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Development And Performance Evaluation Of Intersection Of Line Iteration Method Applied In Optimal Path Length For Terrestrial Microwave Link With Knife Edge Diffraction Loss

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***Abstract*— In this paper, the development and performance evaluation of intersection of line iteration method applied in fade margin-based optimal path length for terrestrial microwave link is presented. In the previous studies, only free space path loss was considered in the path loss computation. In practice, obstruction along the signal path causes diffraction loss. Such loss has not been considered in the determination of optimal path length. As such, in this paper, the optimal path length for a microwave link with knife edge diffraction loss is studied. Particularly, fade margin-based Intersection of Line iteration method is developed to determine the optimal path length for the terrestrial line of sight microwave link. The convergence cycle of the Intersection of Line iteration method is then compared to that of three already published methods for determination of optimal path length, namely; Newton-Raphson Method, Regular Falsi Method and Secant Method. In all the intersection of line method has the lowest convergence cycle for all frequencies, with a convergence cycle of 2. The path length dropped from its initial value of 23.9883km to the optimal value of 8.636km. Also, for free space path loss, the initial value of 140.40dB dropped to a value of 131.17dB at the optimal point and the maximum fade depth dropped from initial value of 140.04dB to optimal value of 28.83dB. Conversely, the Regular Falsi, and Secant methods have the worst convergence cycle for all frequencies, with a convergence cycle of 6.**

Keywords*— *Intersection Of Line Iteration Method, Optimal Path Length, Knife Edge Diffraction Loss, Microwave Link, Microwave Link, Newton-Raphson Method

I. INTRODUCTION

The design and operating characteristics of point-to-point terrestrial Line of Sight (LoS) microwave communication link is greatly affected by rain and multipath fading along with other path losses [1,2,3,4]. As regards fading, only rain and multipath fading parameters are considered for any given link availability, where the larger fade among the two is taken as the effective maximum fade depth which is then used in predicting the link budget, which is path length dependent. However, research findings have shown that the prediction of the maximum path length due to the free space path loss (FSPL) and the maximum path length due to the effective fade depth (EFD) in most cases yield different results. At this point, the path lengths are said to be non-optimal. Also, previous studies on optimal path length [5,6,7] used algorithms that are based on adjustment of the path length.

The use of path length requires that mathematical expression relating the path length to all the path losses and effective fading must be derived. This becomes more difficult as different path losses other that free space path loss are considered. In addition, in the previous studies only free space path loss was considered in the path loss computation. In practice, obstruction along the signal path causes diffraction loss. Such loss has not been considered in the determination of optimal path length. Besides, with the use of path length adjustment approach complex mathematical expressions will be required to relate the path length to the various path losses including the diffraction loss. Consequently, the problem to be solved in this paper is the development of simpler alternative approach for the determination of optimal path length [8,9,10] of terrestrial line of sight (LOS) microwave link as well as makes provision for diffraction loss in the determination of the optimal path length. Particularly, in this paper, fade margin-based Intersection of Line iteration method is developed to determine the optimal path length for a terrestrial LoS microwave link. The convergence cycle of the Intersection of Line iteration method is then compared to three already published methods for determination of optimal path length, namely; Newton-Raphson Method, Regular Falsi Method, Bisection, Secant Method [5,6,7, 8,9,10] and various modified versions of each of the listed iteration methods [11,12,13,14,15,16].

II. METHODOLOGY

First, the terrestrial line of sight (LOS) microwave link budget equation including single knife edge diffraction loss [17,18,19,20,21,22,23,24,25] is presented. Next, the algorithm for the Intersection of Line iteration method for determination of the optimal path length for a terrestrial LoS microwave link is presented. Then, sample numerical examples are presented where the convergence cycle of the Intersection of Line iteration method is compared with those of three already published methods for determination of optimal path length, namely; Newton-Raphson Method, Regular Falsi Method and Secant Method.

A. DETERMINATION OF THE OPTIMAL PATH LENGTH USING METHOD OF INTERSECTION OF TWO LINES

The concept of optimal path length by the intersection of lines is shown in Figure 1. In the intersection of two lines iteration method two initial values of fade depth are required to estimate the tentative optimal fade depth using equations based on the intersection of two lines. In this case, two initial rain fading values, $fd_{me(k-1)}$ and $fd_{me(k-2)}$ are determined for two initial guess path lengths, $d_{e(k-1)}$ and $d_{e(k-2)}$. Also, two initial operating fade margins operating fade margins, $fm_{e(k-1)}$and $fm_{e(k-2)}$ are obtained at those two initial path lengths, $d_{e(k-1)}$ and $d_{e(k-2)}$ as well. The intersection point for the linear equation of the rain fading and the linear equation of the operating fade margin gives the tentative location of the optimal fade margin, $fd_{me(k)} = fm_{e(k)}$.

