Development of Mathematical Models and Algorithms for Exact Radius of Curvature Used in Rounded Edge Diffraction Loss Computation

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***Abstract*— In this paper, plane geometry principles are employed in the development of mathematical expressions for the computation of the exact radius of curvature which can be used for the computation of rounded edge diffraction loss. The mathematical expressions are obtained from the path profile of the terrain with the diffracting obstruction, which in this study is taken as a hilly terrain. Along with the mathematical expressions, some algorithms are also developed to extract some of the parameters needed for the computation from the path profile data. Mathlab program is developed to implement the algorithms and also to facilitate the computations based on the mathematical models derived. Sample path profile of a hilly terrain is used to demonstrate the applicability of the analytical expressions and algorithms. The case study hilly terrain has a path length of 6671.98 m, maximum elevation of 383.21 m at a distance of 2792.02 m from the transmitter. The system is assumed to operate at a frequency of 1.2 GHz which is a wavelength of 0.25 m. The exact radius (m) is 16,981.97 m. The idea presented in the study can help network designers to improve on the accuracy of their computation of diffraction loss for rounded edges such as the ones used for hilly obstructions that exist along the wireless signal path.**

***Keywords*— Diffraction loss, radius of curvature, rounded edge diffraction loss, plane geometry, occultation distance**

I. INTRODUCTION

In general, wireless signals are subjected to diverse factors that cause signal strength degradation [1,2,3,4,5,6]. Notably, the signal spreading loss, widely known as free space loss is unavoidable present whenever wireless signal propagates over a distance. However, in addition to the free space loss, other losses do occur due to climatic conditions and the presence of obstructions in the signal path. Among other effects, obstructions in the signal path can cause diffraction loss [7,8,9,10,11]. As such, when there are obstructions in the signal path, wireless network designers estimate the expected diffraction loss based on a given approximation model of the obstruction. Particular, isolated obstructions like hills and trees have been modeled as single knife edge obstructions [12,13,14]. However, further research has shown that the actual diffraction loss emanating from such hilly obstructions is in most cases greater than what is obtained using the single knife edge approximation. Consequently, the rounded edge diffraction model has been adopted for hilly obstructions [14,15,16,17].

In rounded edge model diffraction computation, the major challenge is how to obtain the radius of curvature of the rounded edge that will be fitted to the apex of the hilly obstruction. In practice, some approximate mathematical expressions have been proposed. However, in this paper, an exact radius of curvature is determined using plans geometry principles and equations. The mathematical expressions are derived in this paper. The motive behind this study is to facilitate automation of the radius of curvature computation base on available path profile of the signal path and that of the hilly obstruction.

II. METHODOLOGY

In this section, mathematical expressions are developed for the determination of the exact radius of curvature which can be used for the computation rounded edge diffraction loss. The mathematical expressions are developed from a rounded edge geometric model based on a given path and diffracting obstruction profiles. The mathematical expressions are used in a Matlab program to determine the radius of curvature for the rounded edge diffraction loss computation.

The data for the computation of the rounded edge diffraction loss is based on the elevation profile data for points from the transmitter to the receiver. The data consist of the longitude, latitude and elevation pf the data points along with the distance of the datapoint from the transmitter. Let d_x denote the distance of datapoint x from the transmitter and let e_x be the elevation of the datapoint x and let there be n data points from the transmitter to the receiver, hence, x = 0, 1,2,3,…,n-1. In this case, the distance between the transmitter and the receiver is d_{n-1} with elevation e_{n-1} whereas the transmitter distance is $d_0 = 0$ with elevation e_0. A typical hill obstruction elevation profile to be used for the rounded edge diffraction loss computation modeling is given in Figure 1. Particularly, Figure 1 shows the rounded edge obtained by a circle inserted at the vicinity of the hill vertex such that the circle is tangential to two lines that are drawn from the transmitter and the receiver.

