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Parametric Analysis Of The Optimal Transmission Range Based On Early Itu Model Foliage Model For Vegetation Covered Areas

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***Abstract*— In this paper, parametric analysis of the optimal transmission range based on Early ITU model foliage model for vegetation covered areas is presented. A fixed point iteration flowchart was developed and used to compute the effective transmission range of a case study 10 GHz Ku-band communication link for four different scenarios, namely, at rain rate of 95 mm/hr with foliage depth of 70 m, at rain rate of 95 mm/hr with foliage depth of 140 m, at rain rate of 145 mm/hr with foliage depth of 70 m, and at rain rate of 145 mm/hr with foliage depth of 140 m. The computation was conducted using a program written in Matlab software. The results show that the link in rain zone P with rain rate of R0.01 = 145 mm/hr had lower optimal transmission range of 3.199 km at 70 m foliage depth and 2.912 km at 140 m foliage depth when compared to that of the link in rain zone N with rain rate of R0.01 = 95 mm/hr with transmission range of 4.598 km at 70 m foliage depth and 4.138 km at 140 m foliage depth. The results showed that the higher the rain rate the higher the rain fading and the lower the transmission range. Also, higher fade depth leads to lower transmission range. In all, the link with rain rate of 145 mm/hr with foliage depth of 140 m had the lowest transmission range and the highest rain fade depth.**

Keywords*— *Transmission Range, Early ITU Model , Propagation Loss, Optimal Path Length , Path Loss Model, Effective Transmission Range

I. INTRODUCTION

Nowadays, wireless sensor networks (WSNs) are increasingly deployed in vegetation covered areas for such applications as precision farming, environmental impact assessment data acquisition system, land use, etc [1,2,3,4,5,6,7]. As such, study of communication links located in vegetation covered areas is essential, especially, in order to properly estimate the propagation loss and other losses like diffraction loss due to obstruction [9,10], multipath fading [11,12] due to variations in atmospheric refractivity gradient [13], etc. Importantly, such area requires foliage propagation loss models that can effectively estimate the propagation loss that will be suffered by the wireless signal as it propagates through area. Also, the effective transmission range of the signal through the foliage depth needs to be estimated. In addition, provisions are always made for fade mechanisms such as rain or multipath fading. In the microwave frequency band above 8 GHz, the rain fade depth dominates the multipath fading. Hence, in such case, rain fades depth need to be considered in the determination of the effective transmission range [14,15,16].

Consequently, in this paper, the optimal or effective path length of Ku-band communication link located in vegetation covered area is studied. The Early ITU foliage propagation loss model [17,18,19] is used along with rain fading to determine the effective path length. A fixed point iteration technique [20,21,22,23] was developed and used to iteratively compute the transmission range until the effective transmission range is obtained. The computation was carried out using a Matlab program. The simulation was conducted for some selected foliage depths. The results were then used to evaluate the impact of foliage depth on the maximum transmission range.

II. METHODOLOGY

A. THE EARLY ITU FOLIAGE PROPAGATION LOSS MODEL

There are several propagation loss models [24, 25, 26, 27, 28] used in the communication industry to estimate the expected path loss a signal can encounter as it propagates through an area. The Early ITU model [17,18, 19] is one of the most popular foliage propagation loss models which specify propagation loss in vegetation covered areas as a combination of the free space propagation loss and the propagation loss due to the foliage cover. Hence, the Early ITU model specifies the effective propagation loss, $PL_{eITU}(dB)$ as follows [17,18,19];

$$PL_{eITU} = PL_{FSP} + PL_{ITU} \quad (1)$$

$$PL_{FSP}(dB) = 32.5 + 20 * \log(f) + 20 * \log(d) \quad (2)$$

$$PL_{ITU}(dB) = \begin{cases} 0.2F^{0.3}(d_f)^{0.3} for \quad 0 \le d_f \le 14m \\ 0.2F^{0.3}(d_f)^{0.6} for \quad 14 \le d_f \le 400m \end{cases} \quad (3)$$

The parameters are, foliage depth (d_f in meter), frequency (f in GHz) and path length (d in km),

B. COMPUTATION OF THE OPTIMAL TRANSMISSION RANGE FOR VEGETATION COVERED AREAS BASED ON EARLY ITU FOLIAGE PROPAGATION LOSS MODEL

A fixed point iteration method is used to compute the optimal transmission range of the link for different foliage depth. The flowchart for the fixed point numerical iteration used in the determination of the optimal (or effective) path length of the communication link is shown in Figure 1. A Mathlab program is written for the fixed point iteration and then sample communication link parameters are used to compute the transmission range for some selected foliage depth.