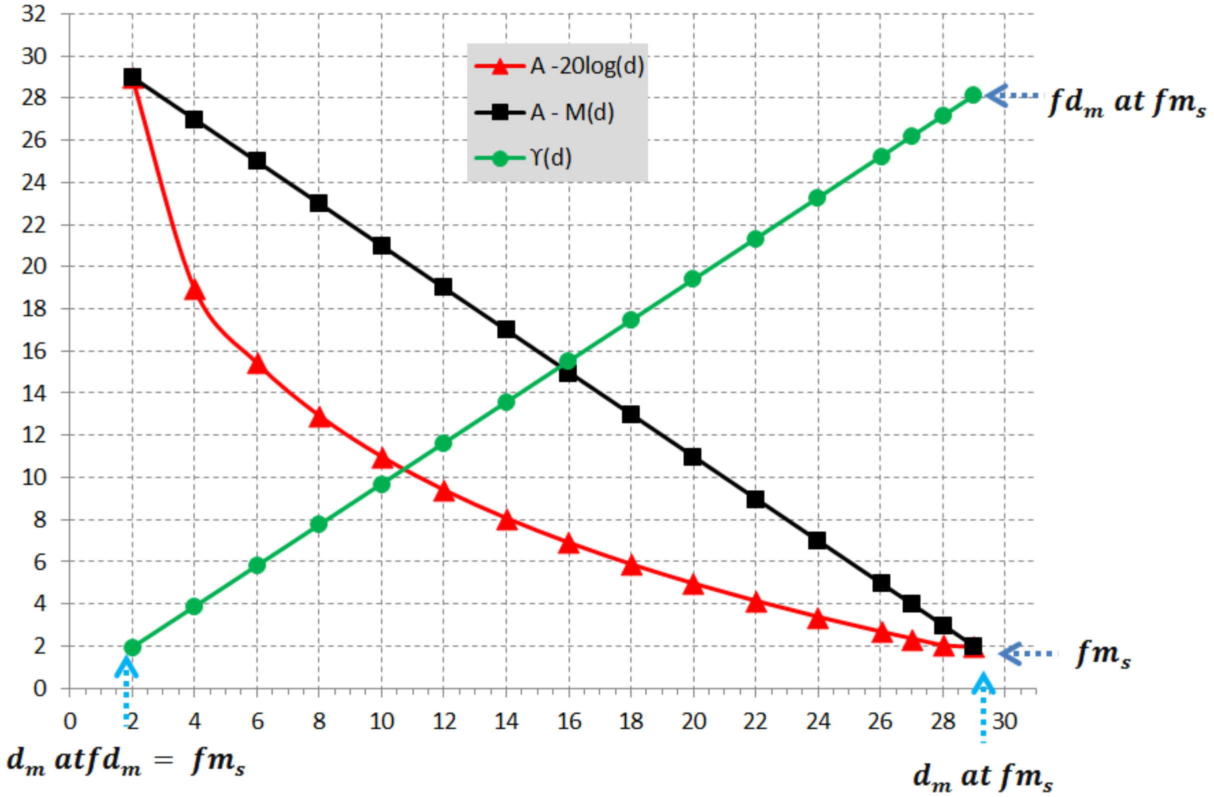

Figure 1 The concept of optimal path length by the intersection of lines

The tentative optimal fade depth, $fd_{me(k)}$ is used to compute tentative optimal path length, $d_{e(k)}$. Then, $d_{e(k)}$ is used to compute the effective free space path loss, $L_{FSPe(k)}$ and the condition for optimal path length is then verified. If the condition is met, the algorithm stops and $d_{e(k)}$ becomes the optimal path length d_{mop}. However, if the condition for optimal path length is not met the next tentative optimal fade depth is estimated using the equations for the intersection of two lines. The procedure is repeated until the optimal path length, d_{mop} is obtained.

B. THE ALGORITHM FOR OPTIMAL PATH LENGTH USING METHOD OF INTERSECTION OF TWO LINES

The algorithm for the method of intersection of two lines is as follows:

Step 1

Step 1.1 Input the following parameters

(i) P_s = the Receiver Sensitivity in dB

(ii) fm_s the specified (required) fade margin in dB

(iii) PT = the Transmitter Power Output (dBm)

(iv) GT = the Transmitter Antenna Gain (dBi)

(v) GR = the Receiver Antenna Gain (dBi)

(vi) LT = the Losses from Transmitter (cable, connectors etc.) (dB)

(vii) LR = the Losses from Receiver (cable, connectors etc.) (dB)

(viii) LM = the Misc. Losses (fade margin, polarization misalignment etc.) (dB)

(ix) Specify the LOS percentage clearance, Pc

(x) Compute diffraction parameter, V

where; $V = \left(\frac{(\sqrt{2})P_c}{100}\right)$

$$\begin{cases} G_d = 0 & \text{for } V < -1 \\ G_d = 20\log(0.5 - 0.62v) & \text{for } -1 \le V \le 0 \\ G_d = 20\log(0.5\exp(-0.95v)) & \text{for } 0 \le V \le 1 \\ G_d = 20\log\left(0.4 - \sqrt{0.1184 - (0.38 - 0.1v)^2}\right) & \text{for } 1 \le V \le 2.4 \\ G_d = 20\log\left(\frac{0.225}{v}\right) & \text{for } V > 2.4 \end{cases}$$

(xi) Compute single knife edge diffraction loss, G_d where

(xii) Specified relative error tolerance, ϵ_s ;
Note: $\epsilon_s = 0.01\% = \frac{0.01}{100} = 0.0001$

Step 1.2 K = 0

Step 1.3 $fme_{(k)} = fm_s$

Step 1.4 j = 0 // j is cycle or iteration counter

Step 2

Step

$$d_{e(k)} = 10^{\left(\frac{(P_T + G_T + G_R - fme_{(k)} - G_d - P_S) - 32.4 - 20\log(f*1000)}{20}\right)}$$

Step 2.2 $L_{FSP(k)} = L_{FSP}$ = 32.4 + 20 log(f*1000) + 20 log($d_{e(K)}$)

Step 2.3 From Eq 3.22 and Eq 3.23 compute effective rain fade depth, A_{eRain} in dB as follows;

$$\left.\begin{aligned} A_{eR(h)(k)} &= \left(\langle \gamma_{R_{po}} \rangle_h\right) d_e = \left(K_h (R_{po})^{\alpha_h}\right) d_{e(k)} \\ A_{eR(v)(k)} &= \left(\langle \gamma_{R_{po}} \rangle_v\right) d_e = \left(K_v (R_{po})^{\alpha_v}\right) d_{e(k)} \end{aligned}\right\}$$

$$A_{eRain(k)} = \max\left(\left(K_v (R_{po})^{\alpha_v}\right) * \left(K_h (R_{po})^{\alpha_h}\right) d_{e(k)}\right) = \max\left(A_{R(h)d_{e(0)}}, A_{R(v)d_{e(0)}}\right) d_{e(k)}$$

If $\left(A_{eR(h)(k)} \ge A_{eR(v)(k)}\right)$ then $\left(\gamma_{R_{po}} = \langle \gamma_{R_{po}} \rangle_h\right)$ otherwise $\left(\gamma_{R_{po}} = \langle \gamma_{R_{po}} \rangle_v\right)$.

$$fd_{me(k)} = \left(\gamma_{R_{po}}\right) d_{e(k)} = A_{eRain(k)}$$

Step 2.4

$$d_{e(j)} = d_{e(k)}$$
$$L_{FSP(j)} = L_{FSP(k)}$$
$$A_{eR(h)(j)} = A_{eR(h)(k)}$$
$$A_{eR(v)(j)} = A_{eR(v)(k)}$$
$$A_{eRain(j)} = A_{eRain(k)}$$
$$fd_{me(j)} = fd_{me(k)}$$
$$fme_{(j)} = fme_{(k)}$$

Step 3

Find the absolute relative approximate error as

$$\left|\epsilon_{s(j)}\%\right| = \left|\frac{fme_{(k)} - fd_{m(k)}}{fme_{(k)}}\right| 100\ \%$$

