

Issues Associated with Decimeter Waves Propagation at 0.6, 1.0 and 2.0 Peak Fresnel Zone Levels

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Abstract: Radio waves propagation is dependent on many variables. Any of these variables employed must ensure that the antennae at both sides of the link can see each other. This is because the radio horizon extends beyond the optical horizon. In spite of this porch, telecommunications' long distance signal suffer degradation. The ratio of the transmitted power to the receiver power is empirically deteriorated. The level of the received signal fluctuation is usually a function of the configured characteristics between the TX-antenna and the RX-antenna. In view of this, operating considerations are usually focused on LOS, NLOS and the FZ of the area, among other environmental issues. The study, therefore, focuses on issues associated with Radio waves propagation under Fresnel zone peak levels of 0.6, 1.0 and 2.0. Five locations were considered along a major economic route (Eket-Mobil Oil giant and Uyo capital city). Signal strength pattern along the route was evaluated using a wireless radio link established in all the surveyed interceptions. This aided to determine any impeding structure tending to obstruct signal propagation; and measurements were taken at five respective nodes along the route. Results indicated the best line-of-sight (LOS) at Etinan (-81dB signal strength). AfahaNsit, recorded the second best on the table (-82dB). On the other hand, locations like Eket and Nsit-Ubium established very poor line-of-sight (signal strength of -84dB and -83dB respectively). The study further noted that obstruction like trees along the route to Eket contributed greatly to the poor results obtained at the terminal point of the signal; except for the meticulous positioning of the antennae. The variance recorded in this work from the previously reported study by the same author, was due to modified Fresnel zone levels and corresponding decrease in transmitting frequency. Comparatively, it was observed that the reduction in the channel frequency, increased the rate of attenuation across the locations, as well as the signal strength.

Keywords: Decimeter wave, Direct transmission mode or Line-of-sight mode, Fresnel zone

1. Introduction

The basic theory of radio wave propagation within the troposphere that aids the propagation of very high frequency (VHF) and ultra-high frequency (UHF) radio waves is anchored on the concept of electricity and magnetism by James Maxwell. The discovery of this concept led to the discovery of the law of gravitation by Newton [1]. These waves, travel through space at about the speed of light (3.0×10^8 m/s). More so, as it travels through space, across cities, its propagation is greatly affected, depending on whether there is direct link or line-of-sight (LOS) between the transmitting and receiving antennae or not. This is because the propagation characteristics of radio wave, such as path loss, fading and attenuation does not only depend on the path distance and frequency, but also on the scattered angle, which also depends on the nature of obstruction to the EM wave.

The LOS as applied to radio links implies that the antenna at one end of the link can see each other. This is because the radio horizon extends beyond the optical horizon [2]. Radio waves follow slightly curved path in the atmosphere, and so if there is a direct curved path between the antenna which does not pass through any obstacle, then one still has radio LOS. This link encounters obstacles such as buildings, trees and hills between the transmitting station and the receiving station. Other sources of reflection of signal, such as the ground also exist which tend to complicate the signal path. Depending on the type of obstacle, the transmitted signal may have multitude of paths known as multi-path (via reflection, refraction and diffraction) to the receiving station. Part of the signal will be detected with sufficient signal

strength while another part attenuated or scattered as a result of these obstructions. Because the paths have different characteristics, the signal is received as multiple individual signals with varying amplitudes, delay and strength depending on the exact location of the receiver. In a situation where the signal power delivered to the receiver is insufficient as a result of attenuation, re-examination of LOS characteristics of such routes needs to be considered. The study therefore takes a critical look at radio waves propagation pattern along the major economic route of the nation (Uyo to Eket - Mobil/Exxon Producing Nigeria). Eket is the operational base of Mobil/Exxon Producing Nigeria, the leading oil producing company in Nigeria. The need for uninterrupted and effective communication along this critical sector of the Nigerian economy engineered this project; most especially when the Nigerian telecommunications environment is totally dependent on wireless network.

1.1 Characteristics of the UHF band

As observed by [4] and [5], radio communication between two points is hampered by some factors like: fog, obstruction by man-made structure, atmospheric variation, etc. These factors tend to cause signal degradation. Also, radio waves are usually absorbed to some degree by the moist in the atmospheric. Consequently, this absorption caused by moisture in the atmosphere results in fading (attenuation) of the intensity of the radiated radio signal, which of course is experienced more severely with increasing frequency. Example is UHF radio signal used for TV transmission which experiences more degradation than when VHF signal is used.

