Journal of Multidisciplinary Engineering Science Studies (JMESS)
ISSN: 2458-925X
Vol. 6 Issue 2, February - 2020

COMPUTATION OF OPTIMAL TRANSMISSION RANGE OF LINE OF SIGHT LINK BASED ON WALFICSH-BERTONI PROPAGATION LOSS MODEL

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***Abstract*— In this paper, computation of optimal transmission range of line of sight (LOS) link based on Walficsh-Bertoni propagation loss model is presented. The optimal transmission range differ from the maximum transmission range obtained using the propagation loss model along. At the optimal point, the fade margin is equal to the fade depth. Seeded Regular Falsi iteration method was adapted and used in the computation of the effective transmission range and the computation was implemented in Matlab software. A 4.5 GHz C-band microwave link with transmitter power of 20 dB, transmitter and receiver antenna gain of 30 dBi was used in the numerical example. The simulation was conducted for the microwave link two cases, namely, for a communication link located in ITU rain zone M with rain rate of 65 mm/hr and for a communication link located in ITU rain zone N with rain rate of 95 mm/hr. The results show that for the link located in rain zone M , it took 41 cycles before the Regular Falsi algorithm could converge and determine the optimal transmission range as 5.605388531 km whereas, for the link located in rain zone N it took 8 cycles before the Regular Falsi algorithm could converge and determine the optimal transmission range as 5.363387406 km. in all, the results showed that the optimal transmission range is inversely proportional to the rain rate.**

Keywords— Transmission Range , Propagation Model, Walficsh-Bertoni Propagation Model, Path Loss, Optimal Transmission Range, Line Of Sight (LOS) Link, Regular Falsi Algorithm

I. INTRODUCTION

In wireless communication industry, there are several propagation loss models that are used to estimate the expected propagation loss in different environments and frequency ranges [1,2,3,4,5]. Particularly, Walficsh-Bertoni propagation model is an empirical model that is used for estimating the expected path loss wireless signal will experience when it propagates in areas that have a good number of buildings [6,7,8,9,10]. It takes into account the building height and the space in-between buildings .As such it is suitable for cities, residential and industrial estates and market areas. In this paper, Walficsh-Bertoni model is used in the computation of optimal path transmission range of line of sight microwave communication link [11,12,13,14,15,16]. The paper adopted an iterative approach whereby; the transmission range was first computed using the link budget equation with the Walficsh-Bertoni model for computation of the path loss after which the fade margin is determined. The same transmission range (distance) used in computing the pathloss in the Walficsh-Bertoni propagation model was used to compute the fade depth based on rain fading. The transmission range was adjusted iteratively until the point at which the fade margin is the same value as the fade depth. At this point, the transmission range is said to be optimal because the available fade margin can accommodate the expected fade depth without any excess or deficit. This ensures that the design time quality of service is maintained in the operation time since the fade depth is adequately taken care of at the design time. Sample LOS link parameters are used to show how the ideas presented here can be employed in practice.

II. METHODOLOGY

A. THE WALFICSH-BERTONI PROPAGATION LOSS MODEL

Propagation loss based on Walficsh-Bertoni model (which is denoted as $LP_{WB}(dB)$) is given as [6,7,8,9,10]:

$$LP_{WB}(dB) = 89.5 - 10\left(\log_{10}\left(\frac{\rho_1 R^{0.9}}{(H_B-h_m)^2}\right)\right) + 21\log_{10}(f) - 18\log_{10}(h_b - H_B) + 38\log_{10}(d_k) \quad (9)$$

Where;

$$\rho_1 = \sqrt{\left(\left(\frac{R}{2}\right)^2 + (H_B - h_m)^2\right)} \quad (10)$$

f is the frequency in MHz; h_b is the base station antenna height in meters; H_B is the building height in meters, h_m is the mobile height in meters; R: Space between buildings in meters and d: is the distance between base station transmitter and mobile station in Km.