Compare the absolute relative approximate error $\left|\epsilon_{s(k)}\%\right|$ with the pre-specified relative error tolerance, $\epsilon_s\%$

If$\left|\epsilon_{s(k)}\%\right| > |\epsilon_s\%|$Then

K = K + 1

j = j + 1

Goto Step 4

Else

Output the following parameters

$d_{e(j)}$; $L_{FSP(j)}$; $A_{eR(h)(j)}$; $A_{eR(v)(j)}$; $A_{eRain(j)}$; $fd_{me(j)}$; $fme_{(j)}$; $\epsilon_{s(j)}\%$

Stop

Endif

Step 4

Step 4.1 $fme_{(k)} = fd_{me(k-1)}$

Step

$$d_{e(k)} = 10^{\left(\frac{(P_T + G_T + G_R - fme_{(k)} - G_d - P_S) - 32.4 - 20\log(f*1000)}{20}\right)}$$

Step 4.3 $L_{FSP(k)} = L_{FSP}$ = 32.4 + 20 log(f*1000) + 20 log($d_{e(k)}$)

Step 4.4 From Eq 3.22 and Eq 3.23 compute effective rain fade depth, A_{eRain} in dB as follows;

$$\left.\begin{aligned} A_{eR(h)(k)} &= \left(\langle \gamma_{R_{po}} \rangle_h\right) d_e = \left(K_h (R_{po})^{\alpha_h}\right) d_{e(k)} \\ A_{eR(v)(k)} &= \left(\langle \gamma_{R_{po}} \rangle_v\right) d_e = \left(K_v (R_{po})^{\alpha_v}\right) d_{e(k)} \end{aligned}\right\}$$

$$A_{eRain(k)} = \max\left(\left(K_v (R_{po})^{\alpha_v}\right) * \left(K_h (R_{po})^{\alpha_h}\right) d_{e(k)}\right) = \max\left(A_{R(h)d_{e(0)}}, A_{R(v)d_{e(0)}}\right) d_{e(k)}$$

If $\left(A_{eR(h)(k)} \ge A_{eR(v)(k)}\right)$ then $\left(\gamma_{R_{po}} = \langle \gamma_{R_{po}} \rangle_h\right)$ otherwise $\left(\gamma_{R_{po}} = \langle \gamma_{R_{po}} \rangle_v\right)$.

$$fd_{me(k)} = \left(\gamma_{R_{po}}\right) d_{e(k)} = A_{eRain(k)}$$

Step 4.5

K = K + 1

Step 5

Step 5.1

$x_{1,1} = d_{e(k-2)}$

$y_{1,1} = fme_{(k-2)}$

$x_{1,2} = d_{e(k-1)}$

$y_{1,2} = fme_{(k-1)}$

$x_{2,1} = d_{e(k-2)}$

$y_{2,1} = fd_{me(k-2)}$

$x_{2,2} = d_{e(k-1)}$

$y_{2,2} = fd_{me(k-1)}$

$$m_1 = \frac{y_{1,2} - y_{1,1}}{x_{1,2} - x_{1,1}}$$

$$m_2 = \frac{y_{2,2} - y_{2,1}}{x_{2,2} - x_{2,1}}$$

$$x = \frac{m_1(x_{1,1}) - m_2(x_{2,1}) + y_{2,1} - y_{1,1}}{(m_1 - m_2)}$$

$d_{e(k)} = x$

$$y = m_2\left(\frac{m_1(x_{1,1}) - m_2(x_{2,1}) + y_{2,1} - y_{1,1}}{(m_1 - m_2)}\right) - m_2(x_{2,1}) + y_{2,1}$$

$fme_{(k)} = y$

Goto Step 2

III. RESULTS AND DISCUSSION

A. SIMULATION OF THE OPTIMAL PATH LENGTH ALGORITHMS

In this paper, four optimal path length algorithms were considered, namely, the Method of Intersection of Two Lines developed as part of this research while the other three algorithms (Newton–Raphson method, Secant method, and Regular Falsi method) were from published works. Each of the four optimal path length algorithms is simulated to determine the optimal path length for a sample fixed point terrestrial LoS microwave link with the following link transmit power, equipment and geo-climatic parameters:

i. Frequency (f) = 10 GHz

ii. Transmit power (P_T) = 10dBm

iii. Transmitter Antenna Gain (G_T) = 35 dBi

iv. Receiver Antenna Gain (G_R) = 35 dBi

v. Fade Margin (fm_s) =20dB

vi. Receiver Sensitivity (P_S) = -80dBm

vii. Rain Zone = N

viii. Point Refractivity Gradient (dN1) = -400

ix. Link Percentage Outage (po) = 0.01%

x. Rain Fade Constants:

k_h = 0.01006, α_h = 1.2747, k_v = 0.008853, α_v = 1.263

xi. R_{po} = 95mm/h

xii. $h_t = 295m$,

xiii. h_r = 320m

For each simulation run, the convergence cycle (n) at which the optimal path length is obtained is noted along with other relevant parameters. The simulation is also carried out for each of the four algorithms for the following frequencies: 10 GHz, 20 GHz, 30GHz, 40 GHz, 50 GHz, 60 GHz, 70GHz, 80 GHz, 90 GHz, 100GHz, 150 GHz and 200 GHz.

B. RESULTS FOR THE INTERSECTION OF LINE (IOL) METHOD

In Table 1 to Table 3 , as well as Figure 2 to Figure 4, the frequency is 10 GHz and the rain zone is N, with percentage availability of 99.99%. The convergence cycle is 2. That means, as shown in Table 1, Table 2, and Table 3, (as well as, Figure 2, Figure 3, and Figure 4), the Intersection of Line (IoL) algorithm is iterated for 2 times before the optimal path length is obtained. Also, the optimal path length is 8.636 km, the optimal free space path loss is 131.17 dB, the optimal fade margin the system can accommodate is 28.83 dB and the optimal fade depth value is 28.83 dB. In essence, for the IoL algorithm, at the optimal path length, a maximum fade depth of 28.83 dB can be accommodated by the link which is the same with the optimal fade depth value of 28.83 dB. It can be recalled from Table 2 and Figure 3 that the initial fade margin specified for the system is 19.60 dB. At this initial point, in Table 2 and Figure 3, the initial maximum path length is 23.9883 km, the initial path loss is 140.40 dB, the initial fade depth is 140.04 dB while the received signal power is -60.04 dB. At the optimal point, the path maximum path loss has reduced by 8.87 dB to a value of 131.17 dB while the received signal power has increased the same value of 8.87 dB to a value of -51.17 dB. From Table 1 and Figure 2, it will be noticed that the rain fading is equal to the effective fade depth. In essence, for the given frequency, rain zone and percentage availability, the rain fading is greater than the multipath fading and hence, determines the effective fade depth that will be experienced in the link.