1.2 Free Space Propagation and Fresnel Zone

Fresnel zone (FZ), “is an ellipse-shaped areas of power radiated between any two radio-antennae”. The path through which signal is expected to travel must be free and unobstructed along the FZ, that spreads out several meters from the LOS. Based on this premise, [1], maintained that for wireless link, “the primary FZ is required to be at least 60 percent clear of any obstruction to ensure the highest performance”. From this postulate, various FZ can be determined as follows:

R - Curved path of the first Fresnel zone radius (at the obstruction in km)

Ht - Height above the earth’s surface at the transmitting antenna (in km)

Hr - Height above the earth’s surface at the receiving antenna (in km)

X - Height of obstruction in (km)

h - Earth curvature, from a flat plane between antennas, at obstruction

d1 - Distance from transmitting antenna to obstruction (in km)

d2 - Distance from receiving antenna to obstruction (in km)

Dt - Total path distance between antenna (in km)

F - Transmitted frequency in (GHz)

For first Fresnel zone

$$R = \frac{15.8\sqrt{d1 * d2}}{Dt * f} \text{ (in Km)} \quad (1)$$

For semi minor axis at mid-path

$$R = \frac{15.8\sqrt{\lambda} * Dt}{Dt * f} \text{ (in Km)} \quad (2)$$

Or

$$R = \frac{274\sqrt{Dt}}{f} \text{ (in inches)}$$

For other points

$$R = \frac{31.6\sqrt{d1 * d2}}{Dt} \lambda \text{ (in Km)} \quad (3)$$

Or

$$R = \frac{547\sqrt{d1 * d2}}{Dt * f} \text{ (in inches)} \quad H = \frac{d1 * d2}{2KrE} * 1000 \quad (6)$$

For the broadest point of the Fresnel zone (in km)

$$R = \frac{15.8\sqrt{Dt}}{4 * f} \text{ (in Km)} \quad (4)$$

Or

$$R = \frac{72.05\sqrt{Dt}}{4 * f} \text{ (in inches)}$$

For a point near the antennas

$$R = 31.6\sqrt{\lambda * d1} \text{ or } 31.6\sqrt{\lambda * d2} \quad (5)$$

Or

$$R = \frac{547\sqrt{d1}}{f} \text{ or } \frac{547\sqrt{d2}}{f} \text{ (in inches)}$$

As opined by [5], Fresnel zone “is the area around the visual line-of-sight that radio waves spread out into, after they leave the antenna”. To achieve a clear LOS means the reception of maximum signal strength, particularly for 2.4 GHz

frequency. In transmitting 2.4 GHz radio frequency, it is proper to take cognizance of the fact that 2.4 GHz radio wave frequency are engrossed (absorbed) by water, similar to the water found in trees.

Naturally, 20 percent FZ obstruction initiates small signal deficit (loss) to the radio link. Above 40 percent obstacle, signal loss is significantly observed [7]. Conversely, if the radio signal is not obstructed, the waves are expected to travel directly from TX to RX. But when this is not achieved, the waves are assumed obstructed and may be reflected before it gets to the receiver. Or, the wave obstructively gets out-of-phase; thereby, tending to reduce the overall power of the signal received. Conversely, this reflected wave would have boasted the overall power of the transmitted signal if it has gotten to the RX in same phase.

According to Augustus Fresnel, obstacles in the first Fresnel zone can create signals with a path-length phase shift of 0 to 180 degrees. In the second zone, they can be 180 to 360 degrees out of phase, and so on. However, odd-number zones are believed to add-up to the signal power while even-number zones tend to cancel each other, thereby reducing the signal power [7].

Furthermore, any obstacle penetrating the FZ can be examined using the Fresnel zone clearance model. The first zone must be free from all perceived obstructions to a very large extent for maximum signal to be received. Basically, a tolerable measure of obstruction into the FZ can be permitted, as the highest permissible obstruction into the FZ must not exceed 40 percent. Usually, 20 per cent obstruction into the FZ is recommended.

According to [3], Fresnel zone analysis of a radio path needs to be carried out in order to check the clearance conditions. The earth bulge, h, which is the earth’s surface height in meters at a point P of the hop compared with the chord between the end TX and RX taking atmospheric refraction into account can be calculated using:

Where:

K = the equivalent earth radius (EER) factor

r_E = the radius of the earth = 6,370km.

In a standard atmosphere and if the whole first Fresnel zone is clear in a path profile, K = k₀ = 4/3. Path profiles are very necessary when considering radio relay link and radio path.

The basic path loss, a₀ is calculated using the equation

$$A = 92.4 (d\beta) + 20\log Dt (d\beta) + 20\log f (d\beta) \quad (7)$$

Optimally, the value of A₀ can also be measured and read from graphs.

