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Estimationof Diffraction Loss over Obstacles and Irregular Terrain on Microwave Link Station Using a Single Knife Edge Mechanism

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Abstract

Diffraction is produced by the surface of the ground or other obstacles. This work seeks to investigate the loss due to diffraction of radio frequency signals in the tropics, by employing single knife edge line mechanism as an obstacle on the Line of Sight (LOS) transmission link.

The numerical calculation for the diffraction loss J (v) in decibel (dB) was done using the International Telecommunication Union Radio (ITUR) methods, at various heights in meters (m) of the obstacles on the Line of Sight (LOS) path.

Keywords: Diffraction, knife edge, Line of Sight

1.0 Introduction

Many propagation paths encounter one obstacle or several separate obstacles and it is useful to estimate the losses caused by such obstacles. To make such calculations it is necessary to idealize the form of the obstacles, either assuming a knife edge of negligible thickness or a thick smooth obstacle with a well-defined radius of curvature at the top [1].

In cases where the direct path between the terminals is much shorter than the diffraction path, it is necessary to calculate the additional transmission loss due to the longer path. The numerical calculations employed for this work apply when the wavelength is fairly small in relation to the size of the obstacles, i.e. mainly to VHF and shorter waves (f > 30MHz) [1].

The benchmark by which we measure the loss in a communication link is the loss that would be expected to occur in a region which is made up of objects that might absorb or reflect the radio energy.Consider a transmitter with power $P_t$coupled to an antenna, which radiates equally in all directions (the isotropic antenna). At a distance d from the transmitter, the radiated power is distributed uniformly over an area (i.e the surface of a sphere of radius d), to produce a power flux density. The transmission loss then depends on how much of this power is captured by the receiving antenna. A case of no mismatch or feed line losses was considered for this work.

2.0 Numerical Calculations

For the purpose of this work, an ideal case was considered. All the geometrical parameters are combined together in a single dimensionless parameter normally denoted by υ which may assume a variety of equivalent forms according to the geometrical parameters selected [2]:

$$\upsilon = h\sqrt{\frac{2}{\lambda}\left(\frac{1}{d_1} + \frac{1}{d_2}\right)} \quad (1)$$

$$\upsilon = \theta\sqrt{\frac{2}{\lambda\left(\frac{1}{d_1}+\frac{1}{d_2}\right)}} \quad (2)$$

$$\upsilon = \sqrt{\frac{2h\theta}{\lambda}} \qquad (\upsilon \text{ has the sign of h and } \theta) \quad (3)$$

$$\upsilon = \sqrt{\frac{2d}{\lambda}\ .\alpha_1\alpha_2} \qquad (\upsilon \text{ has the sign of } \alpha_1 \text{and } \alpha_2) \quad (4)$$

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Where:
h: height of the top of the obstacle above the straight line joining the two ends of the path. If the height is below this line, h is negative.
d_1 and d_2 : distances of the two ends of the path from the top of the obstacle
d: length of the path = 13.2 Km
θ: angle of diffraction (rad); its sign is the same as that of h. The angle θ is assumed to be less than about 0.2rad, or roughly 12^0.
α_1 and α_2 : angles between the top of the obstacle and one end as seen from the other end.
α_1 and α_2 are of the sign of h in the above equations.
Note that equations (1) to (4) inclusive h, d, d_1, d_2, and λ should be in self- consistent units.
The loss due to diffraction as a function of υ, J (υ) was calculated by assuming a single knife edge obstacle mechanism given by the expression [3]:

$$J(\upsilon) = 6.9 + 20 \log \left(\sqrt{(\upsilon - 0.1)^2 + 1} + \upsilon - 0.1\right) \quad (5)$$

The values of υ and J (υ) can thus be calculated respectively. The effective isotropic radiated power (e.i.r.p) [4] is given by the relation:
e.i.r.p = P × G_t
Where,
P: output power of the transmitter in watts
G_t: gain of the transmitter in absolute terms.

Table 1: Basic input parameters of the two NTA microwave stations. (Source: Nigerian Television Authority, (NTA) stations at Oba-Ile and Iju/Itaogbolu).