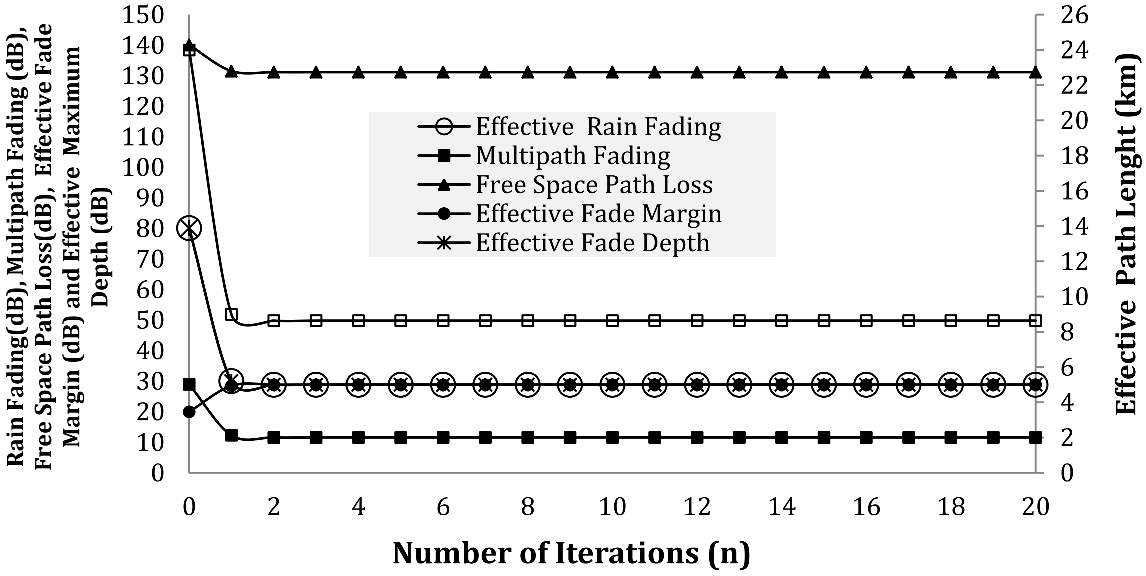

Figure 2: Intersection of Line method: Rain fading, multipath fading, free space path loss, effective fade margin, effective maximum depth and effective path length vs number of iterations (n)

Table 1: Intersection of Line method: Rain fading, multipath fading, free space path loss, effective fade margin, effective maximum depth and effective path length vs number of iterations (n)

Number Of Iterations (n)	Effective Rain Fading (dB)	Multipath Fading (dB)	Free Space Path Loss (dB)	Effective Fade Margin (dB)	Effective Fade Depth (dB)	Effective Path Length (km)
0	80.09	28.95	140.04	19.9600	80.0944	23.9883
1	30.01	12.29	131.51	28.4863	30.0115	8.9885
2	28.84	11.58	131.17	28.8335	28.8356	8.6363
3	28.83	11.58	131.17	28.8340	28.8340	8.6358
4	28.83	11.58	131.17	28.8340	28.8340	8.6358
5	28.83	11.58	131.17	28.8340	28.8340	8.6358
6	28.83	11.58	131.17	28.8340	28.8340	8.6358
7	28.83	11.58	131.17	28.8340	28.8340	8.6358
8	28.83	11.58	131.17	28.8340	28.8340	8.6358
9	28.83	11.58	131.17	28.8340	28.8340	8.6358
10	28.83	11.58	131.17	28.8340	28.8340	8.6358

Table 2: Intersection of Line method: Initial and optimal values for free space path loss, fade depth, fade margin, received power, path length and convergence cycle

	N	Free Space Path Loss (in dB)	Fade Depth (in dB)	Fade Margin (in dB)	Received Power (in dBm)	Path Length (in km)
Initial Value	**0**	140.04	80.09	19.96	-60.04	23.9883
Optimal Value	**2**	131.17	28.83	28.83	-51.17	8.6358

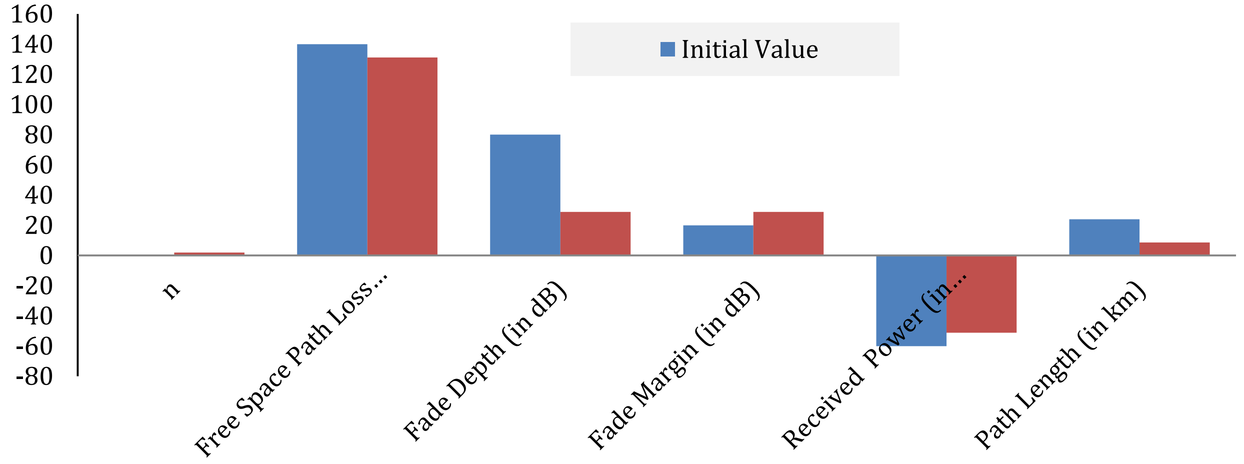

Figure 3: Intersection of Line method: Initial and optimal values for free space path loss, fade depth, fade margin, received power, path length and convergence cycle

Table 3: Intersection of Line method: Differential fade depth and effective path length vs number of iterations (n)