2. Research Method

2.1 Radio Equipment/Materials

To measure the telecommunications signal strength pattern along the route from Uyo to Eket, a wireless link was

established in all the surveyed interceptions to determine any impeding structure tending to obstruct signal propagation. The radio equipment selected and used for this work were the following:

- 1) A global positioning system (GPS)
- 2) A parabolic antenna of Skynet network
- 3) Computer set
- 4) The transmitting antenna and receiving antenna

2.2 Receiving Antenna and Transmitting Antenna

The receiving antenna that was installed at various locations was a 10dB, 180° fixed sectorized antenna for outdoor monitoring. The under listed accessories were used during the installation of the antenna to establish effective connection while monitoring through the computer terminal.

- 1) RF coaxial cable (thin net cable LM400)
- 2) The wireless radio card for the receiving antenna
- 3) An indoor DC injector and outdoor amplifier for the fixed sectorizing antenna
- 4) Rolls of insulation tapes
- 5) PCMCIA adaptor for wireless card
- 6) Pig-tail connector for wireless card.

The transmitting antenna provided by Skynet is a parabolic antenna. Skynet is a wireless service provider that operates on a lease frequency of 2.3 GHz and covers a distance of 64km. The channel frequency used in the study was 2.1GHz. The gain of the antenna was 33.8dB with effective coverage area of 3.5m² and efficiency of 58 per cent. The base station (Skynet) used the bus (base station unit) configuration manager to effectively monitor the signal and the data rate received at the receiver end.

2.3 Methodology

The investigation included physical site survey, GPS measurements, calculation and plotting of Fresnel zone clearance, consideration of antenna location and installation.

2.3.1 Information about the study Location

AkwaiBom is a state in Nigeria named after the Qua Iboe River. It is located in the coastal south-southern region of the country, lying between latitudes 4°32' and 5°33' north, and longitude 7°25' and 8°25' east [6]. The state is bordered on the east by Cross River State, on the west by River State and Abia State, and on the South by the Atlantic Ocean and southernmost tip of Cross River State.

AkwaiBom is one of Nigeria's 36 states with a population of over 5 million people and more than 1 million people in the Diaspora. It was created in 1987 from the former Cross River State and is currently the highest oil and gas producing state in the country [6]. The route under investigation was partitioned into 6 selected locations: Uyo, Afaha-Nsit, Nsit-Ubium, Eket, Ikot-Ekpene and Abak.

Table 1: Locations classifications and their characteristics

Locations	Classification	Characteristics
Uyo	State capital (coastal/hinterland)	Heavy road traffic, level terrain, large number of cluster high-rise buildings and many telecom companies.
Etinan	Semi-Urban (hinterland)	Light road traffic, mile numbers of buildings, level terrain, trees and telecomm companies.
Eket	Urban (hinterland)	Heavy road traffic, large numbers of cluster high-rise buildings, level terrain and telecom companies
Oron	Semi-urban (coastal)	Very light traffic, tall trees, hill and telecom companies.
AfahaNsit	Semi-urban (hinterland)	Light road traffic, sparsely distributed buildings, trees and telecom companies.

3. Results and Discussion

3.1 Results

GPRS was used to collate results from measurements carried out.

Table 2 presents the path distance measured in kilometers and the elevation of each of the location above sea level.

In order to establish a clear line-of-sight, measurements were taken from the point of possible obstruction, starting from the transmitting station to the perceived obstruction and from the perceived obstruction to the receiving station. The Fresnel zone clearance was there after calculated in order to determine the unobstructed line-of-sight. Table 3 shows the distance of possible obstruction from the TX to RX.

Table 2: Path distance from Uyo to the site elevation above sea-level

Locations	Path distance (km)	Elevation (m)
Uyo	5.9	69.3
Etinan	12.5	82.5
Afaha-Nsit	22.6	89.4
NsitUbium	35.3	74.3
Eket	43.4	35.4

Table 3: Distance of possible obstruction from the transmitter to the obstacle and from the obstacle to the receiver

Location	Path distance (km)	Distance from the TX to the obstacle d ₁ (km)	Distance from the obstacle to RX d ₂ (km)
Uyo	5.9	3.4	2.5
Etinan	12.5	7.5	5.0
Afaha-Nsit	22.6	7.3	15.3
NsitUbium	35.3	20.3	15.0
Eket	43.4	13.4	30.0

3.2 Discussions

Table 4 below shows the distance measured in kilometers. In addition, attenuation of signals free from all perceived obstructions was obtained using equation 2.7. The values highlighted in the afore-mentioned table have accorded

credence to the claim that free space attenuation increases as path distance increase.

