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IMPACT OF MECHANICAL DOWN TILT AND HEIGHT ON THE PILOT COVERAGE OF UMTS NETWORKS

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ABSTRACT
The task of planning a network can be very challenging as it involves many careful studies with a lot of considerations and, at times, trial and error. In this paper, the impacts of antenna mechanical down tilt and antenna height on UMTS network performance are studied. First, we used ASSET3G simulation software to design 3G pilot coverage. Optimization techniques were deployed to study the performance of the network. Simulation results show about 2.6% increase in the coverage area when the antenna height was increased from 15 m to 25 m at the same tilt angle of 0° The coverage drops by 24% when transiting from 0° to 6° tilt angle was made for 15 m height antenna. The results also indicated that, pilot pollution could be reduced by choosing optimum down tilt angle.
Key words: Antenna height, Mechanical down tilt (MDT), Universal Mobile Telecommunications System (UTMS)

1. INTRODUCTION
Mobile communication system has been firmly established as a key and convenient means of communication that enables efficient and effective business operation, thereby making it central to business and daily life development. There are more than five (5) billion mobile cellular users across the world (ITU, 2010) and the demand for wireless technologies and services increases rapidly every year. Mobile communication system is one of the most important technologies contributing to social and economic development around the world. Studies have pointed to the significant contribution of mobile communications to GDP growth as a key to sustainability. In Nigeria, the penetration of mobile communication in the market has created job opportunities which contribute to its economic development (Josiah el al, 2007). At microeconomic level, the sector's contribution to GDP increased by 53% in 2003, making it the third highest contributor ahead of the financial sector which has been in operation for about 100 years. In respect of employment, over 135, 000 persons have been directly or indirectly employed by the operators (Josiah et al., 2007). A new report by the GSM Association (GSMA) disclosed that Nigeria stands to gain an additional N862 billion by 2015 from mobile broadband.

Rapid growth of mobile Internet and other mobile services has resulted in increasing demand for higher data transmission capacity. Based on WCDMA, Universal Mobile Telecommunications System (UMTS) is one of the 3G mobile communications plate forms designed to meet this demand as it aimed to provide data rate up to 2 Mbps. The UMTS standard uses the frequency range of 1920-2170 MHz. High bit rates for both circuit and packet switched services allow multiplexing different data services (i.e. voice, data and video) in the same call. Since UMTS uses the same core network as GSM and GPRS, it allows operators to use existing infrastructure during the rollout phase. UMTS supports all services of the worldwide predominant GSM and GPRS networks and is more powerful, more flexible, and more radio spectrum efficient than its predecessors (**Eisenblatter, 2005**). In

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developed countries. 3G and 3.5G such as WIMAX are already deployed and the evolution of 4G (long time evolution) in the nearest future. In Nigeria, the deployment of 3G networks is still at infant age despite some of the mobile operators claimed the deployment of the network in some areas in selected states (Kano, Lagos and Abuja) is already completed. However, the study is still relevant at this information age and, it would be extremely important to accurately investigate parameters that would have tremendous effects on the performance of the network in terms of coverage, capacity and subsequently the roll out cost.

Coverage planning is performed with ASSET3G network planning and analysis tool containing a complete range of functionality for the design and simulation of GSM, PCS, AMPS, TDMA, TACS, PMR/TETRA/iDEN, UMTS, DVB-H, W-CDMA, CDMA2000, EV-DO, TD-SCDMA and WiMAX networks. Many parameters affect the received signal level distribution, such as line-of-sight (LOS) or non-line of-sight (NLOS) propagation, path length difference, number of arriving waves, and received bandwidth. Antenna height and downtilt are two important optimization parameters in universal mobile telecommunications system (UMTS) networks. It is desirable to investigate the impacts of antenna tilt and antenna height on UMTS 3G network.
The antenna height and tilt play an important role in network coverage, as the height and tilt of the antenna must be carefully optimized to improve coverage and signal strength due to the nature of the terrain. Antenna tilting has been identified as an efficient means to reduce inter-cell interference in both uplink and downlink and consequently increase the capacity. Improper base station location and/or improper antenna tilting and height can greatly reduce system capacity (Nawrocki and Wieckowski, 2003). However, the antenna tilt of a base station is significant for the network planning. To obtain good network coverage, it is necessary to have a correct antenna tilt for both the horizontal and vertical planes. Mechanical down tilt (MDT) is achieved when the antenna is physically mounted in such a manner as to lower the angle of the signal on one side. However, this also raises the antenna on the other side, making it useful in only very limited situations.