Number Of Iterations (n)	Differential Fade Depth (dB)	Effective Path Length (de) (km)
0	60.1344	23.9883
1	7.7817	10.4663
2	0.3502	8.7165
3	0.0084	8.6377
4	0.0002	8.6358
5	0.0000	8.6358
6	0.0000	8.6358
7	0.0000	8.6358
8	0.0000	8.6358
9	0.0000	8.6358
10	0.0000	8.6358
11	0.0000	8.6358

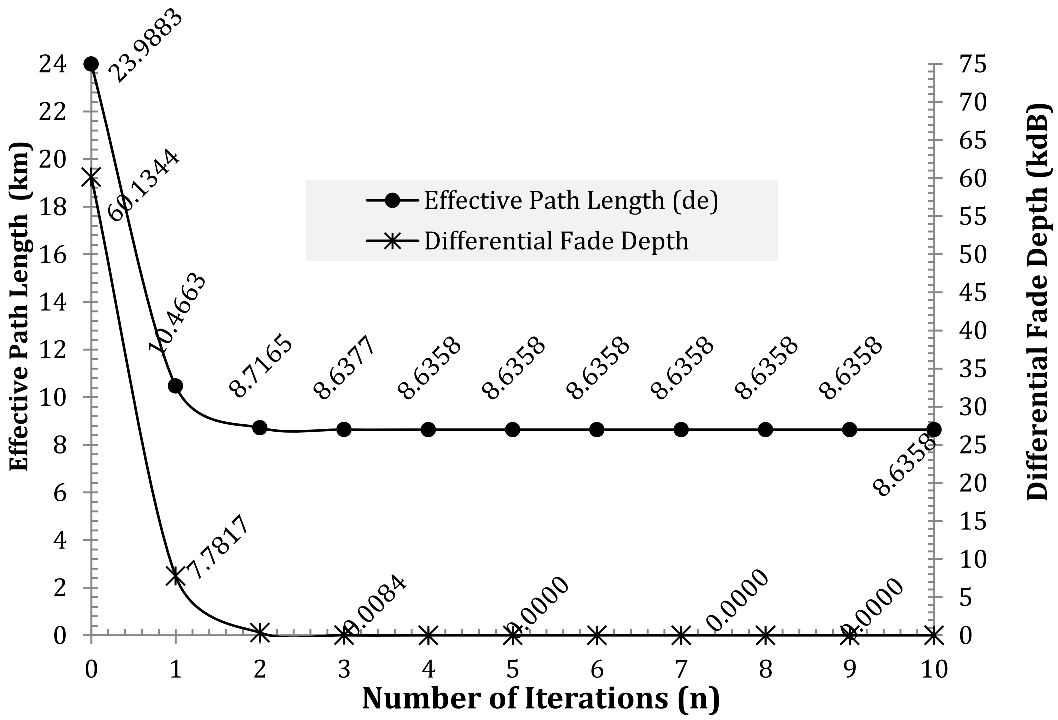

Figure 4: Intersection of Line method: Differential fade depth and effective path length vs number of iterations (n)

C. RESULTS FOR THE EFFECT OF FREQUENCY ON THE INTERSECTION OF LINE (IOL) METHOD

How the various link parameters vary with frequency which is varied from 10 GHz to 200 GHz is shown in Table 4 to Table 6 (as well as, Figure 5 to Figure 7) show. Specifically, Table 4 and Figure 5 show that the convergence cycle for the Intersection of Line algorithm remained constant at 2 cycles as the frequency is varied from 10 GHz to 200 GHz. Essentially, the convergence cycle of the Intersection of Line algorithm does not vary with frequency. In any case, the optimal path length decreases from 8.64 km at 10 GHz to 0.06 km at 200 GHz. The optimal fade depth and optimal path loss decreases from 28.83 dB and 131.17 dB at 10 GHz to 45.77 dB and 114.23 dB at 200 GHz respectively. Also, in Table 4.18 and Figure 4.18, the rain fading is the dominant fading for all the frequencies considered, namely, 10 GHz and to 200 GHz.

Table 4: Intersection of Line method: Initial path Length, optimal path length and convergence cycle vs frequency

f (GHz)	Convergence Cycle	Initial Path Length (km)	Optimal Path Length (km)
10	2	23.9883	8.6358
20	2	11.9942	2.8837
30	2	7.9961	1.7165
40	2	5.9971	1.3126
50	2	4.7977	1.1372
60	2	3.9981	1.0421
70	2	3.4269	0.9810
80	2	2.9985	0.9363
90	2	2.6654	0.9016
100	2	2.3988	0.8734
150	2	1.5992	0.0947
200	2	1.1994	0.0614

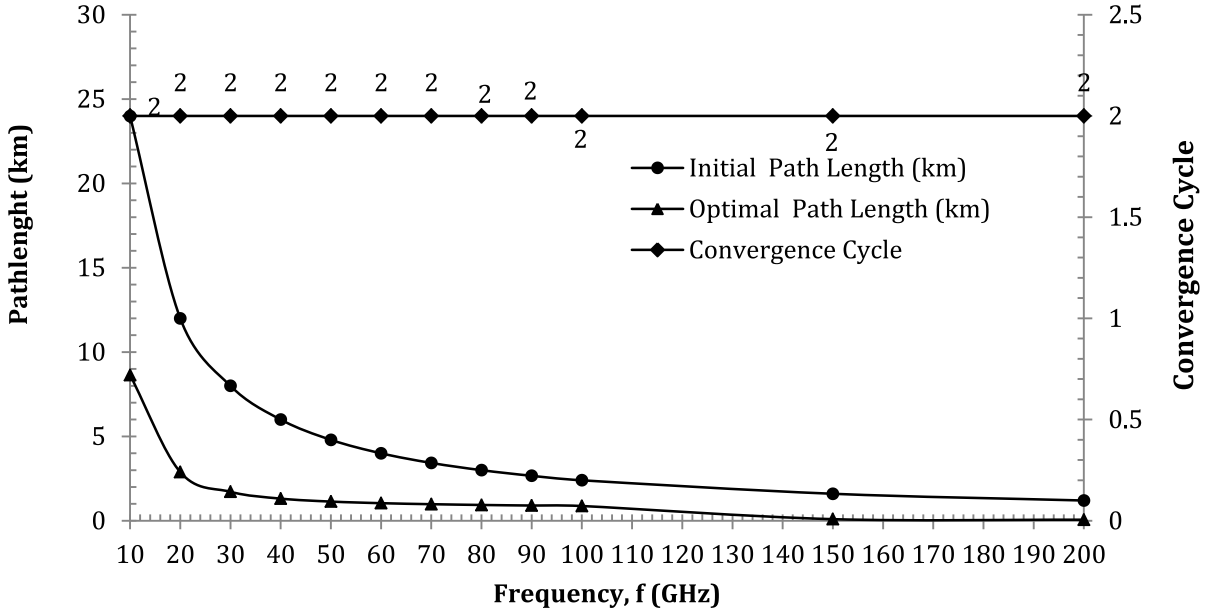

Figure 5: Intersection of Line method: Initial path length, optimal path length and convergence cycle vs frequency