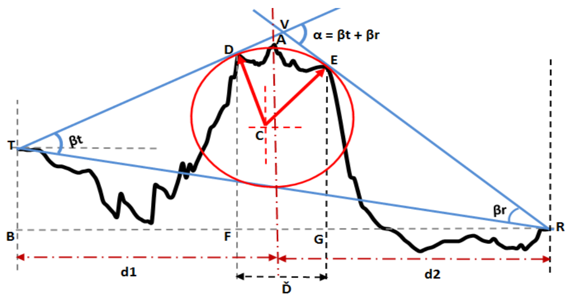

Figure 1 The Rounded Edge Geometry For The Rounded Edge Diffraction Loss Computation

A. Determination of the dimensions of the Triangle TRB

In Figure 1, T denotes the transmitter and R denotes the receiver. If however, the receiver is higher in elevation than the transmitter, then the T and R should be swapped in the analysis. Furthermore, in Figure 1 the origin of the plane axis is at point B; hence, the coordinates of point B is (0,0) where $X_B = 0$ and $Y_B = 0$. The elevation (vertical distance)of point T above point B is denoted as v_{BT} and the elevation of point R above point B is denoted as v_{BR}. Also, the horizontal distance from point B to point T is denoted as h_{BT} and the horizontal distance from point B to point R is denoted as h_{BR}. Hence, the coordinates of point R is (h_{BR}, V_{BR}) where $X_R = h_{BR}$ and $Y_R = V_{BR} = 0$ and the coordinates of point T is (h_{BT}, V_{BT}) where $X_T = h_{BT} = d_0 = 0$ and $Y_T = V_{BT} = e_0$. The length of line BT denoted as L_{BT} where

$$L_{BT} = \sqrt[2]{((X_T-0)^2 + (Y_T-0)^2)} = \sqrt[2]{((X_T)^2 + (Y_T)^2)} \quad (1)$$

But in Figure 1 $X_T = 0$ and $Y_T = V_{BT}$, then

$$L_{BT} = \sqrt[2]{(Y_T)^2} = Y_T = V_{BT} = e_0 \quad (2)$$

The length of line BR denoted as L_{BR} where

$$L_{BR} = \sqrt[2]{((X_R-0)^2 + (Y_R-0)^2)} = \sqrt[2]{((X_R)^2 + (Y_R)^2)} \quad (3)$$

But in Figure 1 $Y_R = V_{BR} = e_{n-1} = 0$ and $X_R = h_{BR} = d_{n-1}$ then

$$L_{BR} = \sqrt[2]{(X_R)^2} = X_R = h_{BR} = d_{n-1} \quad (4)$$

The length of line TR denoted as L_{TR} is given by Pythagoras theorem as;

$$L_{TR} = \sqrt[2]{((L_{BT})^2 + (L_{BR})^2)} = \sqrt[2]{((V_{BT})^2 + (h_{BR})^2)} \quad (5)$$

B. Determination of the Maximum Elevation Point of the Hill Obstruction

The algorithm used to determine the maximum elevation and its location is given as follow:

Step 1: $X_{max} = d_0$

Step 2: $Y_{max} = e_0$

Step 3: $K_{max} = 0$

Step 4: For k = 1 to n-1 step 1

Step 5: If $e_k > Y_{max}$ Then

Step 6: $X_{max} = d_k$

Step 7: $Y_{max} = e_k$

Step 8: $K_{max} = k$

Step 9: End if

Step 10: K = K + 1

Step 11: Next K

Step 12: Output K_{max}, X_{max} , Y_{max}

Step 13: End

C. The algorithm for finding the tangent point from the transmitter to the apex point on the hill obstruction

Given two points on a line with coordinates x_1, y_1 and x_k, y_k the slope (denoted as m_k) of the line is given as

$$m_k = \frac{y_k - y_1}{x_k - x_1} \quad (6)$$

The tangent line from the transmitter to the hill is obtained by finding a point with the coordinates denoted as x_{tkmax}, y_{tkmax} with the highest slope denoted as m_{tkmax}. In this case, $m_k = \frac{y_k - y_0}{x_k - x_0}$ is computed for k = 0 , 1, 2,… K_{max} and the point with the maximum m_k is denoted with coordinates x_{tkmax}, y_{tkmax}. Hence, the algorithm for finding the tangent point from the transmitter to the apex point on the hill obstruction is given as follows;