Most of the previous studies treated these effects on 3G networks separately. In this paper, **the** impact of MDT and height on the coverage has been studied using three-and six-sector antenna. The main aim is to provide a tradeoff between the down tilt angle and height of the Node B. The two effects (i.e. tilt and height) are combined together. The paper presents the results of a simulation study and analysis of these parameters on UMTS network performance. The paper is organized as follows; Section 2 presents the related work; extensive analysis of the simulation results is presented in Section 3; the results of the simulation are presented in Section 4 and finally, Section 5 concludes the paper.

2. RELATED WORKS

Various literatures have been reported on analysis of 3G networks for mobile application, most focusing on the analysis of antenna (Bybi, 2007; Vasalos, 2008; Ben Ahmed and Bouhorma, 2009; Starke and Cook, 2009). Some of the previous work on UMTS network considered base station location as in Yang et al. (2007). Prasad et al (2003) conducted extensive investigations on antenna beam tilting effects in fixed and mobile communication links. The effect of antenna tilting, especially the transmitting one, on the performance of fixed and mobile communication systems was investigated. It was reported that, in the case of the mobile system, the cell radius decreases as the tilting angle increases. A cell radius of 1 km is seen for a tilting angle of 10°. Their investigations have revealed that tilting angle and height of antenna affect the path loss at different distances. Adaptive tilting system shows a more limited but still useful enhancement of system level capacity that can be comparatively cheap. However, the performance enhancement of adaptive tilting is determined by the air interface characteristics of a network. In WCDMA, adaptive tilting fits well

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with the technology as it gives interference reduction and can directly lead to capacity gains. Amaldi et al. (2008) used mathematical programming models for radio planning and coverage optimization of 3G cellular networks. The authors investigate the location of new base stations and how to select their configuration (antenna height and tilt, sector orientations, maximum emission power, pilot signal, etc.) so as to find a trade-off between maximizing coverage and minimizing costs.

3. SIMULATION PARAMETERS

ASSET3G was used to analyze the performance of a UMTS networks under different tilt angles and heights. A macro cellular network was planned with 15 Node B's (3G base stations). The locations of the Node B were kept constant throughout the simulation. For the entire 15 Node B, the azimuths were oriented to have direction of either: 0°, 60°, 120°, 180°, 240° or 360°. Three and six sectors antennas were used with fixed electrical down tilt (EDT) of 6°, and the morphological and topographic information of the simulation area which was defined by high resolution digital map. The digital map includes basic terrain type and building of different heights. The placement of the Node B s is characterized by the demographic information of the area which was categorized into, low, medium and densely population areas. For the pilot coverage prediction, ASSET3G uses generic path loss model which can be adjusted using various parameters. Macrocell model 3 was used in this work for all cells with a radio propagation slope of 44.9 dBm. The mobile antenna heights are set to 1.5 m. The propagation model also includes a function to model diffraction with prediction parameters (K parameters). Other simulation parameters are shown in Table 1. Realistic radiation patterns for the antennas were used. The vertical radiation pattern used in the simulation for three-and six- sector antenna are shown in Figure 1.