B. LINE OF SIGHT COMMUNICATION LINK OPTIMAL TRANSMISSION RANGE ANALYSIS BASED ON WALFICSH-BERTONI PROPAGATION LOSS MODEL

Based on Walficsh-Bertoni Propagation loss model, the transmission range of a Line of Sight (LoS) link can be computed from the link budget formula as follows;

$$P_R = P_T + (G_T + G_R) - LP_{WB}(dB) \quad (11)$$

Therefore, propagation loss due to Walficsh-Bertoni model (denoted as $LP_{WB}(dB)$) is;

$$LP_{WB}(dB) = P_T + G_T + G_R - P_R = 89.5 - 10\left(\log_{10}\left(\frac{\rho_1 R^{0.9}}{(H_B-h_m)^2}\right)\right) + 21\log_{10}(f_m) - 18\log_{10}(h_b - H_B) + 38\log_{10}(d) \quad (12)$$

Therefore, the effective transmission range (d_{eWB}) with respect to the Walficsh-Bertoni model is given as:

$$d_{eWB} = 10^{\left(\frac{(\mathrm{P_T} + \mathrm{G_T} + \mathrm{G_R} - fm_S - P_S) - \left(89.5 - 10\left(\log_{10}\left(\frac{\rho_1 R^{0.9}}{(H_B - h_m)^2}\right)\right) + 21\log_{10}(fm) - 18\log_{10}(h_b - H_B)\right)}{38}\right)} \quad (13)$$

With respect to d_{eWB} the effective path loss, $\left(LP_{WBe}(dB)\right)$ is given as:

$$LP_{WBe}(dB) = 89.5 - 10\left(\log_{10}\left(\frac{\rho_1 R^{0.9}}{(H_B - h_m)^2}\right)\right) + 21\log_{10}(f_m) - 18\log_{10}(h_b - H_B) + 38\log_{10}\left(LP_{WBe}(dB)\right) \quad (14)$$

Effective Received Power (P_{ReWB}) is given as:

$$P_{ReWB} = \mathrm{P_T} + \mathrm{G_T} + \mathrm{G_R} - LP_{WBe}(dB) \quad (15)$$

Effective Fade Margin (fm_{eWB}) is given as:

$$fm_{eWB} = (\mathrm{P_T} + \mathrm{G_T} + \mathrm{G_R}) - LP_{WBe}(dB) - P_S \quad (16)$$

The rain fade depth (fd_{meWB}) at a transmission range (d_{eWB}) is given as;

$$fd_{meWB} = \max\left(\left(\mathrm{K_v}\left(\mathrm{R_{po}}\right)^{\alpha_\mathrm{v}}\right) * d_{eWB}, \left(\mathrm{K_h}\left(\mathrm{R_{po}}\right)^{\alpha_\mathrm{h}}\right) * d_{eWB}\right) \quad (17)$$

Hence, when the propagation loss is based on Walficsh-Bertoni model, the optimal transmission range (denoted as, d_{eWB}) is the value of d_{OPWB} for which $fm_{eWB} = fd_{meWB}$

$$d_{OPWB} = d_{eWB} \text{ at which } fm_{eWB} = fd_{meWB} \quad (18)$$

C. APPLICATION OF REGULAR FALSI ALGORITHM FOR DETERMINATION OF THE OPTIMAL TRANSMISSION RANGE OF TERRESTRIAL LINE OF SIGHT LINK

The seeded Regular Falsi iteration algorithm was adapted and applied in the computation of the effective transmission range of the LoS communication link Based on Walficsh-Bertoni propagation loss model . Flowchart for the adapted seeded Regular Falsi iteration [17,18,19] algorithm is given in Figure 1.