Step 1: $tK_{max} = 1$

Step 2: $X_{tkmax} = d_1$

Step 3: $Y_{tkmax} = e_1$

Step 4: $m_{tkmax} = \frac{y_1 - y_0}{x_1 - x_0}$

Step 5: For k = 2 to kmax step 1

Step 6: $m = \frac{Y_k - Y_{(k-1)}}{X_k - X_{(k-1)}}$

Step 7: If $m > m_{tkmax}$ Then

Step 8: $tK_{max} = K$

Step 9: $X_{tkmax} = d_{tkmax}$

Step 10: $Y_{tkmax} = e_{tkmax}$

Step 11: End if

Step 12: K = K + 1

Step 13: Next K

Step 14: Output tK_{max}, X_{tkmax} , Y_{tkmax}

Step 15: End

So, the coordinates of point D in Figure 1 are X_{tkmax} , Y_{tkmax} which can be referenced also as X_D , Y_D. That is the coordinates of point D in Figure 1 is such that

$$X_D = X_{tkmax} \quad (7)$$

$$Y_D = Y_{tkmax} \quad (8)$$

D. The algorithm for finding the tangent point from the receiver to the apex point on the hill obstruction

The tangent line from the receiver to the hill is obtained by finding a point with the coordinates denoted as x_{rkmax}, y_{rkmax} with the highest slope denoted as m_{rkmax}. In this case, $m_k = \frac{y_k - y_{(n-1)}}{x_k - x_{(n-1)}}$ is computed for k = $K_{max}, K_{max}+1, K_{max}+2, \ldots$ n-1 and the point with the maximum m_k is denoted with coordinates x_{rkmax}, y_{rkmax}. Hence, the algorithm for finding the tangent point from the receiver to the apex point on the hill obstruction is given as follows;

Step 1: $\mathrm{rK_{max}} = \mathrm{K_{max}}$

Step 2: $\mathrm{X_{rkmax}} = \mathrm{d_{K_{max}}}$

Step 3: $\mathrm{Y_{rkmax}} = \mathrm{e_{K_{max}}}$

Step 4: $\mathrm{m_{rkmax}} = \frac{\mathrm{Y_{K_{max}} - Y_{(n-1)}}}{\mathrm{X_{K_{max}} - X_{(n-1)}}}$

Step 5: For k = kmax + 1 to n − 2 step 1

Step 6: $\mathrm{m} = \frac{\mathrm{Y_k - Y_{(n-1)}}}{\mathrm{X_k - X_{(n-1)}}}$

Step 7: If -1*m $> -1 * \mathrm{m_{rkmax}}$ Then

Step 8: $\mathrm{rK_{max}} = \mathrm{K}$

Step 9: $\mathrm{X_{rkmax}} = \mathrm{d_{rkmax}}$

Step 10: $\mathrm{Y_{rkmax}} = \mathrm{e_{rkmax}}$

Step 11: End if

Step 12: K = K + 1

Step 13: Next K

Step 14: Output $\mathrm{e_{K_{max}}}$, $\mathrm{X_{rkmax}}$, $\mathrm{Y_{rkmax}}$

Step 15: End

So, the coordinates of point E in Figure 1 are $\mathrm{X_{rkmax}}$, $\mathrm{Y_{rkmax}}$ which can be referenced also as $\mathrm{X_E}$, $\mathrm{Y_E}$. That is the coordinates of point E in Figure 1 is such that

$$\mathrm{X_E} = \mathrm{X_{rkmax}} \quad (9)$$

$$\mathrm{Y_E} = \mathrm{Y_{rkmax}} \quad (10)$$

E. Determination of the coordinated of the intersection of line tangent line TD and line RE at point V

The gradient of the line TD from the transmitter to the tangent point D is given as

$$m_{\mathrm{tkmax}} = \frac{Y_{\mathrm{tkmax}} - Y_0}{X_{\mathrm{tkmax}} - X_0} \quad (11)$$

