

Analysis of Radio Propagation Characteristics for an Operative GSM Network: A case Study of Makurdi Town.”

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ABSTRACT

The analysis of radio propagation by a GSM operative network seeks to ascertain the signal strength within a giving cell during the planning stage of the GSM network. The frequency of propagation of the GSM operator contacted during this research work lies within the SHF range which has several advantages (like reduced antenna size amongst others) for line-of-sight transmission, however, transmission at such range experiences great losses during its propagation. The aim of network optimization is to achieve a cost-effective radio network in terms of coverage, capacity and quality, we can say that the network of the GSM operator contacted during this research work is optimized in terms of cost because transmission at the SHF range leads to reduced antenna height, smaller antenna installation and other accessories etc. in spite of the Path loss experienced, the received signal is still of good quality within the 10.87km path length

KEYWORDS

BS, MS, Path Loss, Propagation, Model, GSM.

1. INTRODUCTION

An understanding of the radio wave propagation characteristics of an environment is a necessary condition for effective radio network planning. This becomes very important today with the ever-increasing demand for radio channels following explosion in demand for wireless services. The analysis of radio propagation of a GSM network cannot be discussed in isolation because in totality, it implies a communication system. A communication system is a mechanism that provides the information link between a source and a destination. Radio propagation is the behavior of radio waves during transmission within two points near or far on the earth or into other parts of the atmosphere. Like light waves, radio waves are affected by the phenomena of reflection, refraction, diffraction, absorption, polarization and scattering (Ikegmi *et al.*, 1980). Radio propagation generally, is affected not by only meteorological but also environmental factors. The severity of these effects depends largely on the frequency in use. Channel characterization, therefore, requires that the structural profile of the intervening terrain between the transmitter and the receiver, be considered alongside with the frequency of transmission. Radio propagation models enable prediction of path losses/signal strength along a radio path. They are, therefore, major requirements in radio path profiling and network planning. For more accurate coverage design of modern cellular networks, signal strength measurements must be taken into consideration in order to provide an efficient and reliable coverage area. The frequencies used for mobile communication in Nigeria range from 850MHz to 1.8GHz. Characteristically, propagation in this range of frequencies is limited, in addition to meteorological factors, by the nature and structure of the terrain between the transmitter and the receiver (Adesodo, *et al.*, 2012). However, the frequency range of propagation is on the increase due to the limitations above. The process of communication involves the transmission of information from one location to another. Modulation is used to encode the information onto a carrier wave (carried out in the transmitter section) and an electromagnetic wave is created by a local disturbance in electric and magnetic fields. Therefore, wave propagation entails the transfer of energy from one point to another using a particular medium. In the case of a GSM operator, it involves the transfer of electromagnetic energy containing information from the transmitting antenna to the customer and vice versa using the free space as the medium of propagation. Wireless communication is the transfer of information over a distance without the use of electrical conductors or "wires". Wireless communication is generally considered to be a branch of telecommunications. It encompasses various types of fixed, mobile, and portable two-way radios, cellular telephones, personal digital assistants (PDAs), and wireless networking. The physical limitations of the wired line communication systems in satisfying the ever increasing demands seem to be in favor of wireless systems. The consequent phenomenal growth in demand has led to a world-wide number of mobile subscribers to be 5 billion as at July 2010. The scenario in Nigeria has not been any different. The erstwhile P & T/NITEL failed abysmally to satisfy the large number of demands through its total line that stood at 700,000 to a population 120 million out of which only 400,000 lines were actually working on eve of liberalization of the industries. In Nigeria, the penetration of GSM as at July 2011 stood at 117 million lines (.NCC, 2011). Thus wireless communication had come to be a strategic partner to the economic development of Nigeria.

Radio network planning is perhaps the most important aspect of GSM system network planning because of its proximity to mobile users. The objective of the analysis of radio propagation

characteristics of GSM operative network is to come up with a propagation model that will aid planning of the network for effectiveness and efficiency of the operator. The model is useful in cases of future expansion of the network or even the improvement of the service being provided. Propagation models are widely used extensively in network planning, particularly for conducting feasibility studies and during deployment. These models are also useful for performing interference studies as the deployment proceeds (Abhayawardhana *et al.*, 2005). Radio path loss is a particularly important element in the design of any radio communication system or wireless network, it will determine many elements of radio communication system especially the transmitter power, antenna gain, antenna height and general location (Anderson *et al.*, 1995). Radio path loss also affects other elements such as the required receiver antenna sensitivity, form of transmission used and several other factors (Frank, 2001). As a result, it is necessary and justifiable to undertake radio path loss analysis in relation to coverage area and to be able to determine the level of the signal loss for a given radio at a particular distance.

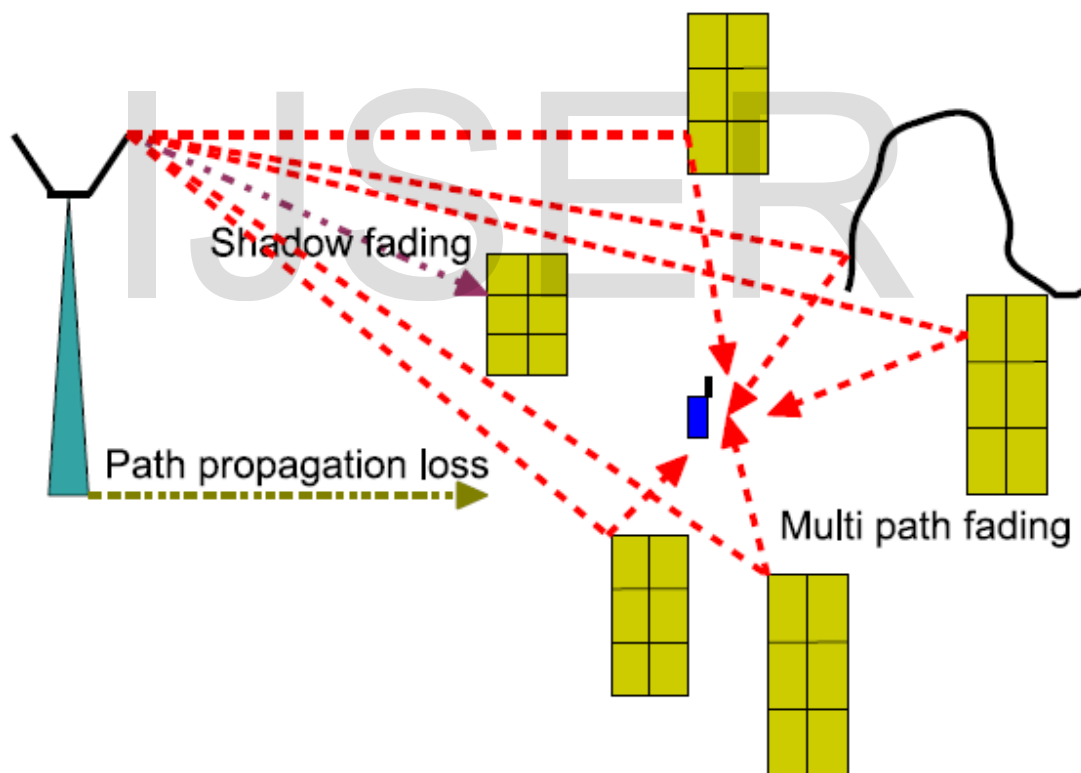


Figure1: Radio propagation: path loss propagation, shadow fading, multi path fading

2. DIFFERENT TYPES OF PROPAGATION PATH-LOSS MODELS:

At times it is impossible to explain a situation by a mathematical model. In that case, the use of some data to predict the behavior approximately is applied. By definition, an empirical model is based on data used to predict, not explain a system and are based on observations and measurements alone. Common empirical propagation models include: The Free Space Model, Hata, Cost 231, and Stanford University Interim (SUI) Models etc.

2.1 FREE SPACE MODEL

This model predicts a clear and unobstructed line of sight transmission to reception terrain. The wave is not reflected or absorbed but radiated equally in all directions. The model also stipulates that the received power decays as a function of the distance between the transmitter and the receiver raised to an exponent. The generic free space path loss can be obtained as follows;

$$P_L(dB) = 32.44 + 20 \log f_c + 20 \log d \quad (1)$$

Where $P_L(dB)$ is the FSPL in dB, f_c is the carrier frequency in MHz and d is the distance between transmitter and receiver in km. The FSPL can also be written as;

$$P_L(dB) = 92.44 + 20 \log f_c + 20 \log d \quad (2)$$

Where f_c is the frequency in GHz and d is the distance given the signal, P_L is power loss that takes place from the transmitting antenna to the receiving antenna

2.2 HATA'S PROPAGATION MODEL

Hata model was based on Okumura's field test results and predicted various equations for path loss with different types of clutter. The limitations on Hata Model due to range of test results from carrier frequency (f) 150MHz to 1500MHz, the distance from the base station ranges from 1Km to 20Km, the height of base station antenna (h_b) ranges from 30m to 200m and the height of mobile antenna (h_m) ranges from 1m to 10m. Hata created a number of representative path loss mathematical models for each of the urban, suburban and open country environments, as illustrated in equations (3-8), respectively. The propagation models dealing with path loss for mobile communication have been emphasized using the Okumura-Hata model best suitable for urban area propagation equation and supplied corrections for other types of area as stated in Odongo, (2008) as given;

$$P_{L_{urban}}(d)[dB] = 69.55 + 26.16 \log_{10} f_c - 13.82 \log_{10} h_b - (ah_m) + [44.9 - 6.5 \log_{10} h_b] \log_{10} d \quad (3)$$

Where $P_{L_{urban}}(d)$ [dB] is the propagation path loss in urban areas, f_c is the carrier frequency in MHz, d is the distance in km, h_b is the height of base station in meters (m), and $a(h_m)$ is a correction term for the receiver antenna height (h_m) given by this formula,

For large cities;

$$a(h_m) = 8.29[\log(1.54h_m)]^2 - 1.1, \text{ for } 150\text{MHz} \leq f \leq 200\text{MHz} \quad (4)$$

$$a(h_m) = 3.20[\log(11.75h_m)]^2 - 4.97, \text{ for } 200\text{MHz} \leq f \leq 1500\text{MHz} \quad (5)$$

The correction factor, $a(h_m)$ in the basic equation, differs as a function of the size of the coverage area.