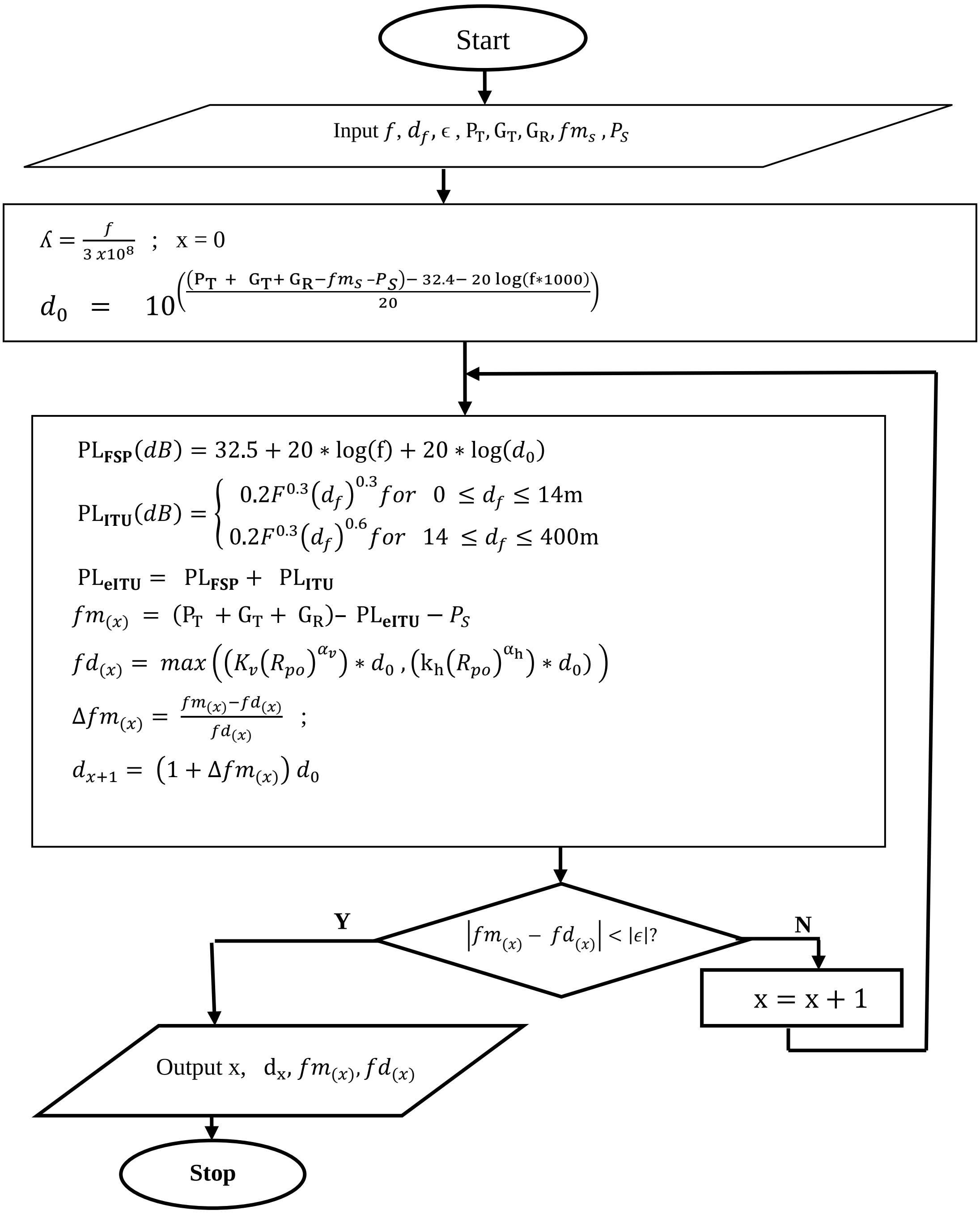

Figure 1 The flowchart for the fixed point numerical iteration used in the determination of the optimal (or effective) path length of the communication link