Table 5: Intersection of Line methods: Optimal path length, optimal fade depth, optimal path loss and convergence cycle vs frequency

f (GHz)	Convergence Cycle	Optimal Path Length (km)	Optimal Fade Depth (dB)	Optimal Path loss (dB)
10	2	8.6358	28.8340	131.1660
20	2	2.8837	32.3405	127.6595
30	2	1.7165	33.3247	126.6753
40	2	1.3126	33.1562	126.8438
50	2	1.1372	32.4640	127.5360
60	2	1.0421	31.6386	128.3614
70	2	0.9810	30.8250	129.1750
80	2	0.9363	30.0696	129.9304
90	2	0.9016	29.3744	130.6256
100	2	0.8734	28.7356	131.2644
150	2	0.0947	44.5112	115.4888
200	2	0.0614	45.7708	114.2292

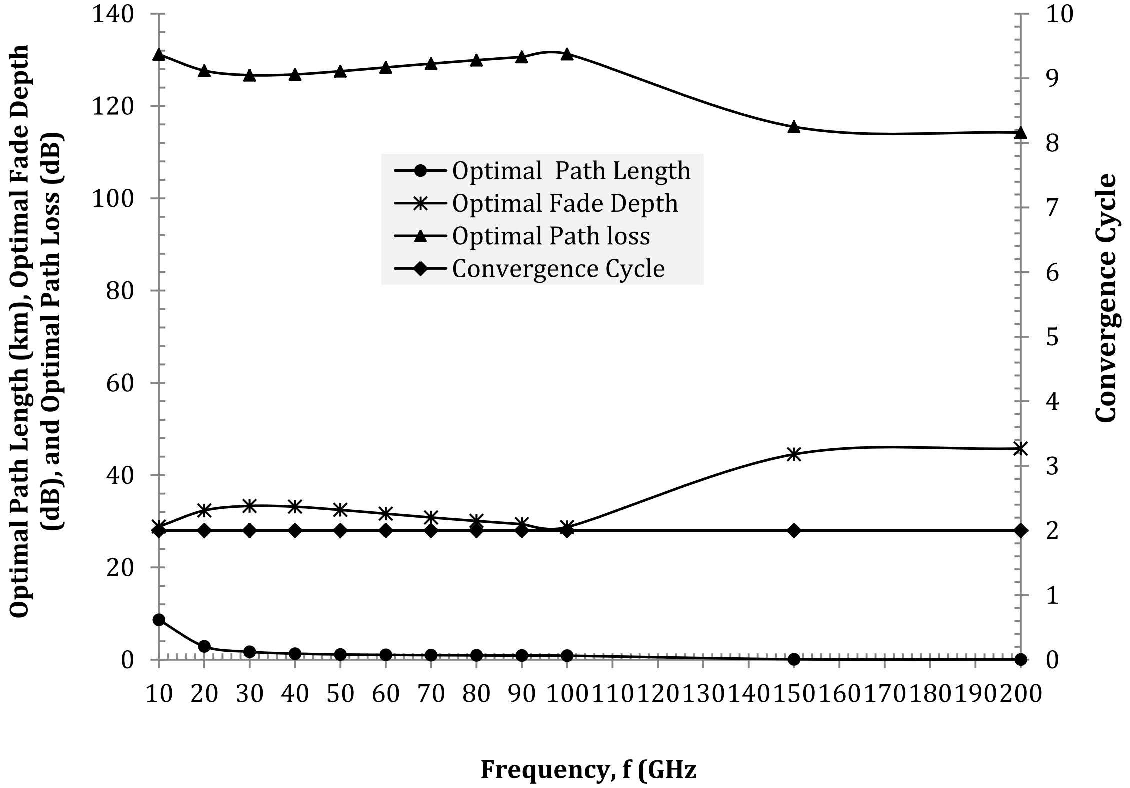

Figure 6: Intersection of Line method: Optimal path length, optimal fade depth, optimal path loss and convergence cycle vs frequency

Table 6: Intersection of Line method: Optimal rain fading, optimal multipath fading and optimal effective fading vs frequency

f (GHz)	Optimal Rain Fading (dB)	Optimal Multi path Fading (dB)	Optimal Effective Fading (dB)
10	28.8340	11.5824	28.8340
20	32.3405	0.0000	32.3405
30	33.3247	0.0000	33.3247
40	33.1562	0.0000	33.1562
50	32.4640	0.0000	32.4640
60	31.6386	0.0000	31.6386
70	30.8250	0.0000	30.8250
80	30.0696	0.0000	30.0696
90	29.3744	0.0000	29.3744
100	28.7356	0.0000	28.7356
150	44.5112	0.0000	44.5112
200	45.7708	0.0000	45.7708