For small or medium sized cities (where the mobile antenna height is not more than 10 meters);

$$a(h_m) = 0.8 + (1.1 \log f_c - 0.7)h_m - 1.56 \log f_c \quad (6)$$

To obtain the path loss in suburban area, equation (13) is modified to

$$Pl_{sub-urban}(d)[dB] = Pl_{urban}(d)[dB] - 2 \left[\log \left(\frac{f_c}{28} \right) \right]^2 - 25.4 \quad (7)$$

And for open rural areas, it has

$$Pl_{openrural}(d)[dB] = Pl_{urban}(d)[dB] - 4.78[\log(f_c)^2] + 18.33 \log f_c - 40.94 \quad (8)$$

The prediction of Hata model compares very closely with the original Okumura model as long as d exceeds 1km. This model is suitable for large cell system, but not for personal communications systems that cover a circular area of approximately 1km in radius. Hata model is not suitable for micro-cell planning where antenna is below roof height and its maximum carrier frequency is 1500MHz. It is not valid for 1800 MHz and 1900 MHz systems.

2.3 COST 231 MODEL

The European Co-operative for Scientific and Technical Research formed the COST 231 committee to develop an extended version of the Hata model such that applicability to 2 GHz is possible (Adesodo, *et al.*, 2012). The model is applicable for mobile station antenna height up to 10m, base station antenna height of 30m to 100m and link distance up to 20km. Path loss in this model is computed as:

$$P_{L_{urban}}(d)[dB] = 46.33 + 33.9 \log f_c - 13.82 \log(h_b) - (ah_m) + [44.9 - 6.55 \log h_b] \log d + X_m \quad (9)$$

2.4 SUI Model

The SUI model developed by Stanford University called Stanford University Interim (SUI). It has accommodated frequency greater than 1900 MHz's. The WiMAX may use frequencies above 3500 MHz, which increase the need of SUI model. In this propagation model, Sun (Sun 2007) have shown path loss for different areas type called terrains but in this case, we show path loss in SUI only for Terrain A (Hilly with heavy tree densities) with highest path loss, the region is very dense and populated. The path loss equation in SUI path loss is as follows, (Sun 2007).

The general path loss expression of the SUI model is presented as:

$$PL = A + 10y \log_{10} (d / d_0) + X_f + X_h + s, d > d_0 \text{ --} \tag{10}$$

where the parameters are as follows,

d= Distance between BS and receiving antenna [m]

d₀= 100 [m]

l=Wave length [m]

X_f=Correction for frequency 940 [MHz]

X_h=Correction for receiving antenna height [m]

s= Correction for shadowing [dB]

and y=Path loss exponent

By statistical method, the random variables are taken as the path loss exponent y and the weak fading standard s is derived. The parameter A is defined as,

$$A = 20 \log_{10} \left(\frac{4\pi d_0}{\lambda} \right) \tag{11}$$

and the path loss exponent y is given as follows,

$$Y_y = a - b h_b + (c/h_b) \tag{12}$$

Here, the parameter h_b is the base station antenna height. This is between 15 m and 90 m range.

The constants a, b, and c depend upon the types of terrain, here our study, urban area. The value of parameter y propagation in an urban area, 6 < y < 9 for urban NLOS environment. The

frequency correction factor X_f and the correction for antenna receiver height

X_h for the model are expressed as follows,

$$X_f = 6.2 \log_{10} (f/2000) \tag{13}$$

$$X_h = -10.9 \log_{10} (h_r/2000) \text{ (Sharma and Singh, 2010).} \tag{14}$$

3. DATA ANALYSIS OF PATHLOSS

Table 1. G.S.M Environments and R.F Parameters

Parameters	Values
TX power (watts)	0.25
TX power (dBm)	24.00
RX threshold level (dBm)	-92.00
Maximum receive signal (dBm)	-15.00
RX signal (dBm)	-39.29
Frequency (MHz)	13000 and 18000
Path length (Km)	10.87
Free space loss (dB)	135.47
Antenna height (m)	24, 36, 50 and 70

Reference mobile station height (m)

2

4 METHODOLOGY

Simulation was done using MATLAB for a distance of 0 – 12 km, (the distance between mobile station (RX) and transmitter TX) in order to ascertain the effect of path loss with varying RX to TX distance. All other parameters like frequency and base station height will be kept constant. The frequency for the Ideal Situation is 10 GHz while that for the Practical Situations is 13 or 18 GHz (depending on the base station considered). The selected base stations include; MAK 026, Lobi Quarter, MAK 013, Behind Modern Market, MAK 002 Con Oil, North Bank, MAK 019, Yema Layout, MAK 007, Sokoto Street, Wadata and MAK 005: Ankpa Road.

In the Ideal Situation the distance between mobile to base station is 8 Km while in the Practical situation, it is 10.7 Km (Path Length, see Table 1).

5 SIMULATED RESULTS OF VARIOUS TERRAINS

13 GHz FREQUENCY AND 36 m BASE STATION HEIGHT (LOBI QUARTERS, MAKURDI)

The Lobi Quarters base station transmits at 13 GHz, and uses a 36 m antenna for transmission, the mobile antenna height is 2 m, and Figure 2 shows the variation of the path loss with variation in mobile station to base station distance.

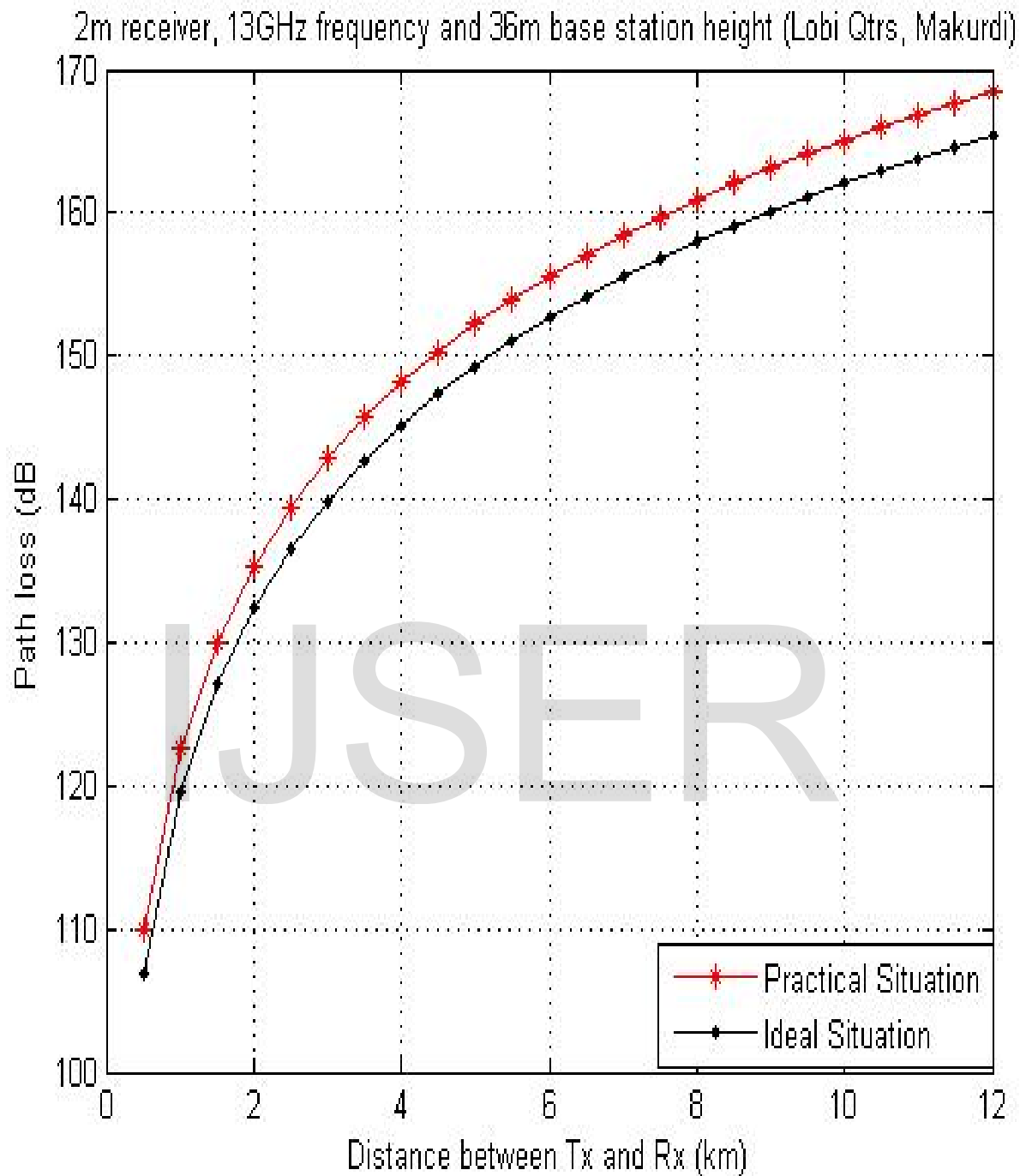


Figure 2: Change in Path Loss with Distance (Lobi Quarters, Makurdi).