At the intersection of line TD and line RE at point V with coordinates $\mathrm{X_V}$, $\mathrm{Y_V}$ the gradient of line TD is given as

$$\frac{Y_{\mathrm{v}} - Y_0}{X_{\mathrm{v}} - X_0} = \frac{Y_{\mathrm{tkmax}} - Y_0}{X_{\mathrm{tkmax}} - X_0} = m_{\mathrm{tkmax}} \quad (11)$$

Hence,

$$Y_{\mathrm{v}} - Y_0 = m_{\mathrm{tkmax}}(X_{\mathrm{v}} - X_0) \quad (12)$$

$$Y_{\mathrm{v}} = m_{\mathrm{tkmax}}(X_{\mathrm{v}} - X_0) + Y_0 \quad (13)$$

The gradient of the line RE from the receiver to the tangent point E is given as

$$m_{\mathrm{rkmax}} = \frac{Y_{\mathrm{rkmax}} - Y_0}{X_{\mathrm{rkmax}} - X_0} \quad (14)$$

At the intersection of line TD and line RE at point V with coordinates $\mathrm{X_V}$, $\mathrm{Y_V}$ the gradient of line TD is given as

$$\frac{Y_{\mathrm{v}} - Y_{n-1}}{X_{\mathrm{v}} - X_{n-1}} = \frac{Y_{\mathrm{rkmax}} - Y_0}{X_{\mathrm{rkmax}} - X_0} = m_{\mathrm{rkmax}} \quad (15)$$

Hence,

$$Y_{\mathrm{v}} - Y_{n-1} = m_{\mathrm{rkmax}}(X_{\mathrm{v}} - X_{n-1}) \quad (15)$$

$$Y_{\mathrm{v}} = m_{\mathrm{rkmax}}(X_{\mathrm{v}} - X_{n-1}) + Y_{n-1} \quad (16)$$

Hence,

$$m_{\mathrm{tkmax}}(X_{\mathrm{v}} - X_0) + Y_0 = m_{\mathrm{rkmax}}(X_{\mathrm{v}} - X_{n-1}) + Y_{n-1} \quad (17)$$

$$m_{\mathrm{tkmax}}(X_{\mathrm{v}}) - m_{\mathrm{tkmax}}(X_0) + Y_0 = m_{\mathrm{rkmax}}(X_{\mathrm{v}}) - m_{\mathrm{rkmax}}(X_{n-1}) + Y_{n-1} \quad (18)$$

$$m_{\mathrm{tkmax}}(X_{\mathrm{v}}) - m_{\mathrm{rkmax}}(X_{\mathrm{v}}) = Y_{n-1} - Y_0 + m_{\mathrm{tkmax}}(X_0) - m_{\mathrm{rkmax}}(X_{n-1}) \quad (19)$$

$$X_{\mathrm{v}}\,(m_{\mathrm{tkmax}} - m_{\mathrm{rkmax}}) = Y_{n-1} - Y_0 + m_{\mathrm{tkmax}}(X_0) - m_{\mathrm{rkmax}}(X_{n-1}) \quad (20)$$

$$X_{\mathrm{v}} = \frac{Y_{n-1} - Y_0 + m_{\mathrm{tkmax}}(X_0) - m_{\mathrm{rkmax}}(X_{n-1})}{(m_{\mathrm{tkmax}} - m_{\mathrm{rkmax}})} \quad (21)$$

$$Y_{\mathrm{v}} = m_{\mathrm{tkmax}}\left\{\left(\frac{Y_{n-1} - Y_0 + m_{\mathrm{tkmax}}(X_0) - m_{\mathrm{rkmax}}(X_{n-1})}{(m_{\mathrm{tkmax}} - m_{\mathrm{rkmax}})}\right) - X_0\right\} + Y_0 \quad (22)$$

