loss will always decrease as the antenna height is increased, except for a free space.

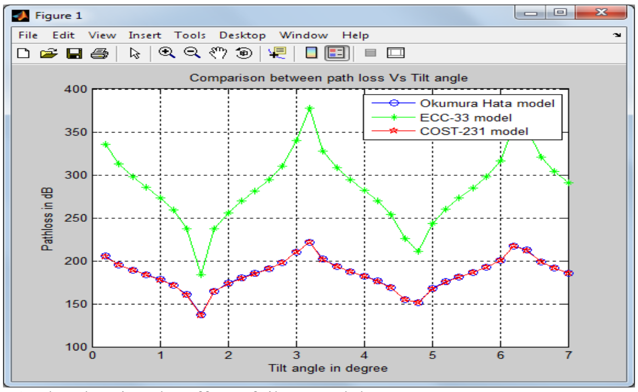

Fig. 4, Plot showing the effect of tilt on path loss

The figure above shows the variations in pathloss on an antenna when the tilt angle is varied from 0^0 to $7^0$and it was observed that a tilt angle of 2^0 will be best for propagation.

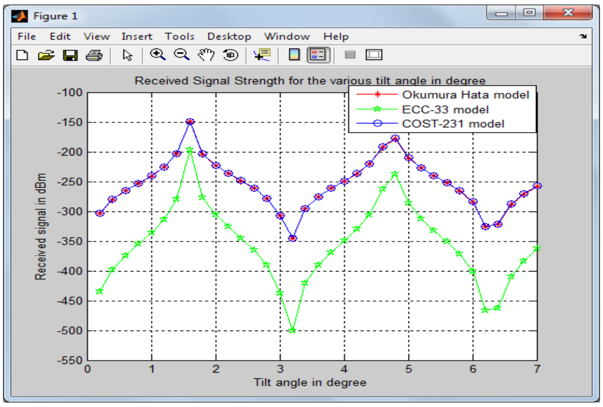

Fig. 5, Plot showing the effect of Received signals Strength on tilt angle

From the above figure, it was observed that the received signal strength is at its peak at a tilt angle close to 2^0, so angle 2^0 is best for efficient propagation.

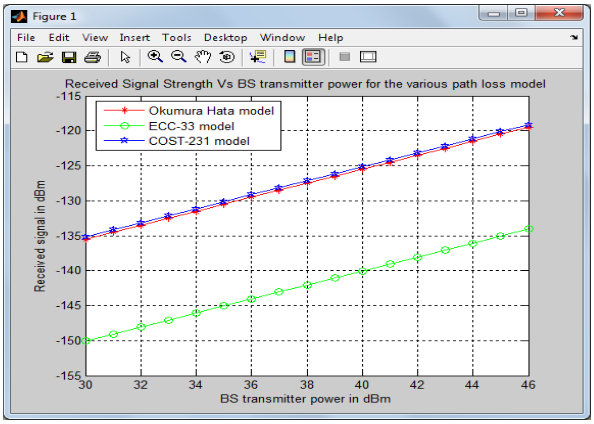

Fig. 6, Coverage Prediction Plot showing the impact of transmitted power on coverage area (received signal strength).

ISSN: 2278 – 909X

From the figure above, it can be observed that as the transmitted power is increased, the received signal strength also increases.

IX. CONCLUSION

The results obtained from the study shows that the coverage in any area is influenced by the antenna height, transmitter power and antenna tilt. These parameters must be put into consideration while designing WCDMA networks.

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X. RECOMMENDATION

The study showed that increasing the antenna will decrease the path loss and strongly recommend this as this will help boost the quality of service in a WCDMA system.

We also strongly recommend dynamic transmitter power as this will boost the signal strength.

When the cell site uses a high-gain antenna, downward tilting can direct the nulls in the antenna pattern towards the horizon to prevent energy from propagating into other cells. In the case of a low-gain antenna, discrimination between horizon and edge of a cell is less. This can be improved with increase in height. Using a high gain, high antenna elevation and downward tilting, the base station can reduce its power relative to what would be required from a low-elevation site.
Downward tilting with a tilt angle of 2^0, high antenna power and increased (high) antenna height is therefore recommended in WCDMA systems.

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ISSN: 2278 – 909X