A. 13 GHz FREQUENCY AND 50 m BASE STATION HEIGHT (BEHIND MODERN MARKET).

This base station transmits at 13 GHz with an antenna height of 50 m; Figure 3 shows the variation of the path loss with variation in mobile station to base station distance

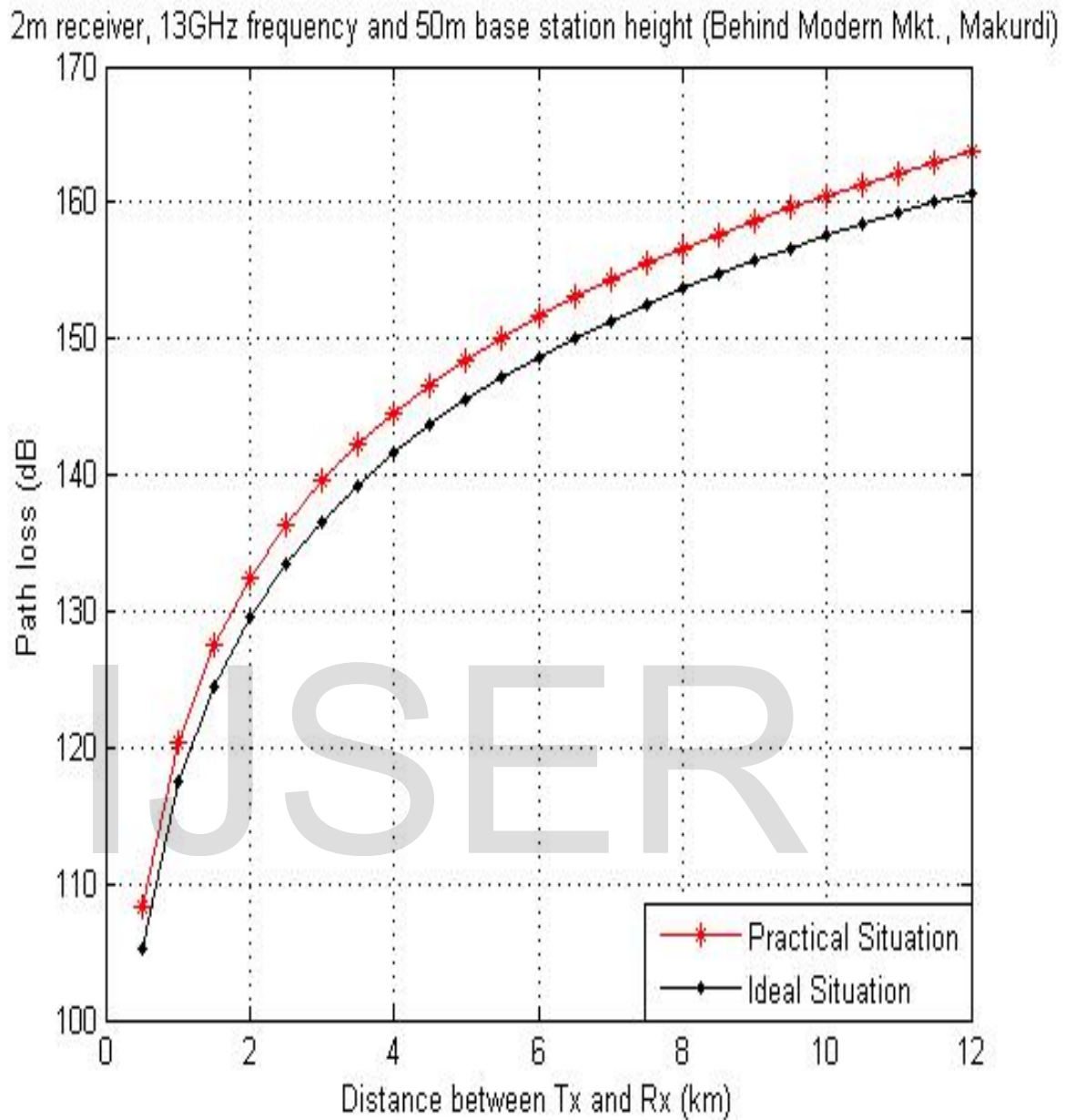


Figure 3: Change in Path Loss with Distance (Behind Modern Market).

13 GHz FREQUENCY AND 70 m BASE STATION HEIGHT (CON OIL NORTH BANK, MAKURDI)

This base station transmits at 13 GHz with an antenna height of 70 m; Figure 4 shows the variation of the path loss with variation in mobile station to base station distance.

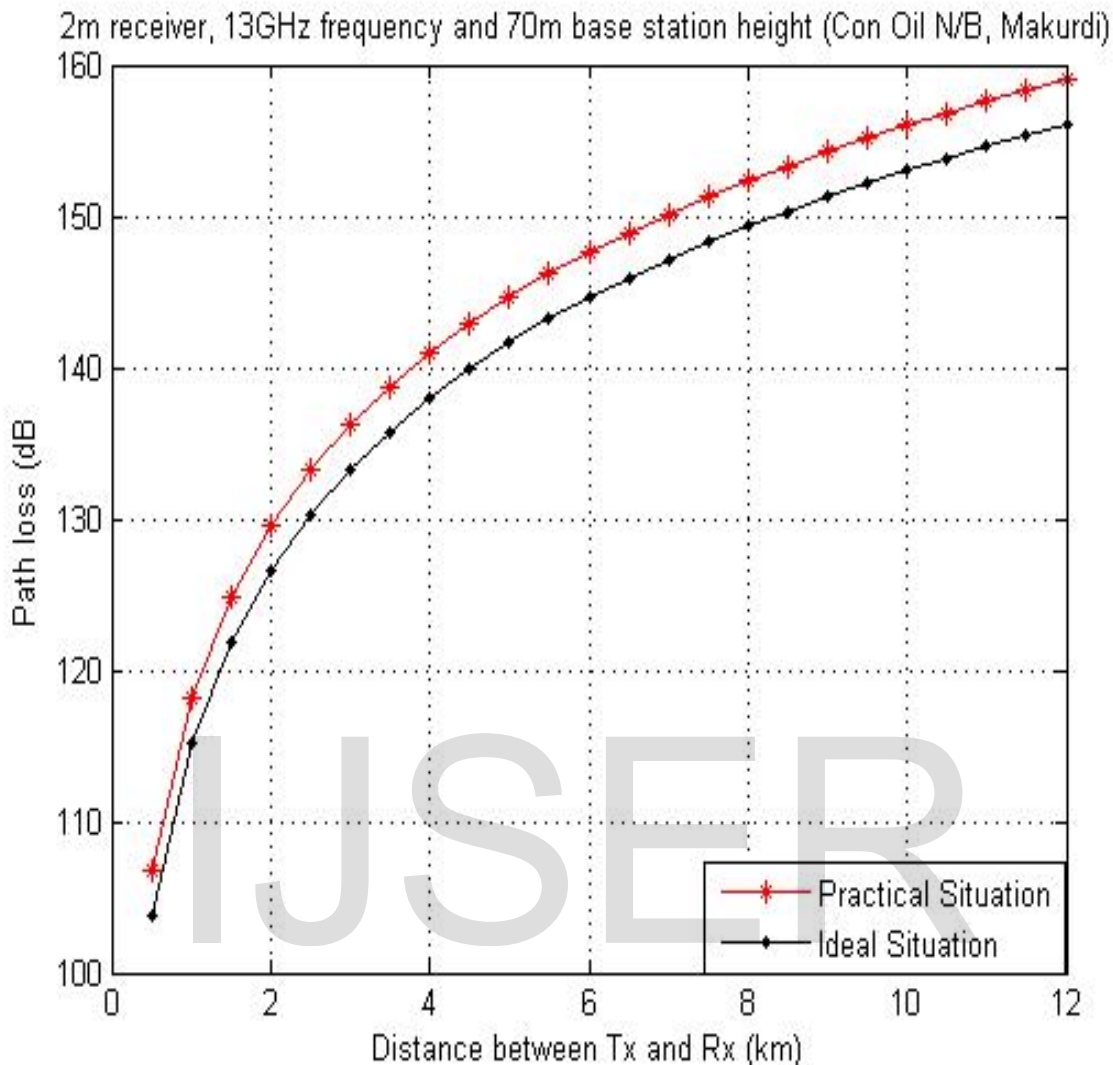


Figure 4: Change in Path Loss with Distance (Con Oil North Bank, Makurdi).