F. Determination of the radius of the circle and the coordinates of the center of the circle that is tangential to Line RE at point E and tangential to Line TD at point D

The center of the circle is at point C with coordinates $\mathrm{X_C}$, $\mathrm{Y_C}$. Now, line DC is perpendicular to the line TD and it passes through point D with coordinates $\mathrm{X_D}$, $\mathrm{Y_D}$. Since the gradient of line TD is $\mathrm{m_{tkmax}}$ then the gradient of line DC is $-\frac{1}{\mathrm{m_{tkmax}}}$ and the point-slope equation of line DC is given as

$$\mathrm{Y - Y_D = -\frac{1}{m_{tkmax}}\,(X - X_D)} \quad (23)$$

$$\mathrm{Y = Y_D - \frac{1}{m_{tkmax}}\,(X - X_D)} \quad (24)$$

Again, line EC is perpendicular to the line RE and it passes through point E with coordinates $\mathrm{X_E}$, $\mathrm{Y_E}$. Since the gradient of line RE is $\mathrm{m_{rkmax}}$ then the gradient of line EC is $-\frac{1}{\mathrm{m_{rkmax}}}$ and the point-slope equation of line EC is given as

$$\mathrm{Y - Y_E = -\frac{1}{m_{rkmax}}\,(X - X_E)} \quad (25)$$

$$\mathrm{Y = Y_E - \frac{1}{m_{rkmax}}\,(X - X_E)} \quad (26)$$

At the interception point, C the equation for line DC and EC give X= $\mathrm{X_C}$ and Y = $\mathrm{Y_C}$ and

$$\mathrm{Y_D - \frac{1}{m_{tkmax}}\,(X_C - X_D) = Y_E - \frac{1}{m_{rkmax}}\,(X_C - X_E)} \quad (27)$$

$$\mathrm{Y_D - \frac{1}{m_{tkmax}}\,(X_C) + \frac{1}{m_{tkmax}}\,(X_D) = Y_E - \frac{1}{m_{rkmax}}\,(X_C) + \frac{1}{m_{rkmax}}\,(X_E)} \quad (28)$$

$$\mathrm{Y_D - \frac{1}{m_{tkmax}}\,(X_C) + \frac{1}{m_{tkmax}}\,(X_D) = Y_E - \frac{1}{m_{rkmax}}\,(X_C) + \frac{1}{m_{rkmax}}\,(X_E)} \quad (28)$$

$$\mathrm{\frac{1}{m_{rkmax}}\,(X_C) - \frac{1}{m_{tkmax}}\,(X_C) = \frac{1}{m_{rkmax}}\,(X_E) - \frac{1}{m_{tkmax}}\,(X_D) + Y_E - Y_D} \quad (9)$$

$$\mathrm{\left(\frac{1}{m_{rkmax}} - \frac{1}{m_{tkmax}}\right)(X_C) = \frac{1}{m_{rkmax}}\,(X_E) - \frac{1}{m_{tkmax}}\,(X_D) + Y_E - Y_D} \quad (30)$$

$$X_C = \left[\frac{\frac{X_E}{m_{rkmax}} - \frac{X_D}{m_{tkmax}} + Y_E - Y_D}{\left(\frac{1}{m_{rkmax}} - \frac{1}{m_{tkmax}}\right)}\right] \quad (31)$$

$$Y_C = Y_E - \frac{1}{m_{rkmax}}\left(\left[\frac{\frac{X_E}{m_{rkmax}} - \frac{X_D}{m_{tkmax}} + Y_E - Y_D}{\left(\frac{1}{m_{rkmax}} - \frac{1}{m_{tkmax}}\right)}\right] - X_E\right) \quad (32)$$

