Determination of Diffraction Loss over Isolated Doubled Edged Hill Using the ITU-R P.526-13 Method for Rounded Edge Diffraction

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Abstract: In this paper, Recommendation ITU-R P.526-13 rounded edge diffraction loss method is used to determine the diffraction loss over a double edged hilltop in the path of 6 GHz C-band microwave signal. The computation is based on the path profile with path length of 6188.665 m. The path profile has maximum elevation of 412.75 m and it occurred at a distance of 2877.3 m from the transmitter. The line of sight clearance height is 35.393521m and occultation distance is 532.203m. The diffraction loss computed for the double edged hilltop using the Recommendation ITU-R P.526-13 model is 42.563065 dB.

Keywords: Diffraction Loss, Diffraction Parameter, Doubled Edged Hill, ITU-R P.526-13 Method, Rounded Edge Diffraction

1. Introduction

In wireless communication system, as signal propagates along the path from transmitter to the receiver, it experiences reduction in signal strength which is generally referred to as path loss [1-5]. The path loss may include propagation losses caused by the natural expansion of the radio wave front in free space, absorption losses, as well as diffraction losses when part of the radio wave front is obstructed by an opaque obstacle [6-12]. In other to estimate the diffraction loss caused by isolated obstacles like hills, mountains, buildings, such isolated obstacles are modeled as single knife edge obstructions [13-15]. However, in reality, the obstruction presents more diffraction loss than the single knife edge approximation. In that case, rounded edge diffraction loss approximation may be applied to such isolated obstacles.

Over the years, several methods for determination of rounded edge diffraction loss have been developed. One of the popular approaches is a method to determine the excess diffraction loss above the knife edge diffraction loss. The access diffraction loss can be computed according to Hacking method [1], [17]. Wait method is another method for computing the access diffraction loss in addition to the knife edge approximation [18], [19]. However, in this paper, the method presented by the International Telecommunication Union (ITU) for computing diffraction loss over single rounded obstacle is used to compute the diffraction loss over double edged hilltop [20].

In all the methods of computing diffraction loss over rounded edge, the basic approach is to fit a rounded edge to the vertex of the obstruction and then use the radius of curvature of the rounded edge to compute the diffraction loss [21], [22]. In most cases, hilly obstructions do not have single edges top. Rather more than one edges that are close together may be presented. In this case, the single rounded edge that will be fitted to vertex of the hill will have to enclose all the adjacent edges on the hilltop. In this case, the radius of curvature of the rounded edge may be well above what the value should have been if the rounded edge was to enclose only one edge on the hilltop. The study in this paper considers a situation where there are two adjacent edges on the hilltop to which a single rounded edge will be fitted and then used to determine the diffraction loss based on the ITU-R P.526-13

method for rounded edge diffraction [20].

2. The ITU-R P.526-13 Method for Diffraction over Single Rounded Edge

The diffraction loss for single rounded obstacle according to Recommendation ITU-R P.526-13 is given as follows [20]:

$$A_{dB} = J(v) + T(m, n) \quad (1)$$

where:

$J(v)$ is the Fresnel-Kirchhoff loss due to an equivalent knife-edge placed with its peak at the vertex point. According to ITU –R 526, t he knife edge diffraction loss, $J(v)$ is given as;

$$J(v) = 6.9 + 20\text{Log}\left[\left(\sqrt{(v-0.1)^2 + 1}\right) + v - 0.1\right] \quad (2)$$

v is the diffraction parameter. The diffraction parameter v is given as;

$$v = h\sqrt{\frac{2(d_1 + d_2)}{\lambda(d_1)(d_2)}} \quad (3)$$

where Λ is the signal wavelength which is given as;

$$\Lambda = \frac{c}{f} \quad (4)$$

f is the frequency in Hz and c is the speed of light which is $3\text{x}10^8$ m/s.

h is the line of sight (LOS) clearance which is obtained from the path profile and obstruction geometry, as shown in figure 2.

d_1 is distance from the transmitter to the point where the LOS clearance is measured, as shown in figure 2.

d_2 is distance from the receiver to the point where the LOS clearance is measured, as shown in figure 2.

