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Algorithm for Computing N Knife Edge Diffraction Loss Using Epstein-Peterson Method

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Abstract: In this paper, algorithm for computing N knife edge diffraction loss using Epstein-Peterson method and International Telecommunication Union (ITU) knife edge diffraction loss approximation model is presented. Requisite mathematical expressions for the computations are first presented before the algorithm is presented. Then sample 10 knife edge obstructions are used to demonstrate the application of the algorithm for L-band 1 GHz microwave signal. The results showed that for the 10 knife edge obstructions spread over a path length of 36 km the maximum virtual hop single knife edge diffraction loss is 8.054711 dB and it occurred in virtual hop j =10 which has the highest diffraction parameter of 0.233333. However, the virtual hop j =10 has line of site (LOS) clearance height of 2.333333 m whereas the highest LOS clearance is 3.454545 m and it occurred in virtual hop j =6. The minimum virtual hop single knife edge diffraction loss is 6.109884 dB and it occurred in virtual hop j =3 which has the lowest diffraction parameter of 0.008909 as well as the lowest LOS clearance height of 0.142857 m. The algorithm is useful for development of automated multiple knife edge diffraction loss system based on Epstein-Peterson method and ITU knife edge diffraction loss approximation model.

Keywords: Diffraction Loss, Diffracting Parameter, ITU-R P 526-13 Model, Knife Edge Obstruction, Epstein-Peterson Diffracting Method, Single Knife Edge Diffraction, Multiple Knife Edge Diffraction

1. Introduction

Propagation paths of line of sight microwave signals are in many cases obstructed by obstacles [1, 2]. When a single isolated obstruction is considered, such as hill or building, such obstruction is approximated as knife edge obstruction [3, 4]. In that case, single knife edge obstruction approach is used to estimate the diffraction loss that signals may suffer as they encounter the knife edge obstruction.

In reality, there are always two or more obtrusions that are often located in the signal path. In such case, multiple knife edge diffraction methods are used to determine the expected diffraction loss [5, 6]. Studies have shown that computation of multiple knife edge diffraction loss is complex and it complexity increases especially as the number of knife edge obstructions considered increases [7, 8]. As such, available studies limit the computation to two or three obstructions. In this paper, an algorithm that can be used to determine the diffraction loss of any number of knife edge obstruction is presented. The multiple knife edge computation is based on the Epstein-Peterson method [9-13] whereas the International Telecommunication Union Recommendations (ITU-R) P 526-13 knife edge diffraction loss approximation model [14-17] is used to determine the diffraction loss for any diffraction parameter obtained for each of the knife edge obstruction. Sample 10 knife edge obstructions are used to demonstrate the applicability of the algorithm.

2. Epstein-Peterson Multiple Knife Edge Diffraction Loss Method

Figure 1 shows N knife edge obstructions with n =1, 2, 3,…, N-1, N. The transmiter is regarded as N = 0 and the receiver is designated as N+1. Each of the N obstructions blocks the line of sight and consitutes an edge that will cause diffraction loss and also introduces a virtual hop in the multiple edge diffraction loss analysis. Each virtual hop has one knife edge that causes diffraction and either one or two other knife edge obstructions that serve as either the virtual transmitter or the virtual receiver for a given virtaul hop. In figure 1 for the N knife edge obstructions there are N virtual hops. The first three virtual hops are;

i. Hop1: H_0-H_1-H_2 with H1 as the diffraction edge
ii. Hop2: H_1-H_2 -H_3 with H2 as the diffraction edge
iii. Hop3: H_2 -H_3 -H_4 with H3 as the diffraction edge