The length of line TD denoted as L_{TD} is given by Pythagoras theorem as;

$$L_{TD} = \sqrt[2]{((X_D - X_T)^2 + (Y_D - Y_T)^2)} \quad (33)$$

The length of line TV denoted as L_{TV} is given by Pythagoras theorem as;

$$L_{TV} = \sqrt[2]{((X_V - X_T)^2 + (Y_V - Y_T)^2)} \quad (34)$$

The length of line RE denoted as L_{RE} is given by Pythagoras theorem as;

$$L_{RE} = \sqrt[2]{((X_E - X_R)^2 + (Y_E - Y_R)^2)} \quad (35)$$

The length of line RV denoted as L_{RV} is given by Pythagoras theorem as;

$$L_{RV} = \sqrt[2]{((X_V - X_R)^2 + (Y_V - Y_R)^2)} \quad (36)$$

The radius of the circle with center at point C whereby the circle is tangential to line RE at point E and tangential to line TD at point D is given by the length of line DC or line EC. By considering line DC, the radius is given as ;

$$L_{DC} = \sqrt[2]{((X_C - X_D)^2 + (Y_{CV} - Y_D)^2)} \quad (37)$$

The occultation distance, which is the horizontal distance between point D and point E, is denoted as D_{OCC}given as ;

$$D_{OCC} = |X_E - X_D| \quad (38)$$

The occultation distance, which is the horizontal distance between point D and point E, is denoted as D_{OCC} given as;

$$D_{OCC} = |X_E - X_D| \quad (38)$$

From cosine rule,

$$Cos\ (\alpha) = \frac{(L_{TR}{}^2)+(L_{RV}{}^2)-(L_{TV}{}^2)}{2(L_{TR})(L_{RV})} \quad (39)$$

Hence,

$$\alpha = Cos^{-1}\left(\frac{(L_{TR}{}^2)+(L_{RV}{}^2)-(L_{TV}{}^2)}{2(L_{TR})(L_{RV})}\right) \quad (40)$$

$$Cos\ (\beta) = \frac{(L_{TR}{}^2)+(L_{TV}{}^2)-(L_{RV}{}^2)}{2(L_{TR})(L_{TV})} \quad (41)$$

Hence,

$$\beta = Cos^{-1}\left(\frac{(L_{TR}{}^2)+(L_{TV}{}^2)-(L_{RV}{}^2)}{2(L_{TR})(L_{TV})}\right) \quad (42)$$

G. Determination of the height h of obstruction above the line of sight

The gradient of the line RT from the receiver, R (where k = n-1) to the transmitter, T (where k = 0) is given as $m_{rkmax} = \frac{Y_0 - Y_{(n-1)}}{X_0 - X_{(n-1)}}$. Similarly, the gradient of the line RP from the receiver, R (where k = n-1) to the location of the maximum elevation, P (where k = K_{max}) is given as:

$$m_{rkmax} = \frac{Y_P - Y_{(n-1)}}{X_{max} - X_{(n-1)}} \quad (43)$$

Hence,

$$\frac{Y_P - Y_{(n-1)}}{X_{max} - X_{(n-1)}} = \frac{Y_0 - Y_{(n-1)}}{X_0 - X_{(n-1)}} = m_{rkmax} \quad (44)$$

$$Y_P = m_{rkmax}(X_{max} - X_{(n-1)}) + Y_{(n-1)} \quad (45)$$

Therefore, the height h of obstruction above the line of sight RT is given as;

$$h = Y_{max} - Y_P = Y_{max} - [m_{rkmax}(X_{max} - X_{(n-1)}) + Y_{(n-1)}] \quad (46)$$

$$h = Y_{max} - Y_P = Y_{max} - Y_{(n-1)} - [m_{rkmax}(X_{max} - X_{(n-1)})] \quad (47)$$

III. RESULT AND DISCUSSIONS

The path profile data for the case study hilly terrain is plotted as shown in Figure 2.