In Figure 1a, the antenna has 33° horizontal beam width. This means that the maximum gain is achieved at 0° and 3 dB below maximum at 16.5° directions. The pattern can be used for 60° sectorisation (six sectored cell) since the power radiated at the boundaries 30° and 330° are approximately 9dB below maximum power at 0°, this can still be accepted within a good coverage. The three sector antenna has 65° horizontal beam width as shown in Figure 1b. This means that the maximum gain is achieved at 0° and 3 dB below maximum at

Table 1: General Simulation Parameters

Parameters	Values
Maximum transmit power	43 dBm
Antenna EIRP	62.5 dBm
Pilot power	33 dBm
Common channel power	33 dBm
Noise figure	5 dB
Orthogonality factor	0.65
Noise rise Limit	3 dB
P-CCPCH TX power	30 dBm
SCCPCH TX	27 dBm
S-SCH power	27 dBm
P-SCH power	30 dBm
Activity factor	0.96
HSDPA link power	30 dBm
Soft hand over gain	3 dB
Noise figure	0 dB

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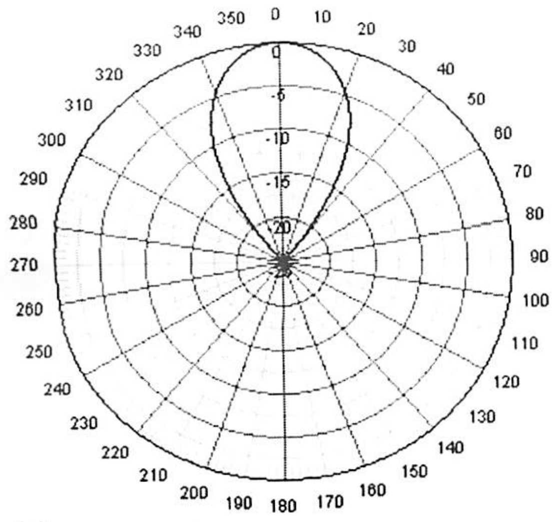

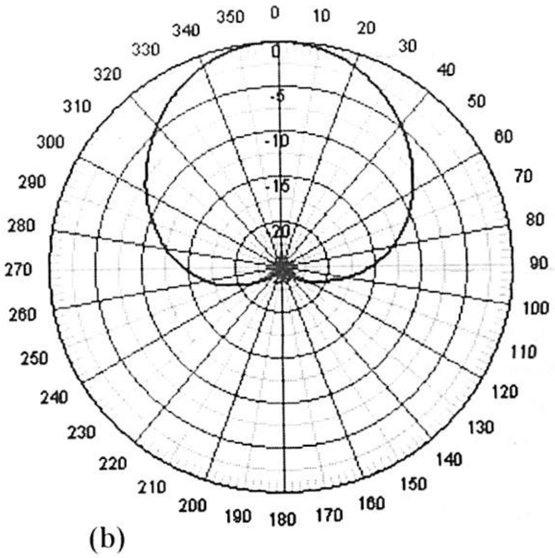

Figure 1: Antenna Radiation Pattern aor (a) Six- and (b) Three Sector Antennas

4. SIMULATION RESULTS

4.1 Effects on the Network Coverage

The effect of antenna height and tilt on the network coverage, using six-and three-sector antennas was studied and analyzed using antenna with 15 m, 20 m and 25 m heights. The bar chart of Figure 2 shows the effects of antenna height and antenna tilt on the network. Figure 2, the simulation indicates about 83.85% coverage when using MDT angle of 0° and at a height of 15 m for the three-sector antenna. This increases to 86.08% using the same tilt angle but at a height of 25 m, thus giving about 2.6% increase in the coverage area. When using MDT of 6°, the coverage percentage decreases to 64.00% and 69.23% for 15 m and 25 m height three-sector antenna respectively. In comparison, for 15 m antenna, the coverage percentage drops by 24% when transiting from 0° to 6° tilt. Conclusively, the coverage increases with increasing antenna height and varies as a function of the tilt. As the tilting angle increases, the coverage decreases.