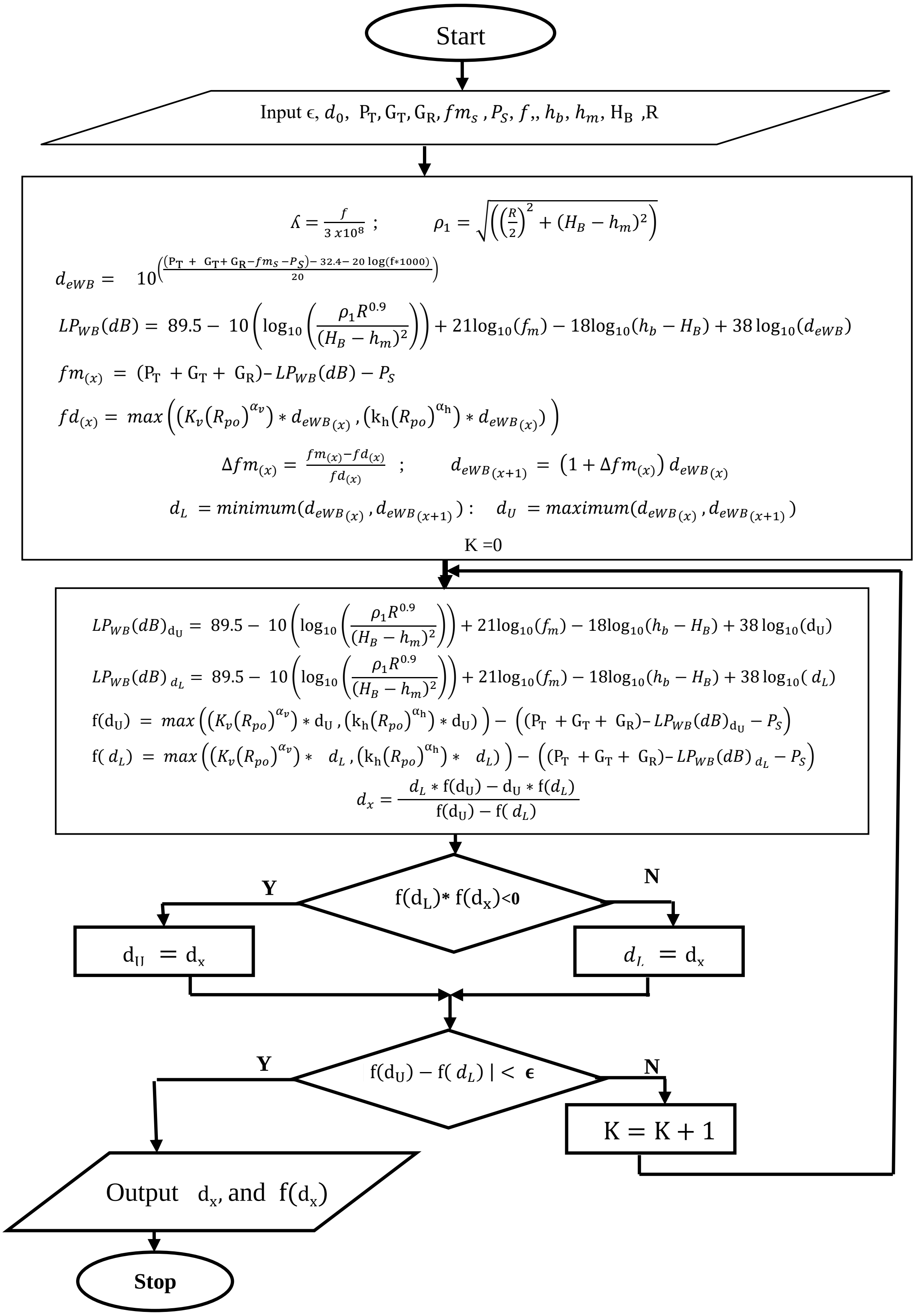


Figure 1 Flowchart for the adapted seeded Regular Falsi iteration applied in the computation of the effective transmission range

III. SIMULATION AND RESULTS

The simulation for the microwave link was conducted for two cases, namely, for a communication link located in ITU rain zone M with rain rate of 65 mm/hr and for a communication link located in ITU rain zone N with rain rate of 95 mm/hr. Table 1 shows that communication link parameters used for the numerical iteration for a microwave link located in rain zone M. The same parameter values were used for the for a microwave link located in rain zone N except that the rain rate was changed to 95 mm/hr.

The network is a 4.5 GHz C-band microwave link with transmitter power of 20 dB, transmitter and receiver antenna gain of 30 dBi. The simulation results for the link located in rain zone M with rain rate of 65 mm/hr is shown in Table 2. The results show that it took 41 cycles before the Regular Falsi algorithm could converge and determine the optimal transmission range as 5.605388531 km, (as shown in Table 2 and Figure 1).Similarly, the simulation results for the link located in rain zone N with rain rate of 95 mm/hr is shown in Table 3. The results show that it took 8 cycles before the Regular Falsi algorithm could converge and determine the optimal transmission range as 5.363387406 km, (as shown in Table 3 and Figure 1). Notably, the communication link in rain zone M has longer transmission range than the link that is located in rain zone N. The difference in the optimal transmission range is associated with the difference in the rain rates of the two rain zones. Essentially, the optimal transmission range is inversely proportional to the rain rate.

Table 1 The communication link parameters used for the numerical iteration for a microwave link located in rain zone M

Parameter Name and Unit	**Parameter** Value		**Parameter Name and Unit**	**Parameter** Value
f (MHz)	4500		**kh**	0.000134
Transmitter power, P_T(dB)	20		**ah**	1.6948
Transmitter antenna Gain, G_T(dB)	30		**kv**	0.000235
Receiver antenna gain, G_R(dB)	30		**av**	1.3987
Receiver sensitivity, P_s (dB)	-85		**Percentage Availability, Pa (%)**	99.99
Fade Margin (dB)	20		**Rain Rate at 0.01 % outage probability, R0.01 mm/hr**	65