The case study is from the elevation data extracted using online Geocontext path profile software which is available at http://www.geocontext.org/publ/2010/04/profiler/en/. For the case study, the transmitter location is taken as the reference point for the x coordinate located at 0 m (used as the origin) whereas the receiver is at a distance of 6671.98 m from the transmitter. The transmitter elevation is 291.80 m and the receiver elevation is 235.09 m. The maximum elevation of 383.21 m occurred at a distance of 2792.02 m from the transmitter. So, the x,y coordinates of the transmitter are 0.00, 291.80 while that of the receiver are 6671.98, 235.09. The x,y coordinates of the maximum elevation is given as 2792.02, 383.206.

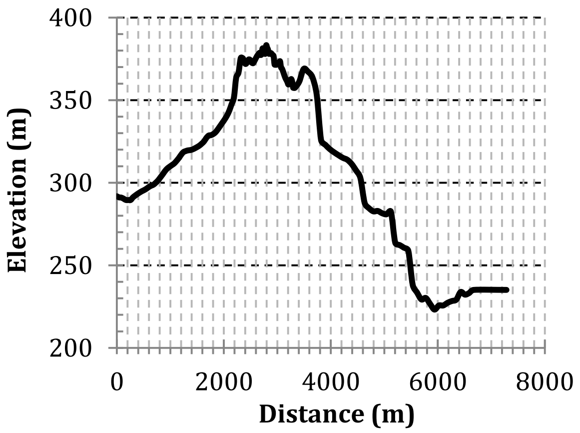

Figure 2 The Elevation Profile Data For The Case Study Hilly Terrain

Table 1 shows the key rounded hilltop parameters obtained for the hill obstruction. The system is assumed to operate at a frequency of 1.2 GHz which is a wavelength of 0.25 m, as shown in Table 1. From Table 1, the path length (d) is 6,671.98 m. Also, the tangent from the transmitter and the tangent from the receiver intersected at a distance of 2,894.80 m from the transmitter and a distance of 3,777.19 m from the receiver. The line of sight makes an angle of 0.043706947 radians with the horizontal. The LOS clearance height is 100.41 m while the occultation distance is 1,337.99

m wide. The ratio of occultation distance to the path length is 0.2005.

Table 1 Rounded Hilltop Parameters For The Plateau Obstruction for D(m)/d(m) of 0.2005

f (MHz)	Frequency	**1200**
λ (m)	Wavelength	**0.25**
S1 (m)	The length of the tangent from the transmitter to the intersection point of the two tangent	**2896.687629**
S2 (m)	the length of the tangent from the receiver to the intersection point of the two tangents	**4357.267166**
S3(m)	the length of the tangent from the receiver from the transmitter	**6672.223589**
d1 (m)	The distance from the transmitter to the intersection point of the two tangents , that is point	**2,894.80**
d2(m)	The distance from the receiver to the intersection point of the two tangents	**3,777.19**
yrt (m)	Elevation of the point of intersection of the two tangents	**396.4488991**
d(m)	The distance from the transmitter to the receiver	**6,671.98**
αt (radian)	The angle that the tangent line from the transmitter makes with the LOS	**0.044634226**
αr(radian)	The angle that the tangent line from the receiver makes with the LOS	**0.034193678**
α(radian)	Sum of angles αt and αr	**0.078827904**
β(radian)	The angle the LOS makes with the horizontal	**0.043706947**
h(m)	The LOS clearance height	**100.4101426**
D(m)	The occultation distance	**1,337.99**
D(m)/d(m)	The ratio of occultation distance to the path length	**0.2005**
R (m)	The exact Radius (m) By Plane Geometry Method	16,981.97

IV. CONCLUSION

Mathematical expressions and algorithms for the determination of the exact radius of curvature which can be used for the computation of rounded edge diffraction loss are presented. Sample path profile of a hilly terrain is used to demonstrate the applicability of the analytical expressions and algorithms. Mathlab program is used to facilitate the implementation of the algorithm and the computation of the various parameters required. In all , the mathematical expressions are based on plane geometry principles. Other approaches can as well be used.