Preferred Resolution	**Description**
0.01GHz	Frequency (GHz) f = 7.776GHz
0.01%	Required time percentages for which the calculated basic transmission loss was not exceeded. p = 50%,60%,7%,80%,90%,and 100% of time.
0.001%	Latitude of transmitting station. Φ_t = N7°15.34
0.0001%	Longitude of transmitting station. Ψ_t = E5°15.565
0.001%	Latitude of receiving station. Φ_r = N7°22.621
0.001%	Longitude of receiving station. Ψ_r = E5°15.484
1m	Transmitting antenna centerheight above ground level (m). H_{tg} = 61m [200ft]
1m	Receiving antenna center heightabove ground level (m). H_{rg}= 202m [663ft]
1m	Transmitting antenna center height above mean sea level (amsl)(m) H_{ts}= 331m [1086ft]
1m	Receiving antenna center height above mean sea level (amsl) (m). H_{rs}= 416m [1365ft]
0.1	Transmitting antenna gain in thedirection of the horizon alongthe great-circle interference path.G_t = 46.5
0.1	Receiving antenna gain in the direction of the horizon along the great-circle interference path. G_t= 46.5

NOTE: t = transmitting station, r = receiving station.

3.0 Results and Discussions

Table 2: Diffraction loss J (υ) at various heights h

h	J(υ)	d_1 to d_2
0	-72	1,000
10	19.9	2,000
20	27.3	3,000
30	30.2	4.000
40	34.0	5,000
50	36.4	6,000
60	38.3	7,000
70	40.1	8,000
80	41.5	9,000
90	42.9	10,000
100	44.2	11,000
110	45.5	12,000
120	46.6	13,000
130	47.5	14,000

The Figures 1 and 2 depict the loss with the height h of obstruction at various points within the microwave link and J (υ) is the diffraction loss.

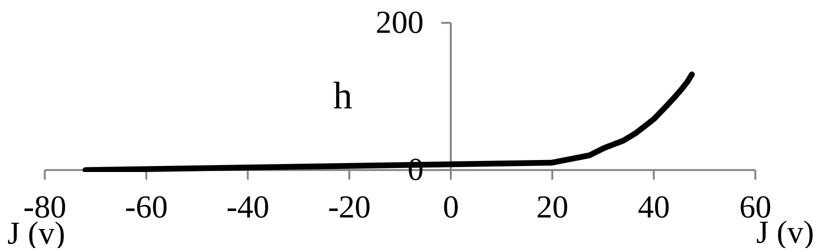

Figure 1: Graph of diffraction loss J (υ)vs obstacle height h

Table 3: Obstacle height h for various difraction loss J(υ)

h	J (υ)
0	-72
10	19.9
20	27.3
30	30.2
40	34.0
50	36.4
60	38.3
70	40.1
80	41.5
90	42.9
100	44.2
110	45.5
120	46.6
130	47.5

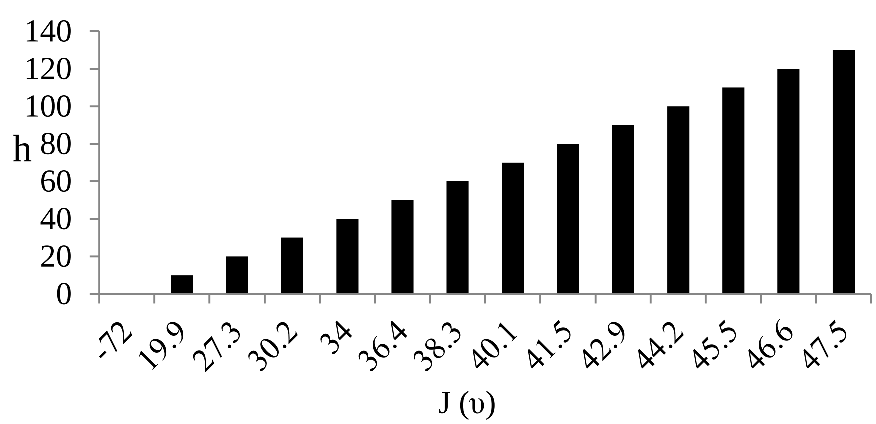

Figure 2: Bar chart of obstacle height h vs diffraction loss J(υ)

From the Figures 1 and 2, the rate of transmission loss increases with the height of the obstacle. This mean that as you progress along the link, there is the tendency of the signal crossing obstacles whose height can cause signal diffraction and reflection.

4.0 Conclusion

The loss of transmission of radio signals can be significant due to diffraction from obstacles of different heights and this is more as the height of the obstacles increases. This loss can pose a great deal of attenuation and impairment to the radio signal. Allowance should be made for the use of tall masts at both ends of the link, transmission be done at an effective isotropic radiated power (e.i.r.p), and both antennas should be of a high gain and the transmission mechanism should be Line of Sight (LOS).

Budget should be made for the signal fading through diffraction losses by obstacles or clutters capable of causing degradation or outage at transmission and receiving times in built up environments or otherwise.

It should be noted that loss capabilities can always arise due to improper Line of Sight (LOS) propagation techniques and so therefore care should be taken to ensure that correct and adequate Line of Sight (LOS) propagation technique is deployed for optimum performance.

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