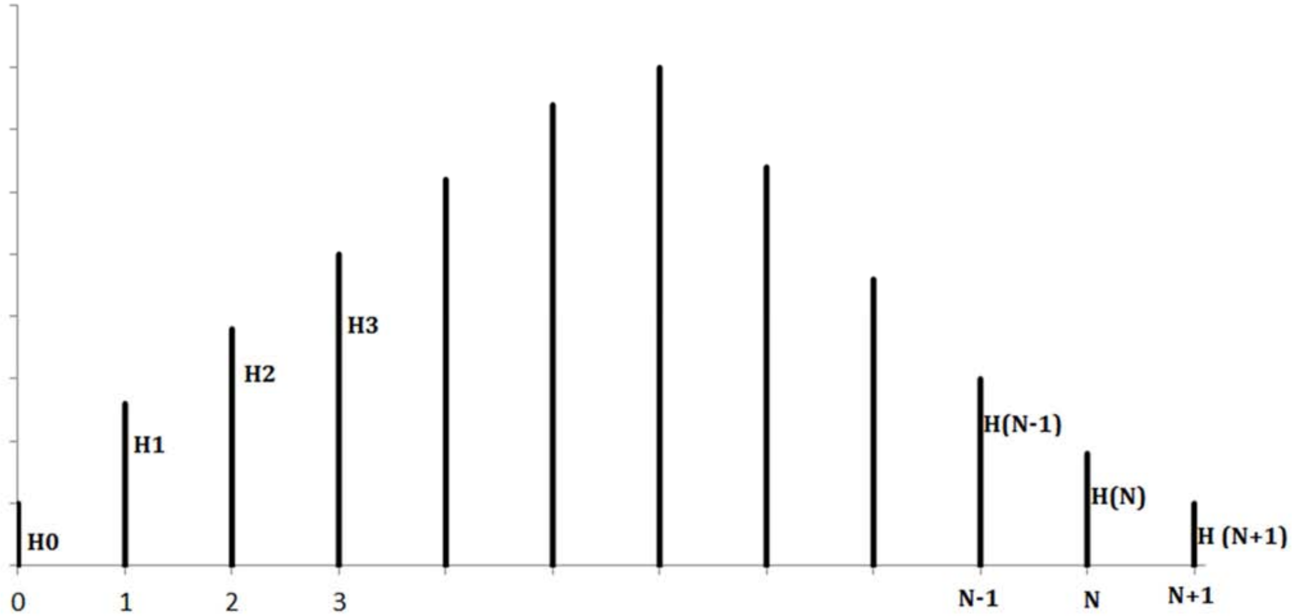

Figure 1. *Knife Edge Obstructions.*

In figure 1, H_j is the height of the obstruction from the sea level. Idealy, H_j takes into account the earth bulge, the elevation and the obstruction height measured from the ground level. Again, j =0 referes to the receiver whereas j =N+1 referes to the transmitter. J = 1 to J = N referes to the obstructions 1, 2, 3,…N respectively. According to Epstein-Peterson multiple knife edge diffraction loss method, for any given hop j, the clearance height to its LOS is given as h_j where [18];

$$h_j = h_{Epstein(j)} = H_j - H_{j-1} - \left(\frac{d_j(H_{j+1} - H_{j-1})}{d_j + d_{j+1}}\right) \quad (1)$$

The knife-edge diffraction parameter for any hop j is given as v_j where [18];

$$v_j = h_{Epstein(j)} \sqrt{\frac{2(d_j + d_{j+1})}{\lambda(d_j)(d_{j+1})}} \quad (2)$$

For any given diffraction parameter, v the knife-edge diffraction loss, A according to ITU-R 526 is given as;

$$A = 6.9 + 20\text{Log}\left(\left(\sqrt{(v - 0.1)^2 + 1}\right) + v - 0.1\right) \quad (3)$$

where A is in dB

Then, in respect of knife-edge diffraction loss for any hop j with diffraction parameter, v_j, the knife-edge diffraction loss is denoted as A_j, where ITU approximation model for A_j is given as;

$$A_j = 6.9 + 20\text{Log}\left(\left(\sqrt{(v_j - 0.1)^2 + 1}\right) + v_j - 0.1\right) \quad (4)$$

where A_j is in dB

According to the Epstein-Peterson multiple diffraction loss method, the effective diffraction loss for all the m hops is given as;

$$A = A_1 + A_2 + \cdots + A_m = \sum_{j=1}^{j=m}(A_j) \quad (5)$$

$$A = \sum_{j=1}^{j=m}\left(6.9 + 20\text{Log}\left(\left(\sqrt{(v_j - 0.1)^2 + 1}\right) + v_j - 0.1\right)\right) \quad (6)$$

3. The Procedure For Computing N Knife Edge Diffraction Loss Using Epstein-Peterson Method

The Procedure for computing N knife edge diffraction loss using Epstein-Peterson method and the ITU knife edge diffraction loss approximation model is as follows:

Step 1: For j = 0 to N +1 obtain height H (j) of obstruction, where j includes the transmitter with j=0, the receiver with j =N +1and the N obstructions with j =1 to N.