18 GHz FREQUENCIES AND 24 m BASE STATION HEIGHT (YEMA LAYOUT, MAKURDI)

This base station transmits at 18 GHz with an antenna height of 24 m; Figure 5 shows the variation of the path loss with variation in mobile station to base station distance

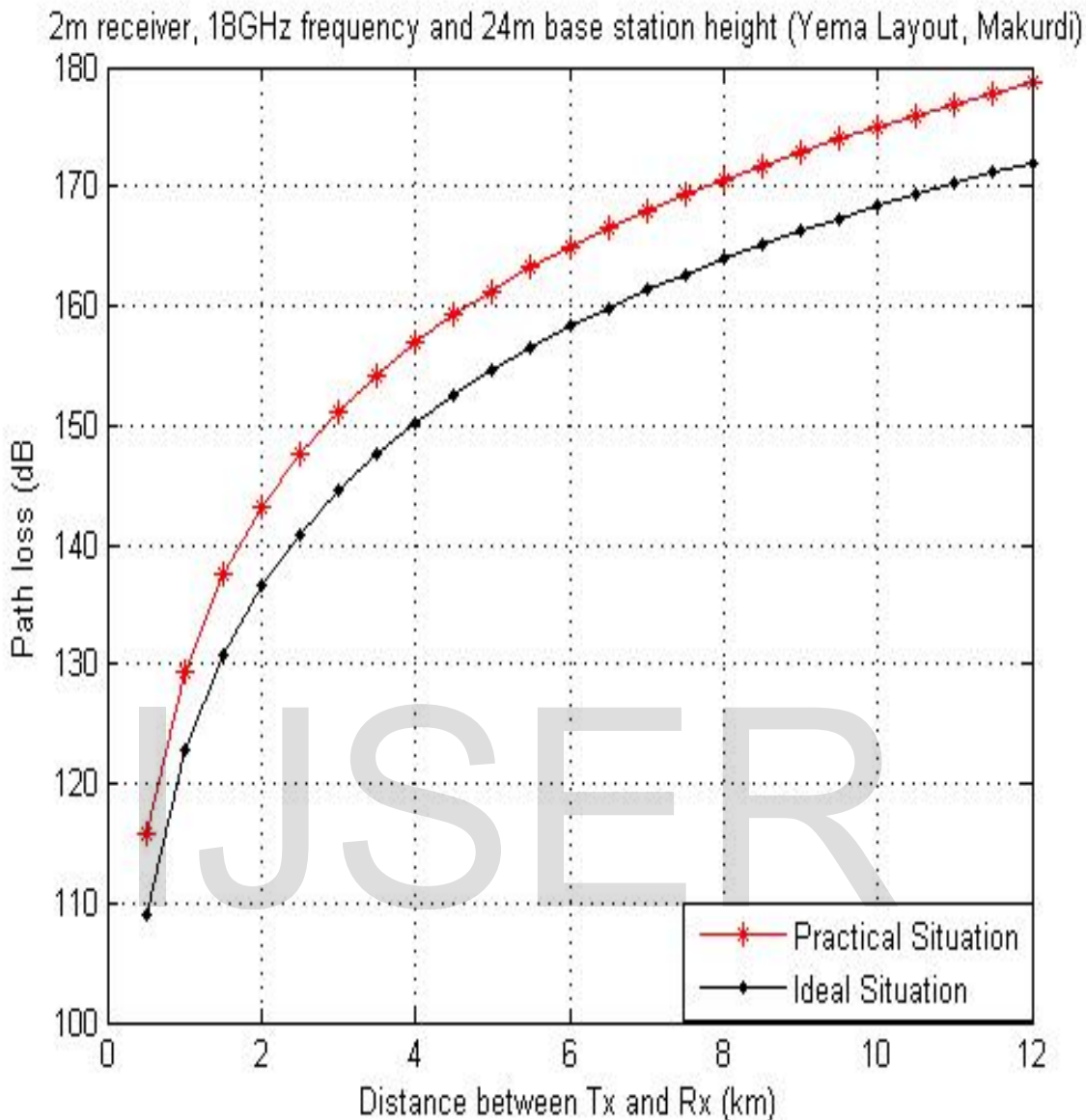


Figure 5: Change in Path Loss with Distance (Yema Layout, Makurdi).

B. 18 GHz FREQUENCIES AND 36 m BASE STATION HEIGHT (SOKOTO STREET WADATA, MAKURDI)

This base station transmits at 18 GHz with an antenna height of 36 m; Figure 6 shows the variation of the path loss with variation in mobile station to base station distance

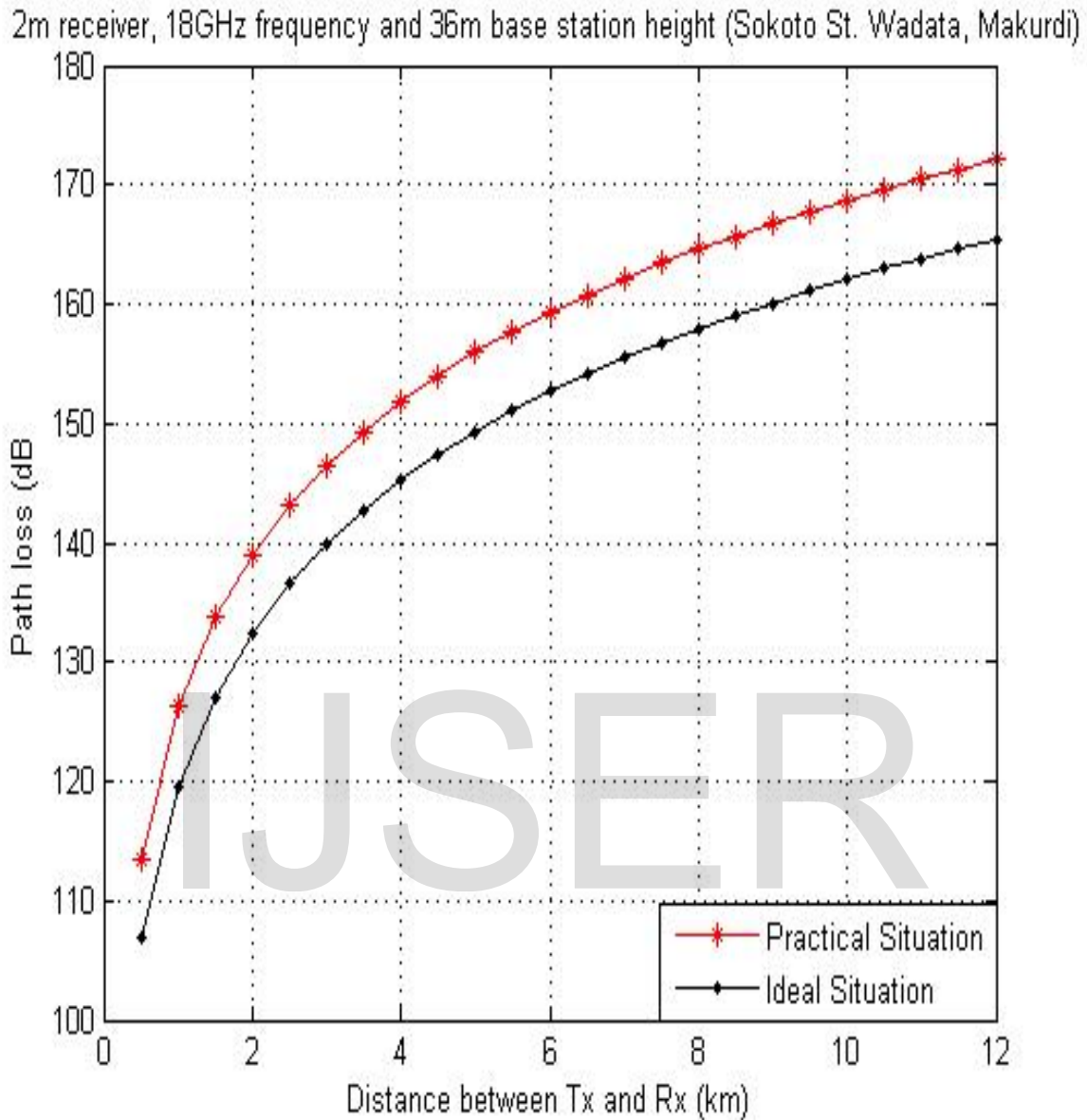


Figure 6: Change in Path Loss with Distance (Sokoto Street Wadata, Makurdi).