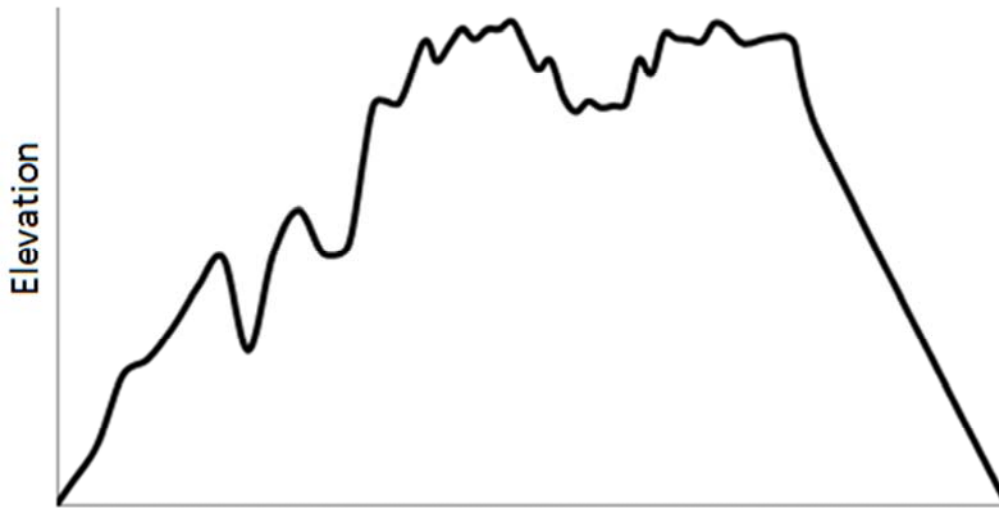h and λ are in meters, and d1 and d2 are in kilometres.

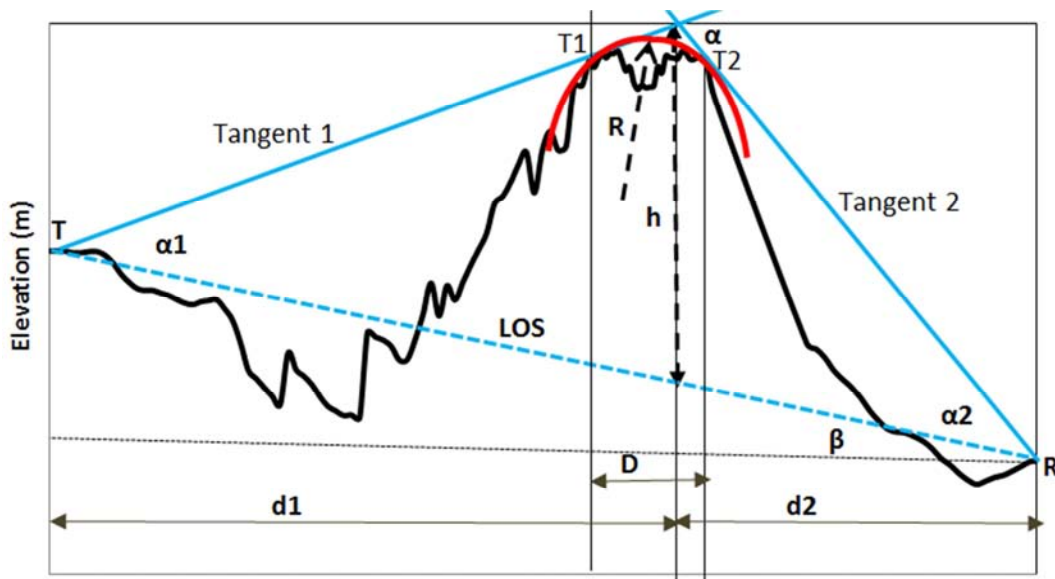*Figure 1. The path Profile Plot Of The Double Edged Hill.*

Figure 2. The Path Profile and Double Edged Hill Obstruction Geometry.

$T(m, n)$ is the additional attenuation due to the curvature of the obstacle and it is given as [20]:

$$T(m, n) dB = 7.2(m)^{1/2} - (2 - 12.5n)m + 3.6(m)^{3/2} - 0.8(m)^2 \; for \; mn \leq 4 \tag{5}$$

$$T(m, n) \; dB = -6 - 20 Log(mn) + 7.2(m)^{1/2} - (2 - 17n)m + 3.6(m)^{3/2} - 0.8(m)^2 \; for \; mn > 4 \tag{6}$$