A critical look at the table shows that the rate of attenuation due to free space, without any obstruction at Uyo was 166.8dB, at a path distance of 5.9km. This was consequent to the fact that Uyo had the lowest path distance in the table. Likewise, the highest rate of attenuation was recorded at Eket which has the farthest path distance from the transmission station as shown in the table. Locations like Etinan, AfahaNsit and NsitUbium had a relatively long path distance of 12.5km, 22.6km and 35.3km and signal attenuation of 173.3dB, 178.4dB and 182.3dB respectively.

Table 4: Path distance and attenuation from free space

Location	Path distance (km)	Attenuation A_0 (dB)
Uyo	5.9	166.8
Etinan	12.5	173.3
AfahaNsit	22.6	178.4
NsitUbium	35.3	182.3
Eket	43.4	184.0

Table 5: Antenna height and the measured Fresnel zone peaks

Location	Antenna height (m)	0.6 Fresnel zone peak (m)	1.0 Fresnel zone peak (m)	2.0 Fresnel zone peak (m)
Uyo	11.2	6.3	10.6	13.6
Etinan	13.4	7.8	13.0	17.6
AfahaNsit	23.6	12.0	20.8	24.1
NsitUbium	40.5	15.6	26.0	31.2
Eket	14.5	17.3	28.9	34.6

Table 5 above shows the calculated Fresnel zone peak values using a computer base Fresnel zone calculator for 0.6, 1.0 and 2.0 peak values. Accordingly, the result of the analysis in the table above was used to plot the Fresnel zone for 0.6, 1.0 and 2.0 peaks values for the five locations shown below.