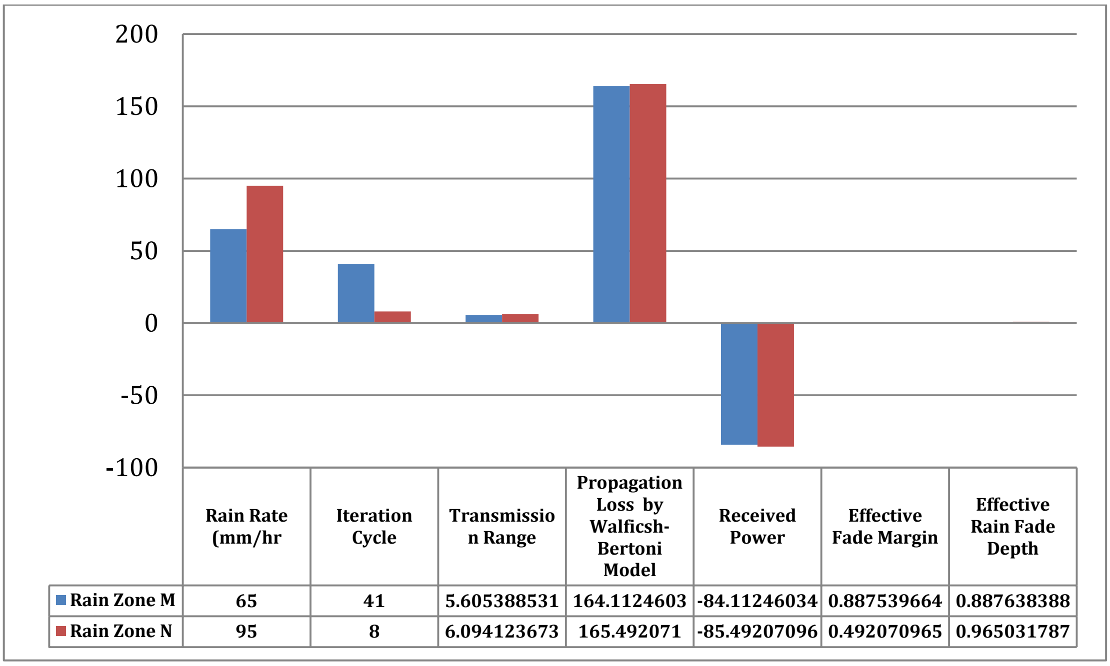
Table 2 The simulation results for a microwave link located in rain zone M with rain rate of 65 mm/hr

Iteration Cycle	Transmission Range	Propagation Loss by Walficsh-Bertoni Model	Received Power	Effective Fade Margin	Effective Rain Fade Depth	Error
0	5	162.2263031	-82.22630312	2.773696883	0.791772401	-1.98E+00
1	6.094123673	165.492071	-85.49207096	-0.492070965	0.965031787	1.46E+00
2	5.228784868	162.9646724	-82.96467235	2.035327646	0.82800151	-1.21E+00
3	5.906253741	164.9753028	-84.97530279	0.024697212	0.935281741	9.11E-01
4	5.371772335	163.4099117	-83.40991169	1.590088313	0.850644216	-7.39E-01
5	5.790823306	164.6495749	-84.64957487	0.350425129	0.917002815	5.67E-01
6	5.460697133	163.6808704	-83.68087037	1.319129632	0.864725856	-4.54E-01
7	5.71977315	164.4458375	-84.44583753	0.554162467	0.905751704	3.52E-01
8	5.515850936	163.8467188	-83.84671875	1.153281248	0.873459708	-2.80E-01
9	5.675982042	164.3190014	-84.31900144	0.680998562	0.898817186	2.18E-01
10	5.550006549	163.9485958	-83.94859578	1.051404216	0.878868402	-1.73E-01
11	5.648967443	164.2402677	-84.24026768	0.759732321	0.894539303	1.35E-01
12	5.571139464	164.0113161	-84.01131611	0.988683891	0.882214894	-1.06E-01
13	5.632292406	164.1914803	-84.19148031	0.808519693	0.891898737	8.34E-02
14	5.584207933	164.049983	-84.04998304	0.950016959	0.884284345	-6.57E-02
15	5.621995701	164.1612823	-84.1612823	0.838717699	0.890268207	5.16E-02
16	5.59228679	164.0738415	-84.07384149	0.926158508	0.885563668	-4.06E-02
17	5.61563606	164.1426032	-84.14260321	0.85739679	0.88926113	3.19E-02
18	5.597280113	164.0885705	-84.08857053	0.911429471	0.886354383	-2.51E-02
19	5.61170752	164.131054	-84.13105401	0.868945994	0.888639028	1.97E-02
20	5.60036598	164.0976665	-84.09766649	0.902333514	0.886843044	-1.55E-02
21	5.609280521	164.123915	-84.12391502	0.876084981	0.888254701	1.22E-02