Where,

$$m = \frac{R\left(\frac{(d_1 + d_2)}{(d_1)(d_2)}\right)}{\left[\frac{\pi(R)}{\lambda}\right]^{1/3}} \tag{7}$$

$$n = \frac{h\left[\frac{\pi(R)}{\lambda}\right]^{2/3}}{R} \tag{8}$$

The radius, R of the circle fitted in the vicinity of the double edged hill vertex can be given the expression (Seybold, 2005, Barué, 200);

$$R = \frac{2\,(D)(d_1)(d_2)}{(\alpha)[(d_1)^2 + (d_2)^2]} \tag{9}$$

where D is the occultation distance and it is obtained from the graph plot of the path profile and geometry of the obstruction, as shown in figure 2. Particularly, a line (referred here as tangent 1) is drawn from the transmitter to be tangential to the path profile at the vicinity of the hill apex. Let the tangent point of tangent 1 with the path profile be denoted as T1. Again, another line (referred here as tangent 2) is drawn from the receiver to be tangential to the path profile at the vicinity of the hill apex. Let the tangent point of tangent 1 with the path profile be denoted as T2. Then, D is the distance between T1 and T2. The point at which the tangent 1 and tangent 2 intersect above the hill vertex, as shown in figure 2. becomes the knife edge point. The LOS clearance is the height from the line of sight to the point of intersection of tangent 1and tangent 2.

Let β be the angle the LOS makes with the horizontal where;

$$\beta = tan^{-1}\left(\frac{H_t - H_r}{d}\right) \tag{10}$$

where

H_t is the height of the transmitter and H_r is the height of the receiver and d is the distance between the transmitter and the receiver. The values of d, H_t and H_r are obtained from the path profile data.

$$d = d_1 + d_2 \tag{11}$$

Let α_1 be the angle (in radian) between the LOS and tangent 1 and let α_2 be the angle (in radian) between the LOS and tangent 2 then, α is the external angle (in radian) between tangent 1 and tangent 2 at their point of intersection above the hill vertex, where

$$\alpha = \alpha_1 + \alpha_2 \tag{12}$$

The angles α_1 and α_2 are obtain by cosine rule as follows;

$$Cos(\alpha_1) = \frac{(S_1)^2 + (S_3)^2 - (S_2)^2}{2(S_1)(S_3)} \tag{13}$$

$$\alpha_1 = Cos^{-1}\left(\frac{(S_1)^2 + (S_3)^2 - (S_2)^2}{2(S_1)(S_3)}\right) \tag{14}$$

Similarly,

$$\alpha_2 = Cos^{-1}\left(\frac{(S_2)^2 + (S_3)^2 - (S_1)^2}{2(S_2)(S_3)}\right) \tag{15}$$

where

S_1 is the length of the tangent 1 measured from the transmitter to the point of intersection of tangent 1 and tangent 2, as shown in figure 2.

S_2 is the length of the tangent 2 measured from the receiver to the point of intersection of tangent 1 and tangent 2, as shown in figure 2.

S_3 is the length of the LOS measured from the transmitter to receiver

S_1, S_2 and S_3 are in meter and they are measured out from the path profile plot and the tangent line drawn on the path profile.

The line of sight (LOS) clearance, h is given as;

$$h = \frac{S_1[Sin(\alpha_1)]}{Sin(90 - \beta)} \tag{16}$$

3. Results and Discussions

The study if conducted for the L-band microwave frequency which ranges from 1 GHz to 2 GHz. Specifically, the 1 GHz and 1.9 GHz frequencies are considered in this paper. The elevation profile data used for the study is given in Table 1. From Table 1 the maximum elevation is 412.75 m and it occurred at a distance of 2877.3m from the transmitter.

***Table 1.** The Elevation Profile For The Plateau.*

Distance (m)	Elevation (m)	Distance (m)	Elevation (m)	Distance (m)	Elevation (m)	Distance (m)	Elevation (m)	Distance (m)	Elevation (m)
0.0	390.9	1206.9	379.8	2413.8	401.7	3180.8	411.8	4876.1	366.9
40.2	390.9	1247.2	378.0	2454.1	397.3	3201.0	412.7	4921.4	367.5
80.5	390.9	1287.4	377.2	2494.3	401.8	3221.2	412.5	4966.7	368.0
120.7	390.7	1327.6	376.3	2534.5	403.9	3248.1	411.7	5011.9	368.0
160.9	390.7	1367.8	375.0	2574.8	401.8	3288.3	412.0	5057.2	368.0
201.2	390.9	1408.1	374.0	2615.0	402.3	3328.6	411.8	5102.4	368.0
241.4	390.9	1448.3	373.4	2655.2	408.8	3368.8	407.4	5147.7	368.0
281.6	390.4	1488.5	372.9	2695.5	408.9	3835.2	380.8	5193.0	368.5