REFERENCES

1. Zhou, G., He, T., Krishnamurthy, S., & Stankovic, J. A. (2006). Models and solutions for radio irregularity in wireless sensor networks. *ACM Transactions on Sensor Networks (TOSN)*, *2*(2), 221-262.
2. Lo, E. C. C. (2007). *An investigation of the impact of signal strength on Wi-Fi link throughput through propagation measurement* (Doctoral dissertation, Auckland University of Technology).
3. Zhou, G., He, T., Krishnamurthy, S., & Stankovic, J. A. (2004, June). Impact of radio irregularity on wireless sensor networks. In *Proceedings of the 2nd international conference on Mobile systems, applications, and services* (pp. 125-138). ACM.
4. Amajama, J., & Eshiet, M. (2016). Impact of weather components on (UHF) radio signal. *International Journal of Engineering Research and General Science (IJERGS)*, *4*(3), 474-480.
5. Idris, A. N., Sathyamoorthy, D., Suldi, A. M., & Hamid, J. R. A. (2014). Effect of Radio Frequency Interference (RFI) on the Precision of GPS Relative Positioning. In *IOP Conference Series: Earth and Environmental Science* (Vol. 18, No. 1, p. 012035). IOP Publishing.
6. Kumar, V. (2014). Effect of Environmental Parameters on GSM and GPS. *Indian Journal of Science and technology*, *7*(8), 1183-1188.
7. Abdulrasool, A. S., Aziz, J. S., & Abou-Loukh, S. J. (2017). Calculation Algorithm for Diffraction Losses of Multiple Obstacles Based on Epstein–Peterson Approach. *International Journal of Antennas and Propagation*, *2017*.

8. Lee, C., & Park, S. (2018). Diffraction Loss Prediction of Multiple Edges Using Bullington Method with Neural Network in Mountainous Areas. *International Journal of Antennas and Propagation*, *2018*.
9. Lee, C., & Park, S. (2017). An approach of the diffraction loss prediction using artificial neural network in hilly mountainous terrain. *Microwave and Optical Technology Letters*, *59*(11), 2917-2922.
10. LeNgoc, S., Chen, J., & Ye, Y. (1994, September). Improved diffraction loss prediction for land mobile radio communication. In *Electrical and Computer Engineering, 1994. Conference Proceedings. 1994 Canadian Conference on* (pp. 242-247). IEEE.
11. Prasad, M. V. S. N., Rao, S. V., Rao, T. R., Sarkar, S. K., & Sharma, S. (2004). Double knife edge diffraction propagation studies over irregular terrain. *92.60. Ta; 94.10. Gb; 84.40. Ua*.
12. Ezenugu, I. A., Edokpolor, H. O., & Chikwado, U. (2017). Determination of Single Knife Edge Equivalent Parameters for Double Knife Edge Diffraction Loss by Deygout Method. *Mathematical and Software Engineering*, *3*(2), 201-208.
13. Meng, Y. S., Lee, Y. H., & Ng, B. C. (2009). Study of propagation loss prediction in forest environment. *Progress In Electromagnetics Research*, *17*, 117-133.
14. Boban, M. (2014). Realistic and efficient channel modeling for vehicular networks. *arXiv preprint arXiv:1405.1008*.
15. Oluropo, O. E., Ezeh, I. H., & Nkwocha, C. P. (2017). Determination of Diffraction Loss over Isolated Doubled Edged Hill Using the ITU-R P. 526-13 Method for Rounded Edge Diffraction. *American Journal of Software Engineering and Applications*, *6*(2), 56.
16. Uko, M. C., Udoka, U. E., & Nkwocha, C. P. (2017). Parametric Analysis of Isolated Doubled Edged Hill Diffraction Loss Based on Rounded Edge Diffraction Loss Method and Different Radius of Curvature Methods. *Mathematical and Software Engineering*, *3*(2), 217-225.
17. Wong, H. (2002). Field Strength Prediction in Irregular Terrain-the PTP Model. *Report of Federal Communication Commission, USA*.