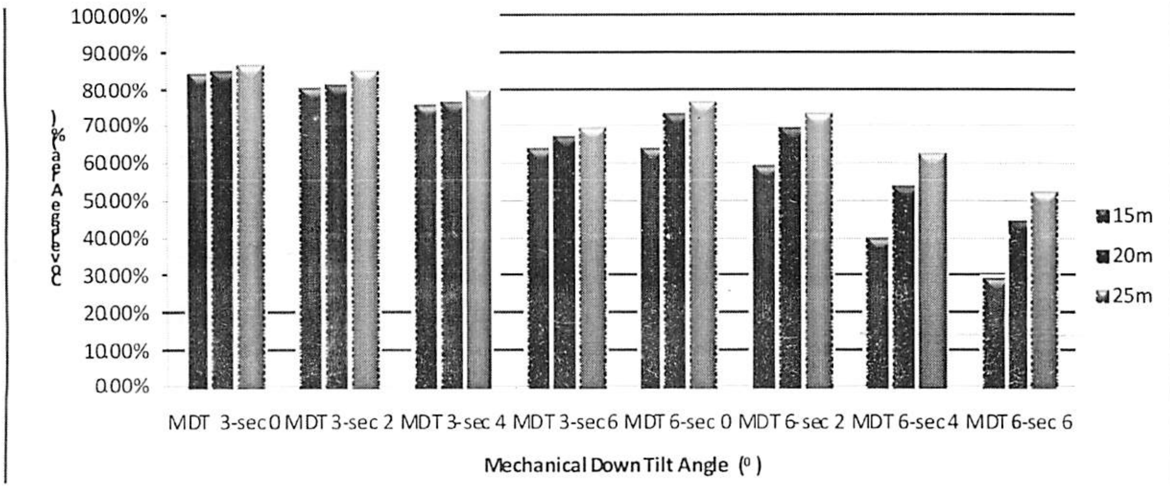

Figure 2: Effects of Antenna Height and Tilt on Network Coverage

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4.2 Impact on the Pilot Signal Level

Mobile stations (MS) in a network are able to identify different Node B sectors according to their primary common pilot channel (P-CPICH) or simply the *pilot signal*. This signal is broadcast by all the Node Bs with a fixed power to cover the entire cell. *Pilot signal* is used for channel selections and re-selections, handover decisions and, under some circumstances to aid in channel estimation. The effect of the antenna height and tilt on total received signal power *(Pilot signal)* as a function of distance was analyzed by simulation for three-sector antenna. The total received power for the antenna was obtained by measuring the receive signal in forward direction for Node8A which is one of the sector in the three sector Node8.

Figure 3 shows the effect of mechanical down tilt (MDT) on signal reception with distance for Node8A with 15 m high antenna. The signal strength decreases with increase in tilt angle and this varies with distance from the antenna. Near the BS (i.e. distance about 100 m), higher power is produced and the power level remains virtually the same despite increase in the tilt angle. Beyond about 150 m distance the effect of tilt becomes more significant and the power level drops significantly with increase in tilt angle and distance. For MDT of 2° and at a distance of 0.2 km, about -68 dBm power level is recorded; this is in contrast to -75 dBm when 8° tilt is applied at the same distance representing 7 dB loss or 9.3% decrease in power. This tilt angle could not be appropriately used in a site where the cells are small, with a range of 500 m or less, as the down tilt angle is more than the angle that corresponds to 3 dB loss at the horizon. As the distance increases, the power level decreases with increase in the tilt angle until after 1 km distance when the power level remains the same. This could be as result of terrain effects which may come into play.