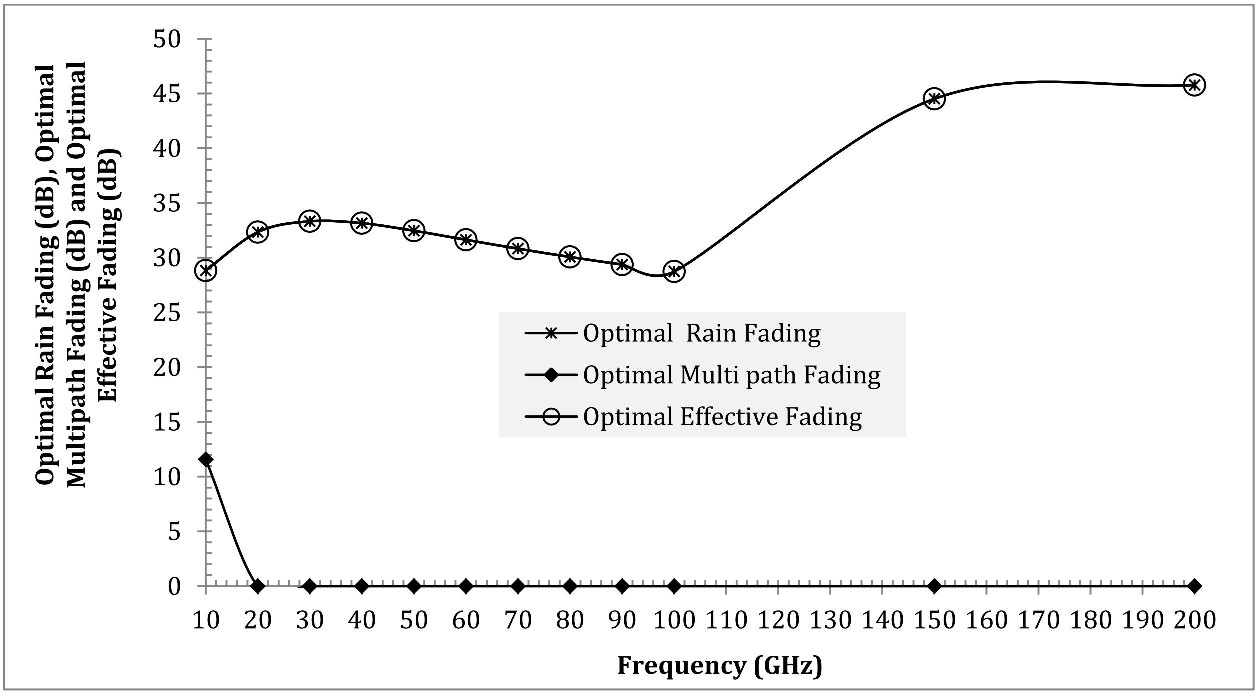

Figure 7: Intersection of Line method: Optimal rain fading, optimal multipath fading and optimal effective fading vs frequency

D. COMPARISON OF THE CONVERGENCE CYCLE OF THE INTERSECTION OF LINE METHOD WITH THOSE OF NEWTON–RAPHSON METHOD, SECANT METHOD, AND REGULAR FALSI METHOD

Also, the results from Table 7 and Figure 8 show that the convergence cycle for the intersection of line remains constant at 2 cycles as the frequency is varied from 10 GHz to 200 GHz. The developed algorithms where compared with three existing algorithms namely: Newton-Raphson Method, Regular Falsi Method and Secant Method. The results for the three existing methods were also presented. Table 7 and Figure 8 show that the convergence cycle for Newton-Raphson remained constant at 4 cycles for all frequencies while secant method has a convergence cycle of 6 for all frequencies. However, the convergence cycle for Regular Falsi Method Varies from 6 cycles (for frequencies from 10 GHz to 70 GHz) to 5 cycles (for frequencies from 80 GHz to 70 GHz).

In all, from the results in Table 7 and Table 8, as well as Figure 8 and Figure 9, it can be seen that the Intersection of Line method has the lowest overall convergence cycle for all the frequencies considered. The worst algorithm based on the convergence cycle is the Secant method and the Regular Falsi method. In essence, the Intersection of Line method developed in this research has proven to be the best algorithm for the determination of the optimal path length of LOS terrestrial microwave link.

Table 7: Comparison of the convergence cycle of the four methods

f (GHz)	Convergence Cycle for Intersection of Line method	Convergence Cycle for Newton–Raphson method	Convergence Cycle for Secant method	Convergence Cycle for Regular Falsi method
10	2	4	6	6
20	2	4	6	6
30	2	4	6	6
40	2	4	6	6
50	2	4	6	6
60	2	4	6	6
70	2	4	6	6
80	2	4	6	5
90	2	4	6	5
100	2	4	6	5
150	2	4	6	5
200	2	4	6	5

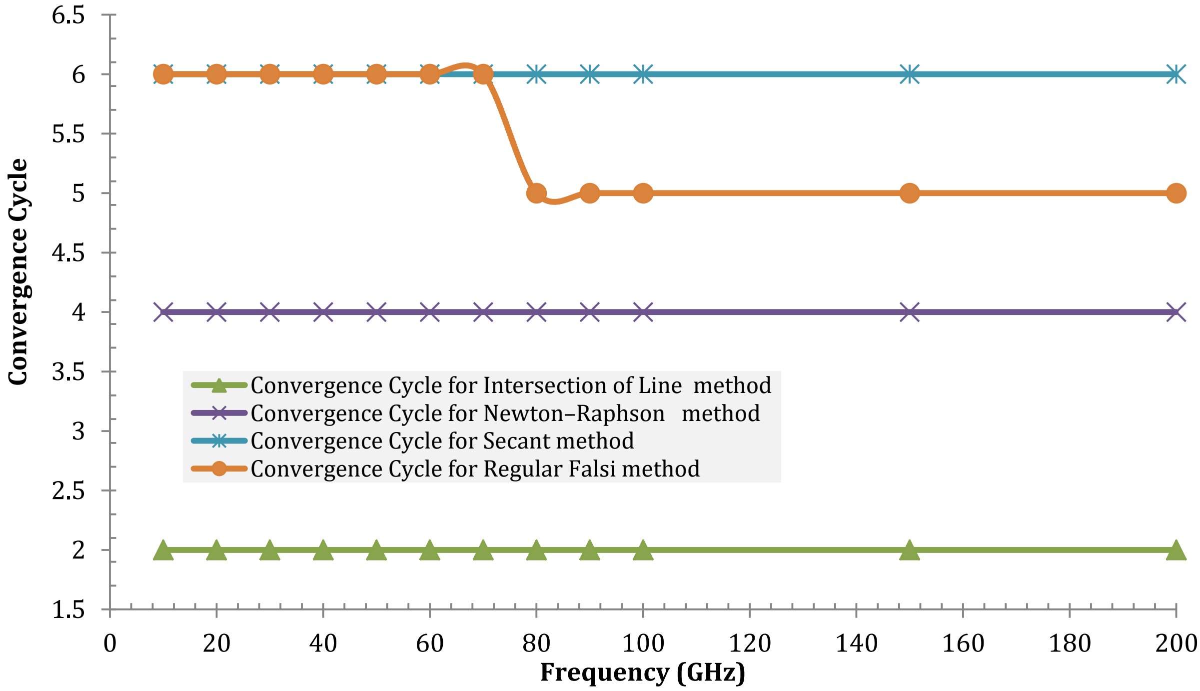

Figure 8: Comparison of the convergence cycle of the seven methods

IV. CONCLUSION

In this paper, fade margin-based Intersection of Line iteration method was developed to determine the optimal path length for a terrestrial LoS microwave link. The convergence cycle of the Intersection of Line iteration method was compared to three already published methods for determination of optimal path length, namely;

i. Method 1: Newton-Raphson Method;

ii. Method 2: Regular Falsi Method;

iii. Method 3: Secant Method;

Although other published works have used iteration methods to determine the optimal path length for a terrestrial LoS microwave link, none of the published works considered knife edge diffraction loss. However, the work in this paper included the diffraction loss in the computation of the optimal path length for the terrestrial LoS microwave link.