22	5.602272901	164.1032849	-84.10328485	0.896715145	0.887145013	-9.57E-03
23	5.607781066	164.1195029	-84.11950285	0.880497148	0.888017256	7.52E-03
24	5.603451235	164.1067556	-84.10675563	0.893244372	0.887331608	-5.91E-03
25	5.606854638	164.1167762	-84.11677623	0.883223769	0.887870552	4.65E-03
26	5.604179336	164.1088999	-84.10889988	0.891100119	0.887446906	-3.65E-03
27	5.606282237	164.1150913	-84.11509134	0.884908658	0.88777991	2.87E-03
28	5.604629227	164.1102247	-84.11022467	0.889775332	0.887518148	-2.26E-03
29	5.605928569	164.1140502	-84.11405022	0.885949779	0.887723905	1.77E-03
30	5.604907211	164.1110432	-84.11104319	0.888956812	0.887562168	-1.39E-03
31	5.605710049	164.1134069	-84.11340691	0.886593091	0.887689301	1.10E-03
32	5.605078973	164.1115489	-84.11154892	0.88845108	0.887589368	-8.62E-04
33	5.60557503	164.1130094	-84.11300941	0.886990589	0.887667921	6.77E-04
34	5.605185102	164.1118614	-84.1118614	0.888138605	0.887606174	-5.32E-04
35	5.605491606	164.1127638	-84.1127638	0.887236198	0.88765471	4.19E-04
36	5.605250677	164.1120545	-84.11205447	0.887945535	0.887616558	-3.29E-04
37	5.60544006	164.112612	-84.11261204	0.887387957	0.887646547	2.59E-04
38	5.605291195	164.1121738	-84.11217376	0.887826242	0.887622974	-2.03E-04
39	5.60540821	164.1125183	-84.11251827	0.887481726	0.887641504	1.60E-04
40	5.60531623	164.1122475	-84.11224747	0.887752533	0.887626938	-1.26E-04
41	5.605388531	164.1124603	-84.11246034	0.887539664	0.887638388	9.87E-05

Table 3 The simulation results for a microwave link located in rain zone N with rain rate of 95 mm/hr

Iteration Cycle	Transmission Range	Propagation Loss by Walficsh-Bertoni Model	Received Power	Effective Fade Margin	Effective Rain Fade Depth	Error
0	5	162.2263031	-82.22630312	2.773696883	1.506332232	-1.27E+00
1	5.470044671	163.7090961	-83.70909613	1.290903874	1.647940919	3.57E-01
2	5.332760572	163.2896222	-83.2896222	1.710377805	1.606581826	-1.04E-01
3	5.372264132	163.4114225	-83.41142252	1.588577481	1.618482924	2.99E-02
4	5.36084858	163.3763175	-83.37631749	1.623682509	1.615043801	-8.64E-03
5	5.364143336	163.3864572	-83.38645717	1.613542829	1.6160364	2.49E-03
6	5.363192066	163.3835303	-83.38353026	1.616469742	1.615749815	-7.20E-04
7	5.363466691	163.3843753	-83.38437529	1.61562471	1.61583255	2.08E-04
8	5.363387406	163.3841313	-83.38413133	1.615868667	1.615808664	-6.00E-05



	Rain Rate (mm/hr	Iteration Cycle	Transmission Range	Propagation Loss by Walficsh-Bertoni Model	Received Power	Effective Fade Margin	Effective Rain Fade Depth
🟦 Rain Zone M	65	41	5.605388531	164.1124603	-84.11246034	0.887539664	0.887638388
🟥 Rain Zone N	95	8	6.094123673	165.492071	-85.49207096	0.492070965	0.965031787

Figure 1 Comparison of the iteration results for the microwave link in rain zone M and the rain zone N

IV. CONCLUSION

Determination of the optimal transmission range for line of sight communication link was presented. The optimal range is computed based on the Walficsh-Bertoni propagation loss model along with rain fade depth. The optimal transmission range is attained when the fade margin obtained from the link budget analysis is equal to the fade depth in the link. Sample optimal transmission range was computed for a C-band microwave link located in the ITU rain zone M and rain zone N. The results showed that the link in M rain zone with a smaller rain rate has a higher transmission range than the link that is located in rain zone N with higher rain rate.

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