C. 18 GHz FREQUENCIES AND 50 m BASE STATION HEIGHT (ANKPA ROAD, MAKURDI)

This base station transmits at 18 GHz with an antenna height of 50 m; Figure 7 shows the variation of the path loss with variation in mobile station to base station distance

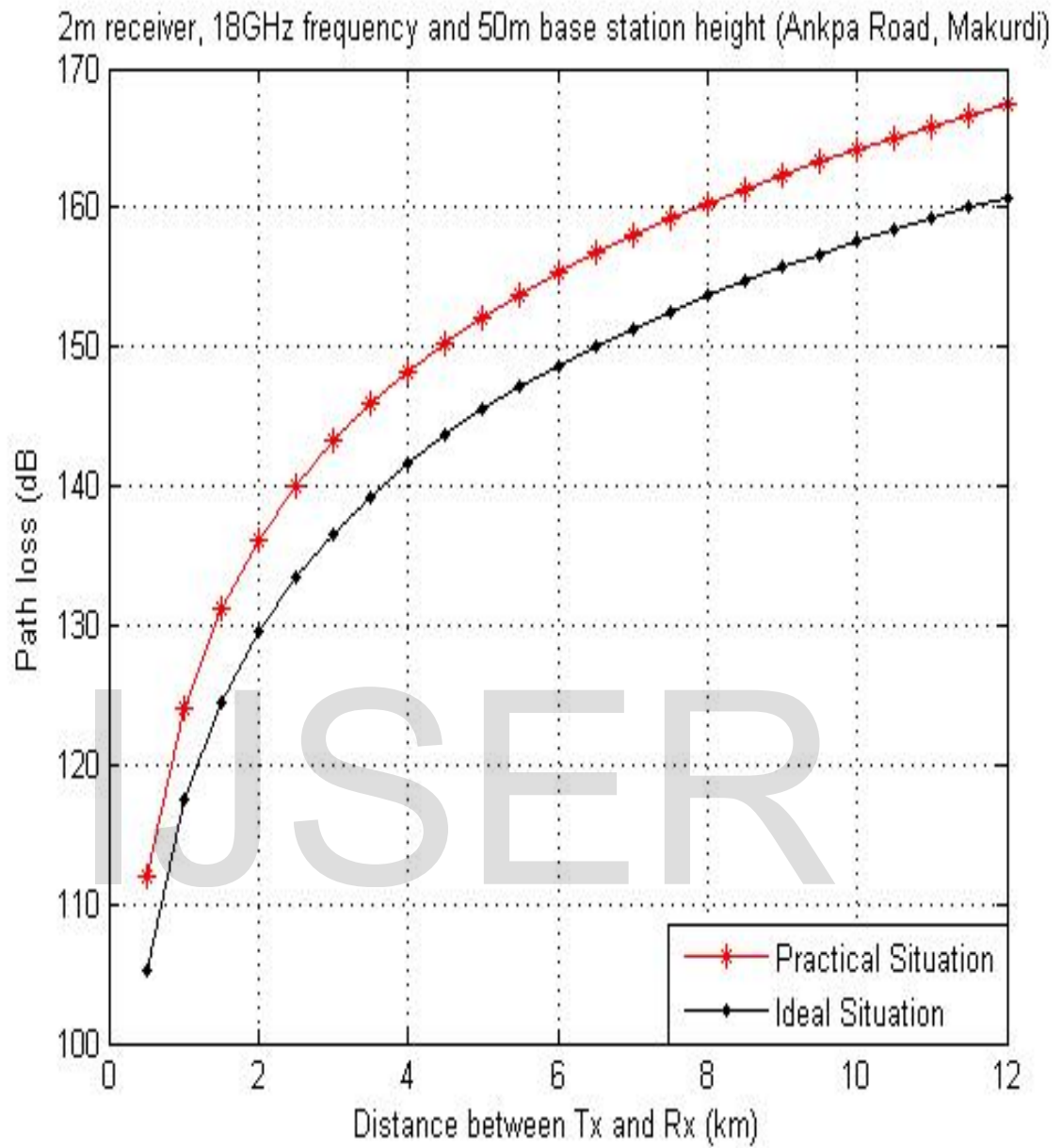


Figure 7: Change in Path Loss with Distance (Ankpa Road, Makurdi).

YEMA LAYOUT, MAKURDI (24 m TX ANTENNA)

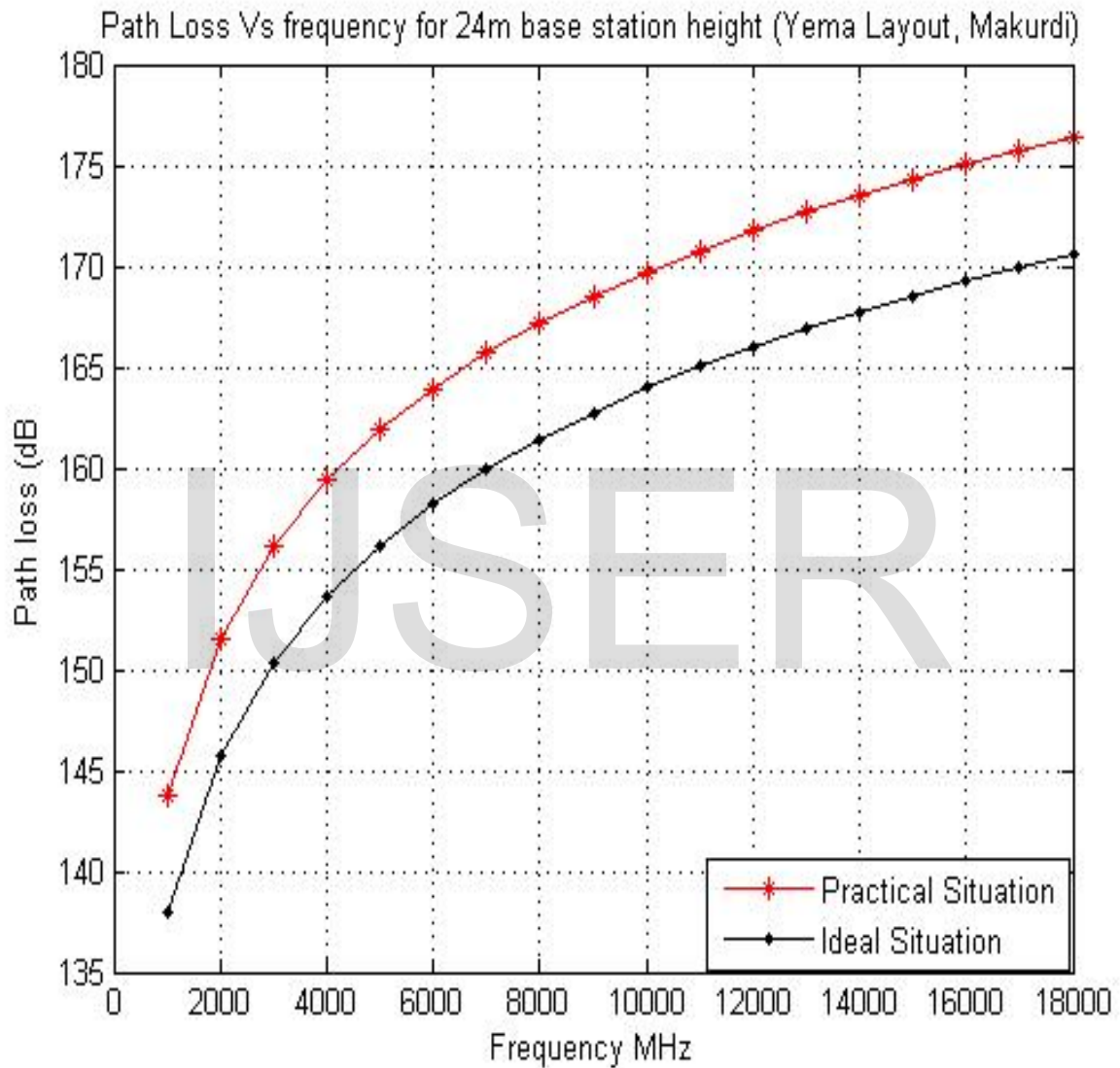


Figure 8: Change in Path Loss with Frequency (24 m TX Antenna).