REFERENCES

1. Ononiwu, G., Ozuomba Simeon , & Kalu, C. (2015). Determination of the dominant fading and the effective fading for the rain zones in the ITU-R P. 838-3 recommendation. *European Journal of Mathematics and Computer Science Vol*, *2*(2).
2. Ozuomba, Simeon, Constance Kalu, and Akaninyene B. Obot. (2016) "Comparative Analysis of the ITU Multipath Fade Depth Models for Microwave Link Design in the C, Ku, and Ka-Bands." *Mathematical and Software Engineering* 2.1 (2016): 1-8.
3. Kalu, C., Ozuomba Simeon & Jonathan, O. A. (2015). Rain rate trend-line estimation models and web application for the global ITU rain zones. *European Journal of Engineering and Technology, 3 (9)*, 14-29
4. Ozuomba Simeon, Henry Akpan Jacob and Kalu Constance (2019) Analysis Of Single Knife Edge Diffraction Loss For A Fixed Terrestrial Line-Of-Sight Microwave Communication Link Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. xx Issue xx, xxxx – 2019
5. Kalu, C. (2019). Development and Performance Analysis of Bisection Method-Based Optimal Path Length Algorithm for Terrestrial Microwave Link. *Review of Computer Engineering Research*, *6*(1), 1-11.
6. Emenyi, M., Udofia, K., & Amaefule, O. C. (2017). Computation of optimal path Length for terrestrial line of sight microwave link using Newton–Raphson algorithm. *Software Engineering*, *5*(3), 44.
7. Ezenugu, I. A. Link Budget Analysis For Non-Line-Of-Sight Microwave Communication Link With Single Knife Edge Diffraction Obstruction.
8. Ozuomba, Simeon (2019) EVALUATION OF OPTIMAL TRANSMISSION RANGE OF WIRELESS SIGNAL ON DIFFERENT TERRAINS BASED ON ERICSSON PATH LOSS MODEL , Science and Technology Publishing (SCI & TECH) Vol. xx Issue xx, xxxx – 2019
9. Johnson, E. H., Ozuomba Simeon., & Asuquo, I. O. (2019). Determination of Wireless Communication Links Optimal Transmission Range Using Improved Bisection Algorithm.
10. Johnson, E. H., Ozuomba Simeon & Asuquo, I. O. (2019). Determination of Wireless Communication

Links Optimal Transmission Range Using Improved Bisection Algorithm. Universal Journal of Communications and Network 7(1): 9-20, 2019

11. Ozuomba, Simeon (2019) SEEDED SECANT NUMERICAL ITERATION USING SINGLE INITIAL VALUE MECHANISM , International Multilingual Journal of Science and Technology (IMJST) Vol. x Issue x, xxxx- 201

12. Ozuomba, Simeon (2019) SEEDED BISECTION NUMERICAL ITERATION BASED ON SINGLE TO DUAL INITIAL ROOT VALUES MECHANISM, Science and Technology Publishing (SCI & TECH) Vol. xx Issue xx, xxxx - 2019

13. Ozuomba, Simeon (2019) SEEDED REGULAR FALSI ITERATION USING SINGLE TO DUAL INITIAL ROOT VALUES MECHANISM, Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. xx Issue

14. Ozuomba, Simeon (2019) ANALYSIS OF EFFECTIVE TRANSMISSION RANGE BASED ON HATA MODEL FOR WIRELESS SENSOR NETWORKS IN THE C-BAND AND KU-BAND, Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. xx Issue xx, xxxx – 2019

15. Ozuomba, Simeon (2019) ANALYSIS OF THE STATIC PERTURBATION-BASED SEEDED SECANT ITERATION METHOD, Journal of Multidisciplinary Engineering Science and Technology (JMEST) Vol. xx Issue xx, xxxx – 2019

16. Ozuomba, Simeon (2019) PERTURBATION-BASED SEEDED REGULAR FALSI ITERATION METHOD, Science and Technology Publishing (SCI & TECH) Vol. xx Issue xx, xxxx – 2019

17. Jude, O. O., Jimoh, A. J., & Eunice, A. B. (2016). Software for Fresnel-Kirchoff single knife-edge diffraction loss model. *Mathematical and Software Engineering*, *2*(2), 76-84.

18. 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.

19. Ezeh, I. H., & Nwokonko, S. C. (2017). Determination of Single Knife Edge Equivalent Parameters for Triple Knife Edge Diffraction Loss by Giovanelli Method. *International Journal of Information and Communication Sciences*, *2*(1), 10.

20. Eduediuyai, D., Enyenihi, J., & Markson, I. (2019). Analysis of the Effect of Variations in Refractivity Gradient on Line of Sight Percentage Clearance and Single Knife Edge Diffraction Loss. *International Journal of Sustainable Energy and Environmental Research*, *8*(1), 1-9.

21. Samuel, W., Nwaduwa, F. O. C., & Oguichen, T. C. (2017). Algorithm for Computing N Knife Edge Diffraction Loss Using Epstein-Peterson Method. *American Journal of Software Engineering and Applications*, *6*(2), 40-43.

22. Amadi, C. H., Kalu, C., & Udofia, K. (2020). Modelling of Bit Error Rate as a Function of Knife Edge Diffraction Loss Based on Line of Sight Percentage Clearance. *International Journal of Engineering & Technology*, *5*(1), 9-24.

23. Nwokonko, S. C., Onwuzuruike, V. K., & Nkwocha, C. P. (2017). Remodelling of Lee's Knife Diffraction Loss Model as a Function of Line of Site Percentage Clearance. *International Journal of Theoretical and Applied Mathematics*, *3*(4), 138.

24. Opeyemi, O. A., Simeon, O., & Kalu, C. (2017). Shibuya Method for Computing Ten Knife Edge Diffraction Loss. *Software Engineering*, *5*(2), 38.

25. 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.