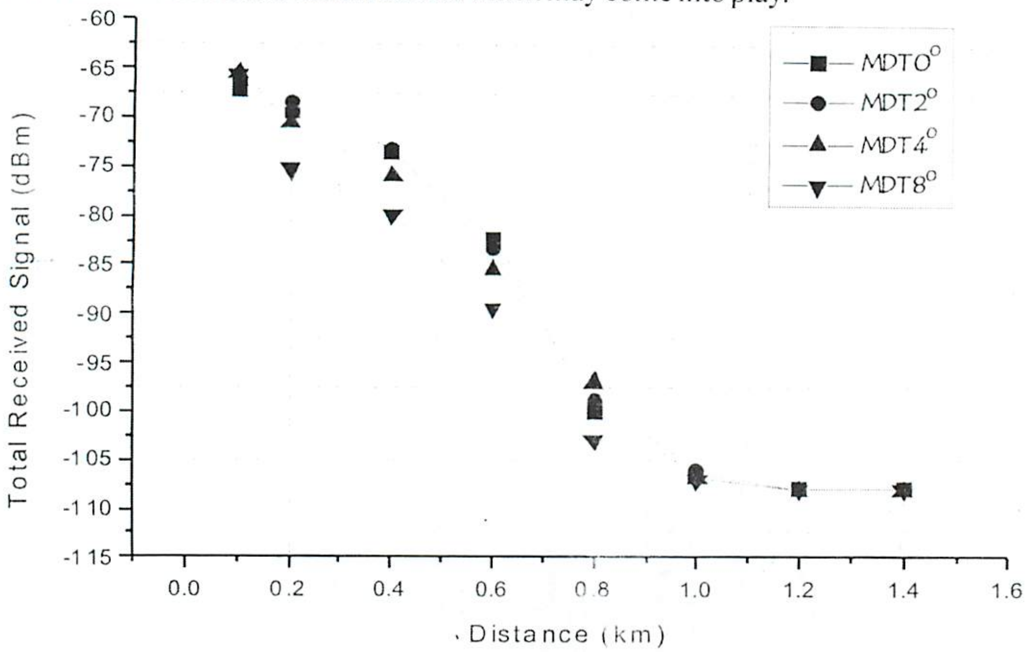

Figure 3: Plot of Total Received Power (dBm) with Distance (km) For Node 8A, 15 m Height Antenna Signal Measured in Forward Direction.

Further analysis of effect of increasing the antenna height for 8° tilt for Node8A was also investigated. The simulation result indicates that the received *pilot signal* of the antenna could be increased by increasing antenna height as shown in Figure 4.

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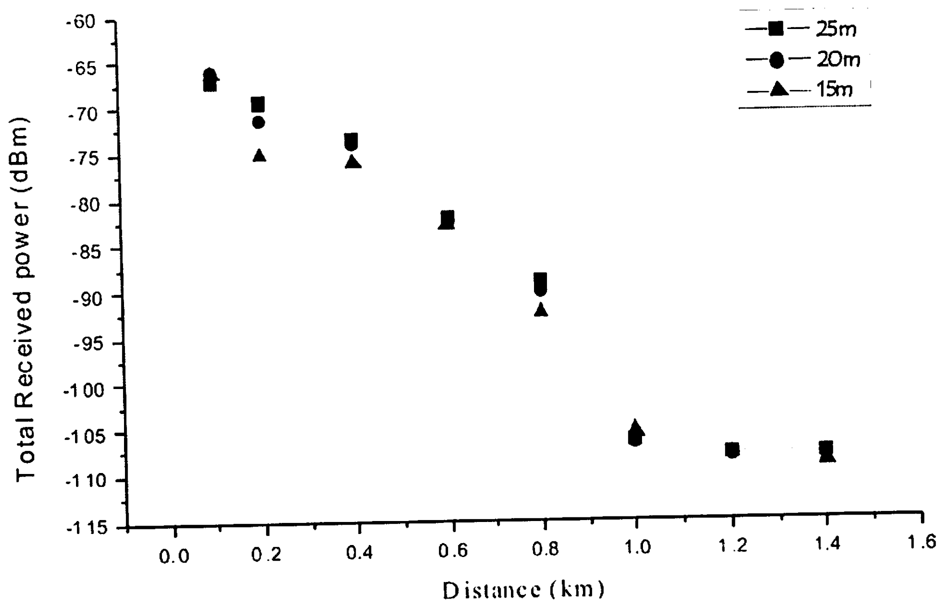


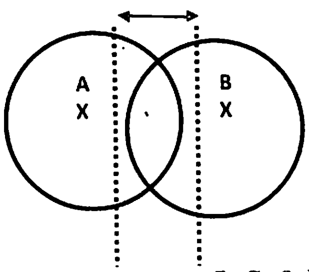
Figure 4: Total Received Pilot Signal Power (dBm) with Distance for Node 8A Antenna at different Heights

In Figure 4, effects similar to those of Figure 3 were observed when the variation in the *pilot signal* strength varies significantly within the range of 200 m to 1 km radius. Beyond 1km radius, no significant variation was observed in the results despite increasing the antenna heights. Also, the total received *pilot signals* measured are all above the sensitivity of -117.2 dBm (Nasir, 2011) needed for any service area. The results of the simulation are found to be consistent for every site investigated; therefore, one typical graph for received *pilot signal* is presented here.