LOBI QUARTERS MAKURDI (36 m TX ANTENNA)

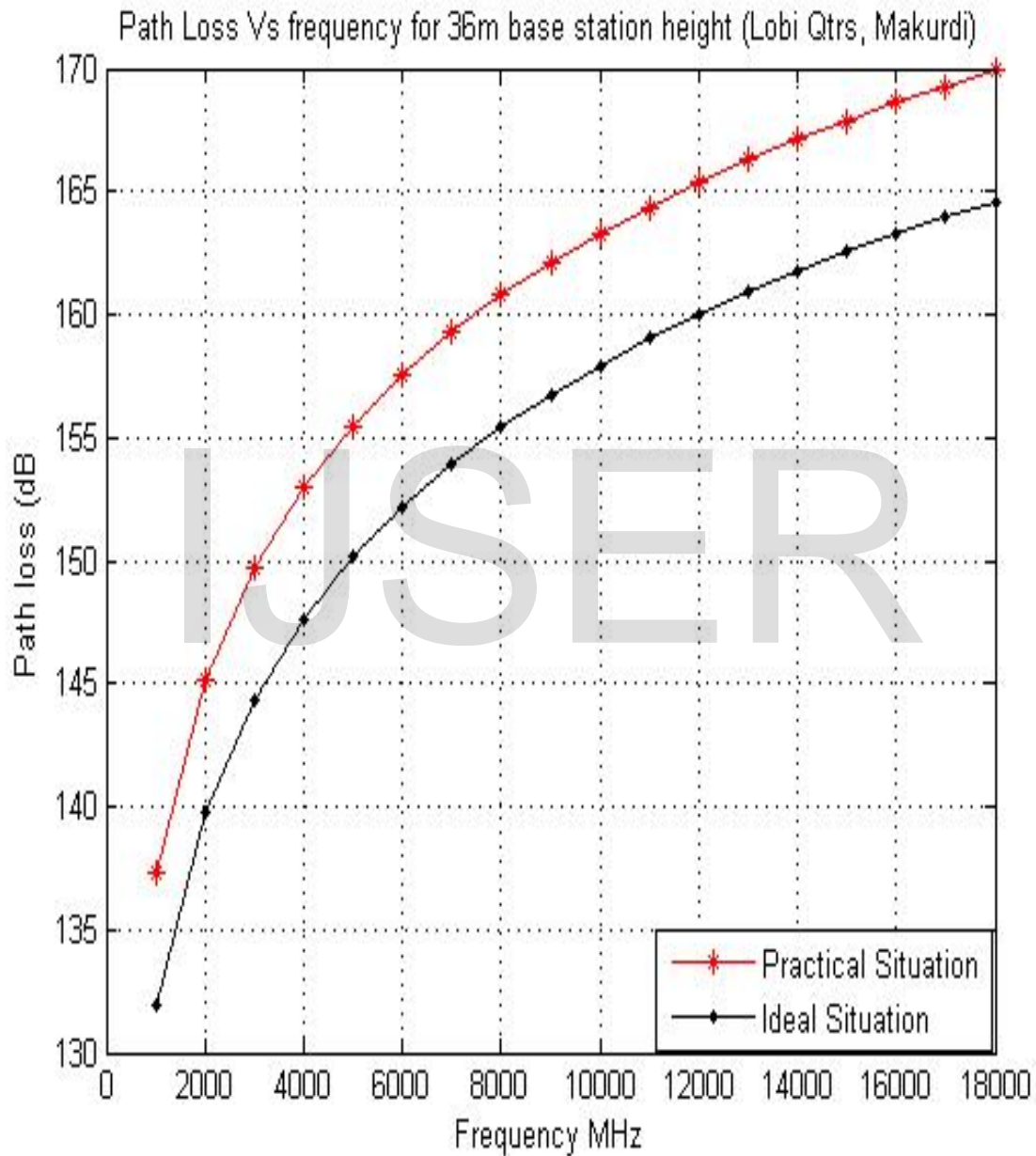


Figure 9: Change in Path Loss with Frequency (36 m TX Antenna).

ANKPA ROAD MAKURDI (50 m TX ANTENNA).

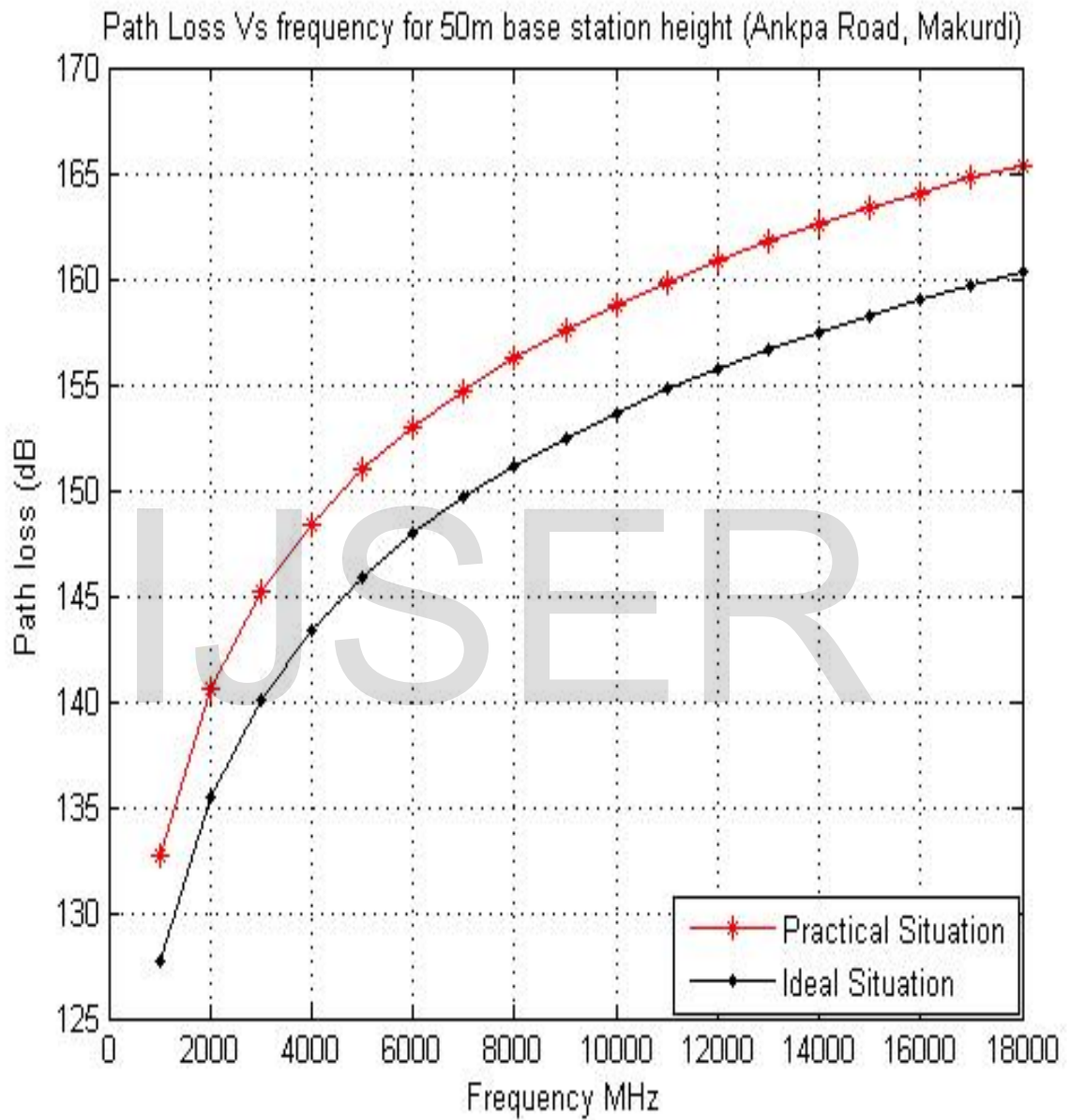


Figure 10: Change in Path Loss with Frequency (50 m TX Antenna).

CON OIL NORTH BANK, MAKURDI (70 m TX ANTENNA)