Distance (m)	Elevation (m)	Distance (m)	Elevation (m)	Distance (m)	Elevation (m)	Distance (m)	Elevation (m)	Distance (m)	Elevation (m)
321.8	389.6	1528.8	373.0	2735.7	411.8	3880.4	380.3	5238.2	369.0
362.1	388.4	1569.0	372.7	2755.9	410.9	3925.7	379.3	5283.5	369.3
402.3	387.5	1609.2	382.0	2776.1	411.7	3971.0	377.9	5328.7	369.4
442.5	386.9	1649.5	381.5	2796.4	412.4	4016.2	376.9	5374.0	368.9
482.8	386.7	1689.7	381.2	2816.6	411.9	4061.5	376.0	5419.3	368.3
523.0	386.7	1729.9	380.5	2836.8	412.4	4106.7	374.9	5464.5	368.0
563.2	386.4	1770.1	379.0	2857.1	412.4	4152.0	373.5	5509.8	367.9
603.5	386.1	1810.4	379.1	2877.3	412.8	4197.2	372.4	5555.0	368.7
643.7	385.6	1850.6	381.3	2897.5	411.7	4242.5	371.5	5600.3	367.5
683.9	385.2	1890.8	384.0	2917.8	410.5	4287.8	371.2	5645.6	366.9
724.2	385.1	1931.1	387.5	2938.0	411.0	4333.0	371.1	5690.8	366.3
764.4	385.4	1971.3	383.8	2958.2	409.2	4378.3	370.7	5736.1	366.4
804.6	385.5	2011.5	387.2	2978.5	408.5	4423.5	370.2	5781.3	366.4
844.8	385.6	2051.8	385.6	2998.7	409.0	4468.8	369.4	5826.6	366.2
885.1	384.6	2092.0	387.5	3018.9	408.7	4514.1	368.3	5871.8	367.1
925.3	383.4	2132.2	389.4	3039.1	408.8	4559.3	367.6	5917.1	366.0
965.5	380.9	2172.5	391.1	3059.4	408.9	4604.6	366.7	5962.4	366.9
1005.8	377.9	2212.7	392.8	3079.6	411.0	4649.8	366.0	6007.6	367.7
1046.0	377.0	2252.9	396.1	3099.8	410.3	4695.1	365.5	6052.9	368.6
1086.2	376.0	2293.1	396.8	3120.1	412.2	4740.4	365.9	6098.1	370.9
1126.5	375.0	2333.4	398.3	3140.3	412.0	4785.6	366.3	6143.4	370.9
1166.7	374.1	2373.6	400.3	3160.5	411.9	4830.9	366.5	6188.7	370.9

Table 2. *The diffraction loss and associated parameters for the double edged hilltop using the Recommendation ITU-R P.526-13 model.*

f (GHz)	Frequency	6000
λ (m)	Wavelength	0.05
S1 (m)	The length of the tangent from the transmitter to the intersection point of the two tangent	3086.7642
S2 (m)	the length of the tangent from the receiver to the intersection point of the two tangents	3102.3379
S3 (m)	the length of the tangent from the receiver from the transmitter	6188.6974
d1 (m)	the distance from the transmitter to the intersection point of the two tangents, that is point	3086.6596
d2 (m)	the distance from the receiver to the intersection point of the two tangents	3102.0054
d (m)	the distance from the transmitter to the receiver	6188.665
αt (radian)	The angle the tangent line from the transmitter makes with the LOS	0.0114088
αr (radian)	The angle the tangent line from the receiver makes with the LOS	0.0114664
α (radian)	Sum of angles αt and αr	0.0228753
β (radian)	The angle the LOS makes with the horizontal	0.0032335
h (m)	The LOS clearance height	35.393521
D (m)	The occultation distance	532.203
n		19.596466
m		0.1324933
k		243.35759
b		1
V	Diffraction parameter for the ITU-R P.526-13 Method	0.1798348
R (m)	The radius of the circle fitted in the vicinity of the hill vertex	23265.392
J (v)		7.5927016
T (m, n)		32.243248
A (dB)	The diffraction loss for the double edged hilltop using the Recommendation ITU-R P.526-13 model	42.563065

Table 2 shows diffraction loss and associated parameters for the double edged hilltop using the Recommendation ITU-R P.526-13 model. From Table 2, the path length (d) is 6188.665 m. Also, the tangent from the transmitter and the tangent from the receiver intersected at a distance of 3086.6596m from the transmitter and a distance of 3102.0054 m from the receiver. The line of sight makes an angle of 0.0032335 radians with the horizontal. The LOS clearance height is 35.393521m. The occultation distance is 532.203m. The diffraction loss computed for the double edged hilltop using the Recommendation ITU-R P.526-13 model is 42.563065 dB.

4. Conclusions

Recommendation ITU-R P.526-13 model for rounded edge diffraction loss method is presented. The method is used to determine the diffraction loss over a double edged hilltop in the path of 6 GHz C-band microwave signal. The computation is based on the path profile of a cases study with double edged hilltop.

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