Step 2: For j=1 To N +1 obtain the distance d (j) of obstruction (j) from obstruction (j-1)

Step 3: For j = 1 to N compute the LOS clearance heights

$h_j = h_{Epstein(j)}$. (Use Eq 1)

Step 4: For j = 1 to N compute the knife-edge diffraction parameter (v_j) for each h_j. (Use 2)

Step 5: For j = 1 to N compute the knife-edge diffraction loss (A_j) for each v_j (Use 4)

Step 8: $A = A_1 + A_2 + A_3 + \cdots + A_{N-1} + A_N$ (Use Eq 5)

4. Numerical Example and Discussion of Results

The numerical example is for 10 knife edge obstructions located in the path of 1 GHz microwave signal. In this case, N = 10. The height, H (j) of the obstructions for j = 0 to j = N +1 are given in Table 1 while Table 2 shows the distance d (j) of obstruction (j) from obstruction (j-1) for j=1 to j= N+1. The results of the computations are presented according to the steps given in the algorithm. In all, for the given 10 obstructions, the total diffraction loss is 67.35065 dB. The path length is the sum of all the d (j) for j=1 to N+1. From Table 2, the path length is 36 km.

Result for Step 1: The height H (j) of obstruction for j = 0 to N +1, where j includes the transmitter with j=0, the receiver with j =N +1and the N obstructions with j =1 to N.

Table 1. *Height H (j) of obstruction for j = 0 to N, where j includes the transmitter with j=0, the receiver with j =N and the N obstructions with j =1 to N.*

J	Height H (j)	Height in m
0	H0	1
1	H1	4
2	H2	8
3	H3	12
4	H4	17
5	H5	21
6	H6	25
7	H7	22
8	H8	17
9	H9	12
10	H10	7
11	H11	1

Result for Step 2: The distance d (j) of obstruction (j) from obstruction (j-1) for j=1 to N+1.

Table 2. *The distance d (j) of obstruction (j) from obstruction (j-1) for j=1 to N+1.*

j	d (j)	Distance in km
1	d1	1
2	d2	2
3	d3	3
4	d4	4
5	d5	5
6	d6	6
7	d7	5
8	d8	4
9	d9	3
10	d10	2
11	d11	1

Result for Step 3: The LOS clearance heights $h_j = h_{Epstein(j)}$ for 1 to N

Table 3. *LOS clearance heights $h_j = h_{Epstein(j)}$ for 1 to N.*

j	h_j	LOS clearance heights in m
1	h1	0.666667
2	h2	0.8
3	h3	0.142857
4	h4	1
5	h5	0.363636
6	h6	3.454545
7	h7	1.444444
8	h8	0.714286
9	h9	1
10	h10	2.333333

Result for Step 4: For j = 1 to N compute the knife-edge diffraction parameter (v_j) for each h_j

Table 4. *The knife-edge diffraction parameter (v_j) for j = 1 to N.*

j	v_j	Diffraction Parameter
1	v1	0.066667
2	v2	0.059628
3	v3	0.008909
4	v4	0.054772
5	v5	0.017979
6	v6	0.170797
7	v7	0.079115
8	v8	0.044544
9	v9	0.074536
10	v10	0.233333

Result for Step 5: For j = 1 to N compute the knife-edge diffraction loss (A_j) for each v_j

Table 5. *The knife-edge diffraction loss (A_j) for j = 1 to N.*

j	A_j	The knife-edge diffraction loss in dB
1	A1	6.610527
2	A2	6.549428
3	A3	6.109884
4	A4	6.507288
5	A5	6.188371
6	A6	7.514422
7	A7	6.718608
8	A8	6.418562
9	A9	6.678846
10	A10	8.054711

Result for Step 8: $A = A_1 + A_2 + A_3 + \cdots + A_{N-1} + A_N$ = 67.35065 dB

From the results, the maximum virtual hop single knife edge diffraction loss is 8.054711 dB and it occurred in virtual hop j =10 which has the highest diffraction parameter of 0.233333. However, the virtual hop j =10 has LOS clearance height of 2.333333 m whereas the highest is 3.454545 m that occurred in virtual hop j =6. The minimum virtual hop single knife edge diffraction loss is 6.109884 dB and it occurred in virtual hop j =3 which has the lowest diffraction parameter of 0.008909 as well as the lowest LOS clearance height of 0.142857 m.

5. Conclusion

Algorithm for computing N knife edge diffraction loss using Epstein-Peterson method and ITU knife edge diffraction loss approximation model is presented. The mathematical expressions required for the computations are first presented before the algorithm. Then sample 10 knife edge obstructions are used to demonstrate the application of the algorithm for L-band 1 GHz microwave signal.

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