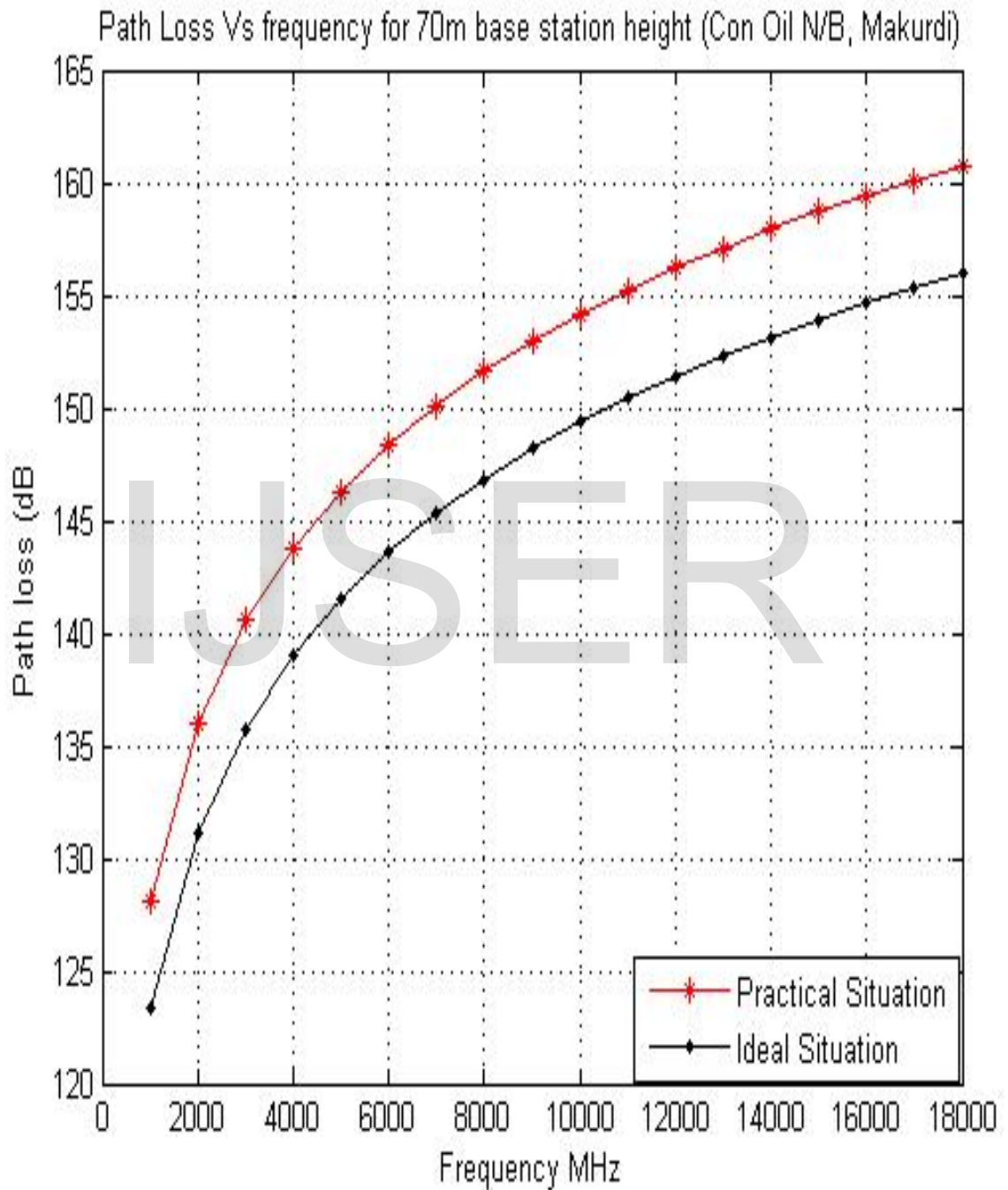


Figure 11: Change in Path Loss with Frequency (70 m TX Antenna).

A 2 m MOBILE STATION AT A DISTANCE OF 8KM FROM TRANSMITTER.

The accumulated result for the simulations can be shown in Figure 12, and Figure 13 shows a plot of the base station parameters for both Ideal and Practical Situations with path loss at 8 Km distance. It is worth noting that the Path loss is lowest when transmitting at a frequency of 13 GHz using an antenna of 70 m and highest when using a frequency of 18 GHz with a transmitting antenna height of 24 m.

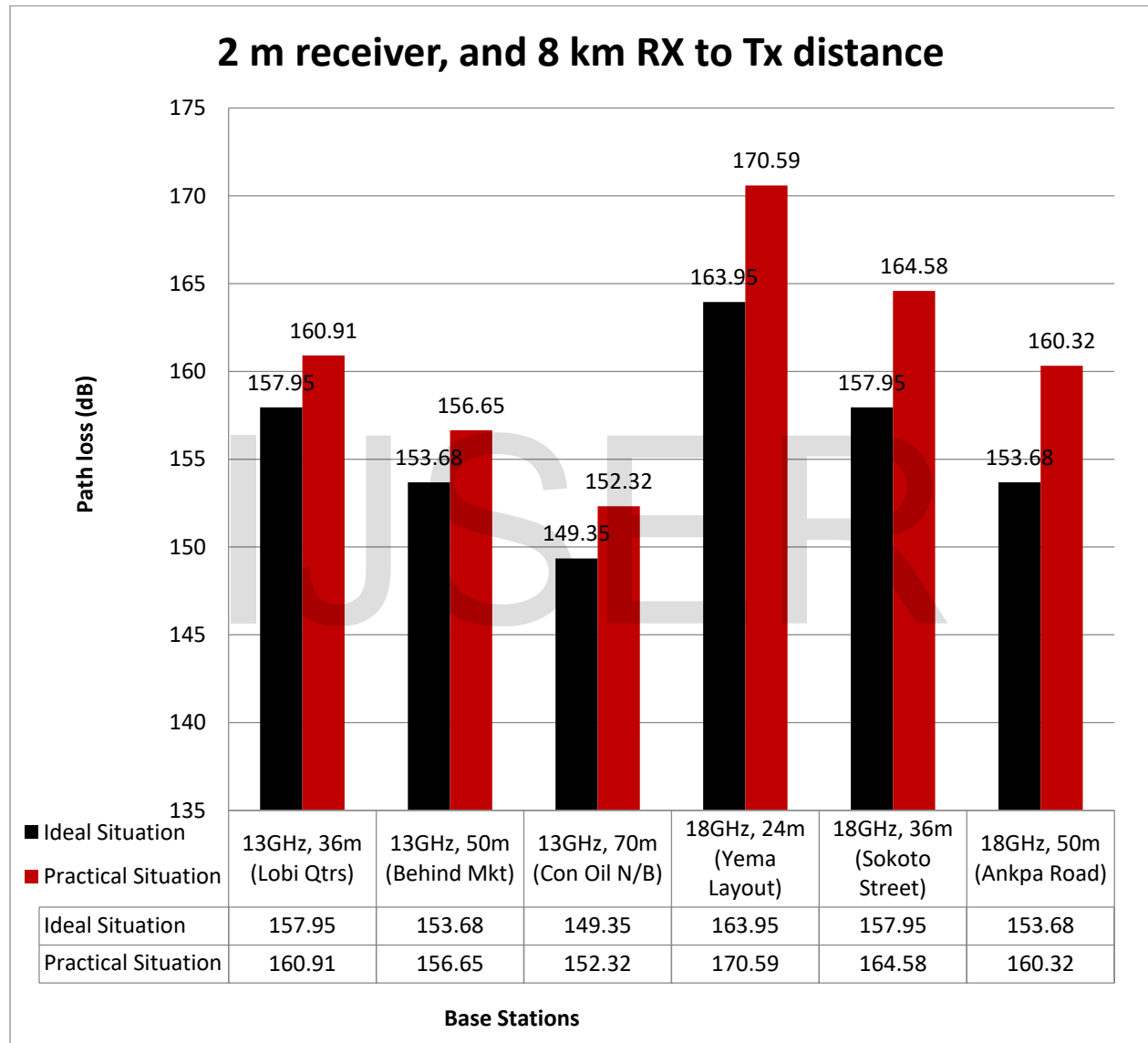


Figure 12: Analysis of Simulated Results at 8 km RX to TX Distance.

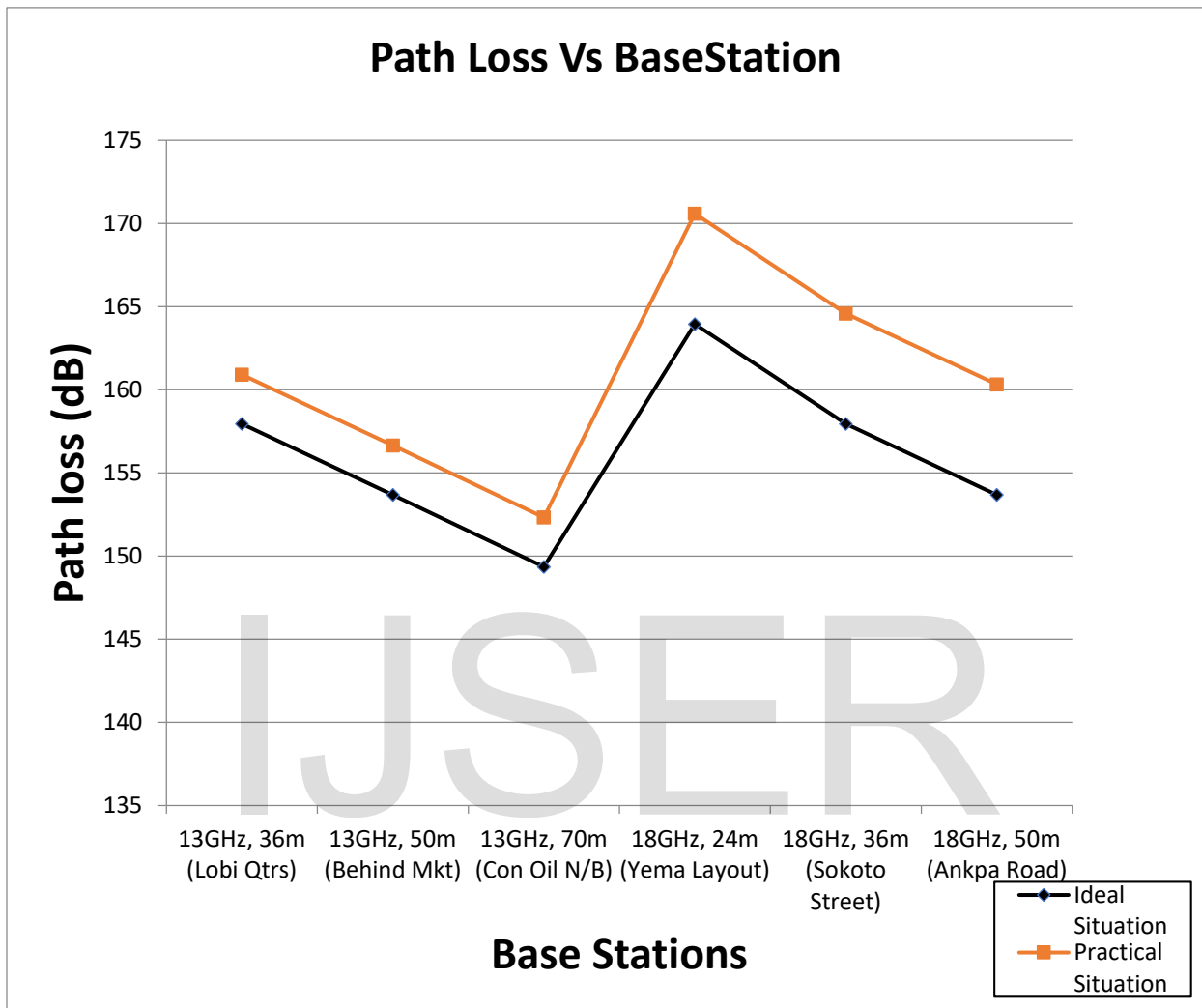


Figure 13: Path loss Against Base Stations at 8 Km.