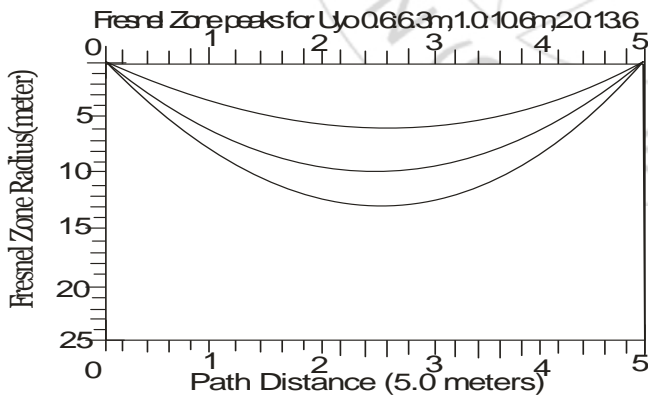


Fig.1: Fresnel zone Clearance for Uyo

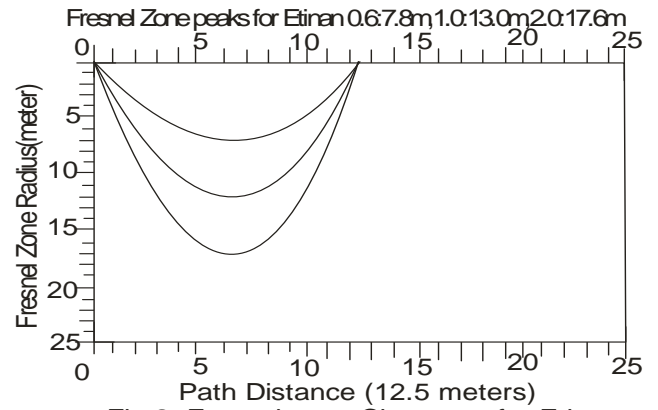


Fig.2: Fresnel zone Clearance for Etinan

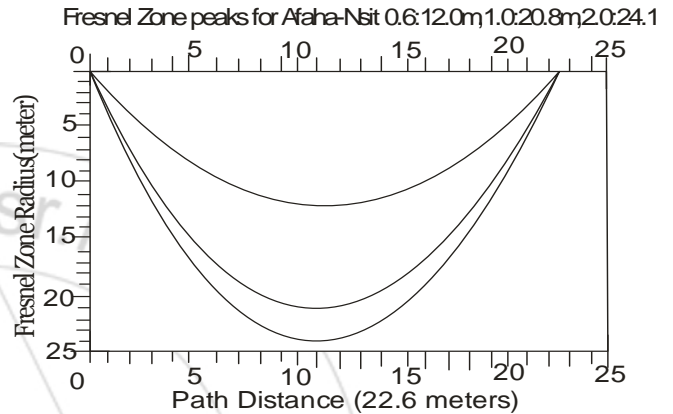


Fig.3: Fresnel zone Clearance for Afaha-Nsit

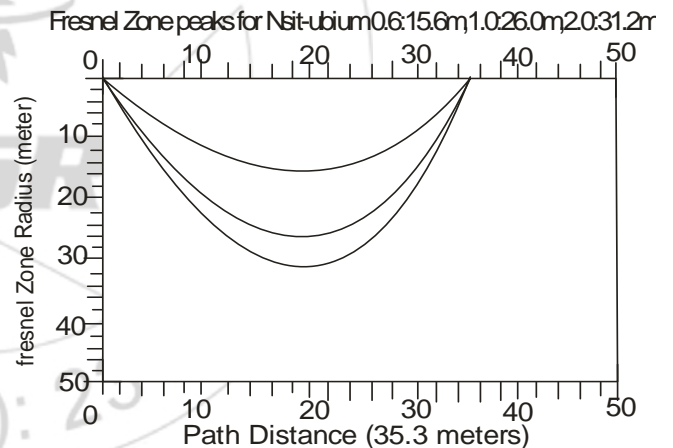


Fig.4: Fresnel zone Clearance for Nsit-Ubium

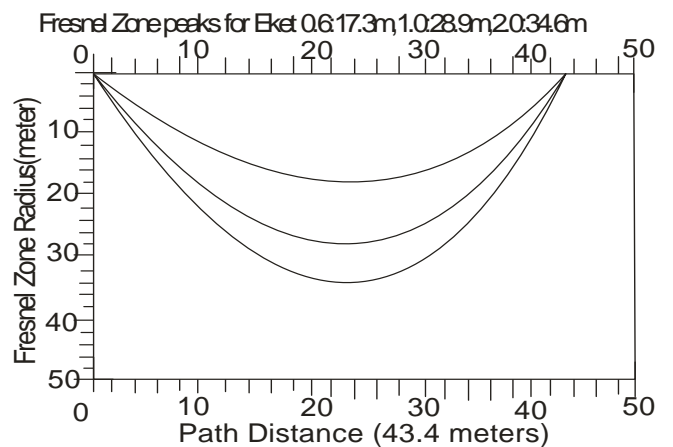


Fig.5: Fresnel zone Clearance for Eket

Table 6: Signal Strength and Signal-to-noise ratio (SNR) values.

Location	Signal strength (dB)	Received signal to noise ratio (dB)	
		Lowest signal value (dB)	Highest signal value (dB)
Uyo	-83	11	17
Etinan	-81	10	19
AfahaNsit	-82	11	17
NsitUbium	-83	12	16
Eket	-84	13	18

Table 6 shows the values obtained from the wireless client manager. The table shows that the signal strength was highest at Etinan with -81dB and the lowest signal-to-noise ratio (SNR) value of 10dB. The highest was 19 dB. Uyo and Nsit-Ubium had similar values of -83dB as indicated in the table. Though, Uyo had a better signal-to-noise ratio of 11dB, representing the lowest and 17dB as the highest, while Nsit-Ubium recorded 12dB as the lowest and 16dB for the highest, also recorded a value of -83dB. The weakest signal strength of -86dB was recorded for Eket. Eket, the main focus of the study recorded signal strength of -84dB and signal-to-noise ratio (SNR) of 13dB as the lowest, while 18dB for the highest.

From the result in Table 6, the fact that Etinan was classified as an urban area with few clutters of high buildings, few trees, light road traffic along the path of line-of-sight, gave strong signal strength of -81dB and a good signal-to-noise ratio. Further highlight were presented in the table.

4. Conclusion

From the result of the survey conducted in this work, line-of-sight was established in all the five (5) locations linking Uyo and Eket. (Uyo, Etinan, AfahaNsit, NsitUbium and Eket). Though, the best line-of-sight (LOS) was established at Etinan (-81dB signal strength). AfahaNsit, recorded the second best on the table (-82dB). On the other hand, locations like Eket and Nsit-Ubium established very poor line-of-sight (signal strength of -84dB and -83dB respectively). This is in line with [3], who deduced that signal strength and attenuation increased as the path distance increased. The study further noted that, obstruction like trees along the route to Eket contributed greatly to the poor results obtained at the terminal point of the signal; except for the meticulous positioning of the antennae. Moreover, interference from other transmitting stations like Globacom, Etisalat, Airtel and MTN could be one factor obstructing good signal strength. The study noted the variance recorded in this work from the previous reported study by the same author, where the Fresnel zone was changed and the frequency correspondingly decreased; while increase in signal wavelength was observed. This modification, as shown in the figures, reduced the energy of the transmitted wave. Comparatively, from this study, it was observed that the reduction in the channel frequency increased the rate of attenuation across the locations as well as the signal strength.

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