4.3 Mitigation of Pilot Pollution through Node B MDT and its Impact on the Signal Quality

Interference and lack of coverage are two main factors that would cause call failures or call drop in a network. As stated earlier, the *pilot signal* is broadcast with fixed and high transmit power antenna across the cell for channel selections, re-selections and handover decisions. Soft handover (SHO) is one of the essential parts of WCDMA network functionality (*Tero et al, 2011)*. SHO enables seamless transfer of call from one cell to another. Typical scenario of two cells SHO is shown in Figure 5.

Soft hand over region



Pilot pollution is observed in an area when there are too many *pilot signals* received at the receiver of the MS. Other received *pilot signals,* apart from the serving cell, are considered to be interfering signals which could degrade the signal-to-interference ratio (E_c/I_o) or signal quality.

Figure 5: Soft Handover (SHO) Scenario for UMTS Networks

To enhance SHO in a network, the *pilot signal* from the sectors must overlap since; a radio link to a new Node B shouid be established before breaking the connection to the old one. This is in contrast to hard handover where the connection to the preceding cell is first cut, and then connection to the new cell is established; therefore, the need for overlap is not necessary. It has been discussed in Leino

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et al. (2002) that pilot pollution might have impact on SHO operation. In Figure 6a, simulation results indicate that Node 2 is receiving unwanted *pilot signal* from sector A of Node 1. Similarly, Nodes 3 and 4 receive from sector B of Node 1. These unwanted *pilot signals* would result to pilot pollution interference which would have great effect on the signal quality. For all these regions indicated by circles, the measured signal quality is less than the target/minimum signal quality to maintain a call; and as such, this would have negative impact on the SHO process of Figure 5.

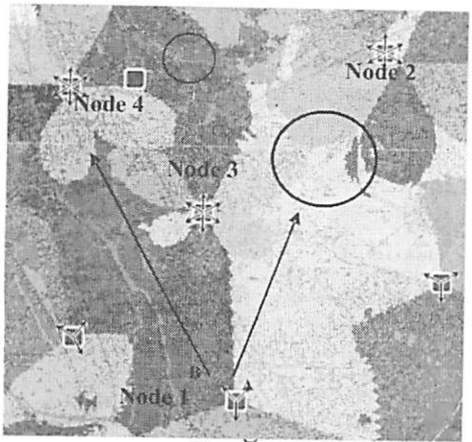

Figure 6a

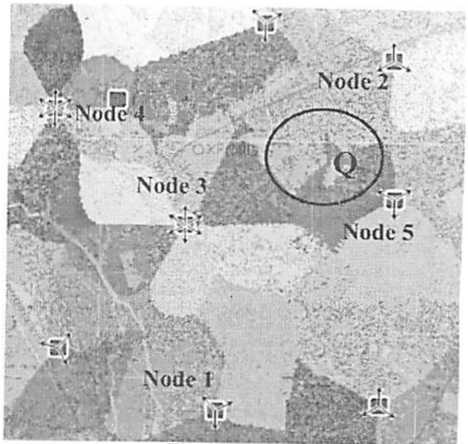

Figure 6b

Figure 6: Mitigation of Pilot Pollution through Node B MDT

Minimization of pilot polluted areas can, however improve the network performance. The optimum down tilt angle is achieved if the other cell interference is reduced without compromising the coverage area. MDT technique has been used to decrease the amount of inter-cell interference as shown in Figure 6b. The MDT decreases the coverage area but tends to reduce overlaps of the pilot signal from neighboring cells, thus reducing other cell interference in the main lobe direction. Observing the patterns with well defined boundaries, it can be seen that from position Q the signals from Node 2 and 5 are scattered and overlapped as the result of high hill which is about 314 ft above sea level. Analysis of the effects of MDT on the SIR is also studied and d the results are shown in Figure 7.