A 2 m MOBILE STATION AT A DISTANCE OF 10.87 KM FROM TRANSMITTER.

Similarly, the accumulated result for the simulations can be shown in Figure 14, and Figure 15 shows a plot of the base station parameters for both Ideal and Practical Situations with path loss at 10.7 Km distance. It is worth noting that the Path loss is lowest when transmitting at a frequency of 13 GHz using an antenna of 70 m and highest when using a frequency of 18 GHz with a transmitting antenna height of 24 m.

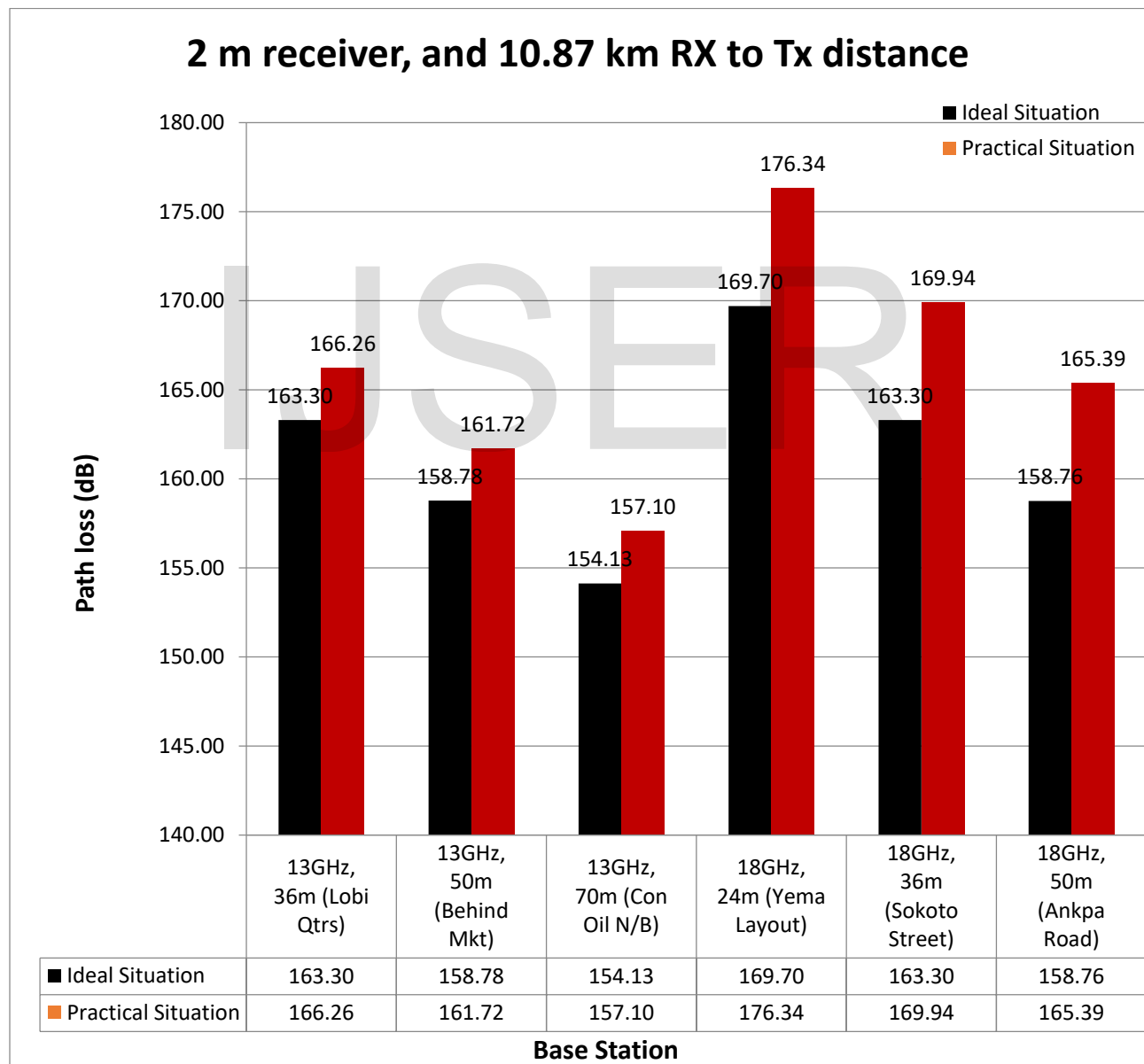


Figure 14: Analysis of Simulated Results at 10.87 km RX to TX Distance.

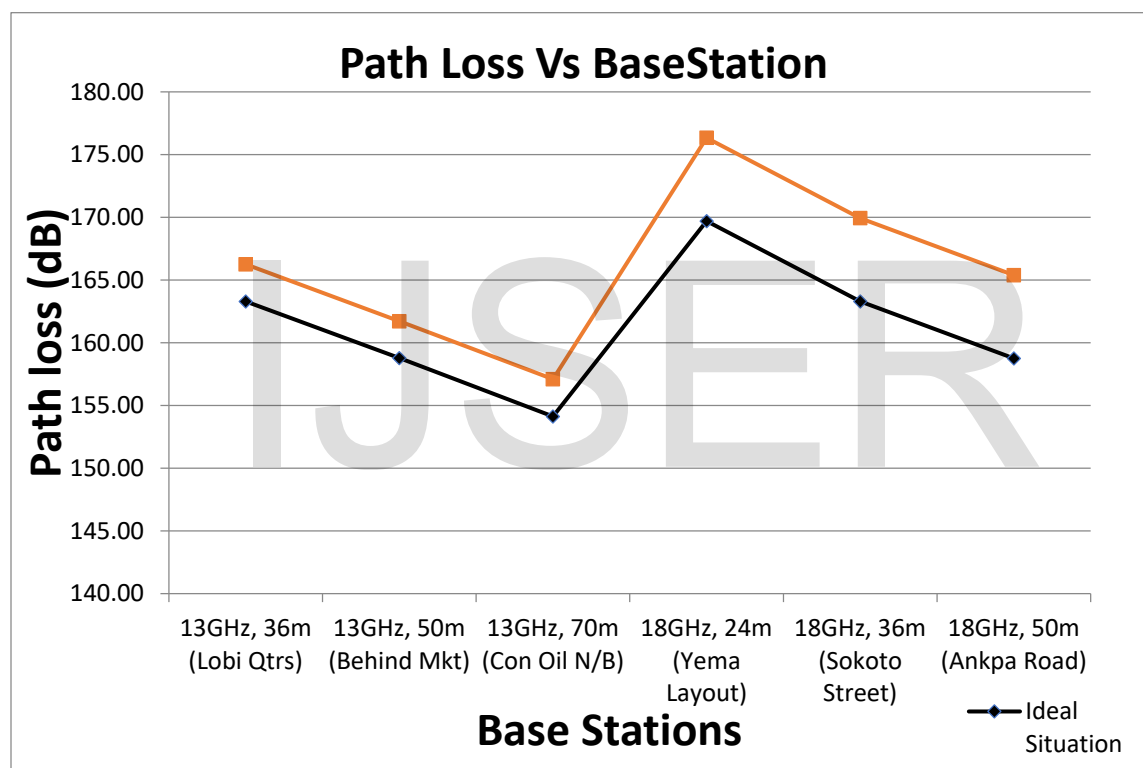


Figure 15: Path loss Against Base Stations at 10.87 Km.

6 CONCLUSION

The following could be deduced from the simulation results:

From figure 2 – 7, it can be concluded that the radio Path loss increases with increasing distance between the mobile station and the base station. Using the SUI model, the Path loss is least when transmitting at 13 GHz using a 70 m antenna (Con Oil base station) and it is greatest when transmitting at 18 GHz using a 24 m antenna (Yema base station).

Figure 8-11 it can be concluded that the radio Path loss increases with increasing frequency of propagation using the SUI model. The Path loss is least at the Con Oil base station (70 m base station antenna) and it is greatest at the Yema base station (24 m base station antenna).

Figure 13 and 15, it can be concluded that the Path loss decreases with increasing base station height when using the SUI model

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