Figure 7 shows the variation of *Ec/Io (dB)* with MDT and distance. *Ec/Io* defines the quality and it gives the level of pilot pollution in the network. Ec/Io > -12 dB is defined as the threshold level for most network providers. Values less than the threshold levels are considered as poor signal quality. The simulation result shows that close to Near the BS at distances 0-0.6 km radius, high power is produced so, the wanted pilot signal from the serving sector dominates the unwanted (interfering) *pilot signal* from the neighboring sectors thus making the *Ec/Io* to be reasonably high. Average *Ec/Io* value of of – 3 dB was measured in these locations for all tilt angles. As the distance increases (i.e. beyond 0.8 km radius), the signal strength from the antenna start decreasing while the strength of the *pilot signal* from the neighboring cell increases, this causes, thus causing the *Ec/Io* to decrease. At around 1 km radius, the signal quality falls sharply, but the simulation results indicate that, by applying tilting to the antenna, the *Ec/Io* level increases by about 42.8% when transiting from 2° to 8° MDT. Beyond 1 km radius, the *Ec/Io* drops below the threshold level of -12 dB despite increase in tilt angle.

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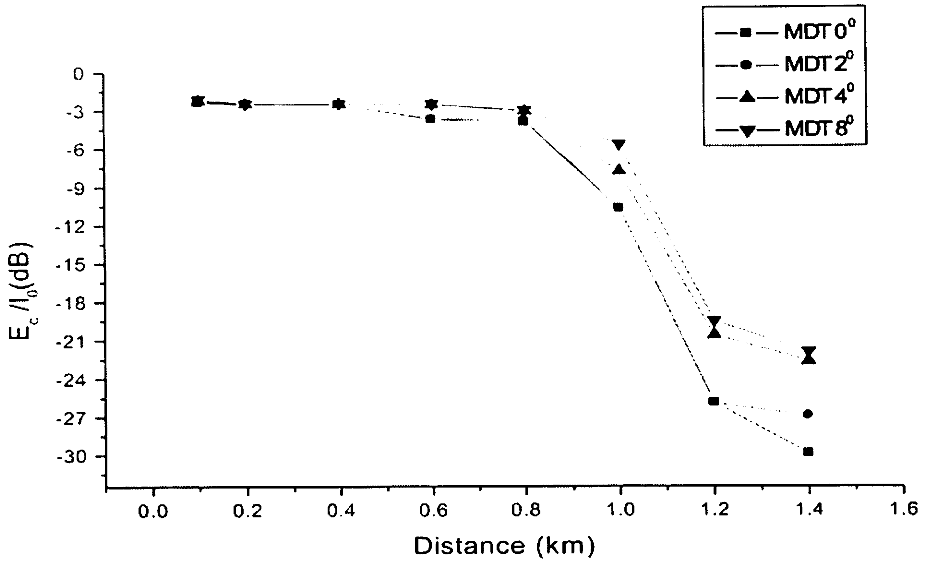

Figure 7: Signal-to-Interference (SIR) Ratio for Three Sector Antenna at different Tilt Angle for 15m

5. CONCLUSION AND RECOMMENDATIONS

In this paper, impacts of antenna height and tilt on the coverage of UMTS network signals are investigated. The work concluded that network coverage increases with increase in antenna height and decreases with increase in the tilt angle. It also shows that an overall down tilt can give positive effects on the signal-to-interference ratio. This is however only true if the cell size does not exceed the distance where the MDT will reduce the coverage. Conclusively, measurements show that the effect of tilting was pretty much as could be expected from theoretical predictions. As far distances the *pilot signal* strength becomes lower when the antenna is tilted, but not as much as expected from theoretical calculations as the pilot signal becomes the same due to terrain effects. In this regard, network planners should note the tradeoff between choosing appropriate antenna heights and the optimum tilt angles in order to provide better coverage and interference reduction in the network.

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