III. RESULTS AND DISCUSSIONS

The simulation of the fixed point numerical iteration in Figure 1 was conducted using Matlab program. The input parameters are given in Table 1. The simulation was conducted for communication link located in ITU rain zone N and rain zone P at percentage outage of 0.01% or link availability of 99.99 %. In addition, for each of the rain zones, the simulation was conducted for foliage depth of 70 m and 140 m. The simulation results are presented in Table 2 for the study at foliage depth of 70 m while the simulation results are presented in Table 3 for the study at foliage depth of 140 m. The results in Table 2 show that it took 3 cycles for the iteration to converge for the case of foliage depth of 70 m whereas in Table 3 , it took 5 cycles for the iteration to converge for the case of foliage depth of 140 m.

The comparison of the transmission range for the various cases (rain zones and foliage depths) considered in the study is shown in Figure 2 while the comparison of the propagation loss for the various cases (rain zones and foliage depths) considered in the study is shown in Figure 3. In all the results presented, the link in rain zone P with rain rate of R0.01 = 145 mm/hr has lower optimal transmission range of 3.199 km at 70 m foliage depth and 2.912 km at 140 m foliage depth when compared to that of the link in rain zone N with rain rate of R0.01 = 95 mm/hr with transmission range of 4.598 km at 70 m foliage depth and 4.138 km at 140 m foliage depth . In essence, higher rain rate amounts to lower effective transmission range. Also, the transmission range with foliage depth of 140 m is smaller than the transmission range with foliage depth of 70

m. As such, the higher the foliage depth, the lower the transmission range. In all, the results show that areas with larger foliage depth require more network resources, such as higher transmission power, antenna with higher gain, etc.

Table 1 The simulation input dataset

S/N	Parameter Name and Unit	Parameter Value	S/N	Parameter Name and Unit	Parameter Value
1	F (MHz)	10000	7	kh	0.01217
2	Transmitter power, PT(dB)	10	8	ah	1.2571
3	Transmitter antenna Gain, GT(dB)	29	9	kv	0.01129
4	Receiver antenna gain, GR(dB)	29	10	av	1.2156
5	Receiver sensitivity, Ps (dB)	-80	11	Percentage Availability, Pa (%)	99.99
6	Fade Margin (dB)	10	12	Rain Rate at 0.01 % outage probability, R0.01 mm/hr	95

Table 2 The simulation results for the study at foliage depth of 70 m

S/N	Parameter Name and Unit	Rain Zone N with rain rate of R0.01 of 95 mm/hr and foliage depth of 70 m	Rain Zone P with rain rate of R0.01 of 145 mm/hr and foliage depth of 70 m
1	Rain Rate (mm/hr)	95	145
2	Convergence Cycle	3	3
3	Transmission Range (km)	4.598	3.199
4	Propagation Loss by Hata Urban Model (dB)	130.858	127.707
5	Received Power (dB)	-62.858	-59.707
6	Effective Fade Margin (dB)	17.142	20.294
7	Effective Rain Fade Depth(dB)	17.142	20.294
8	Error (dB)	2.40098E-06	8.6892E-05

Table 3 The simulation results for the study at foliage depth of 140 m

S/N	Parameter Name and Unit	Rain Zone N with rain rate of R0.01 of 95 mm/hr and foliage depth of 140 m	Rain Zone N with rain rate of R0.01 of 145 mm/hr and foliage depth of 140 m
1	Rain Rate (mm/hr)	95	145
2	Convergence Cycle	5	5
3	Transmission Range (km)	4.138	2.912
4	Propagation Loss by Hata Urban Model (dB)	132.574	129.524
5	Received Power (dB)	-64.574	-61.524
6	Effective Fade Margin (dB)	15.426	18.476
7	Effective Rain Fade Depth(dB)	15.426	18.476
8	Error (dB)	4.96442E-08	1.60112E-06

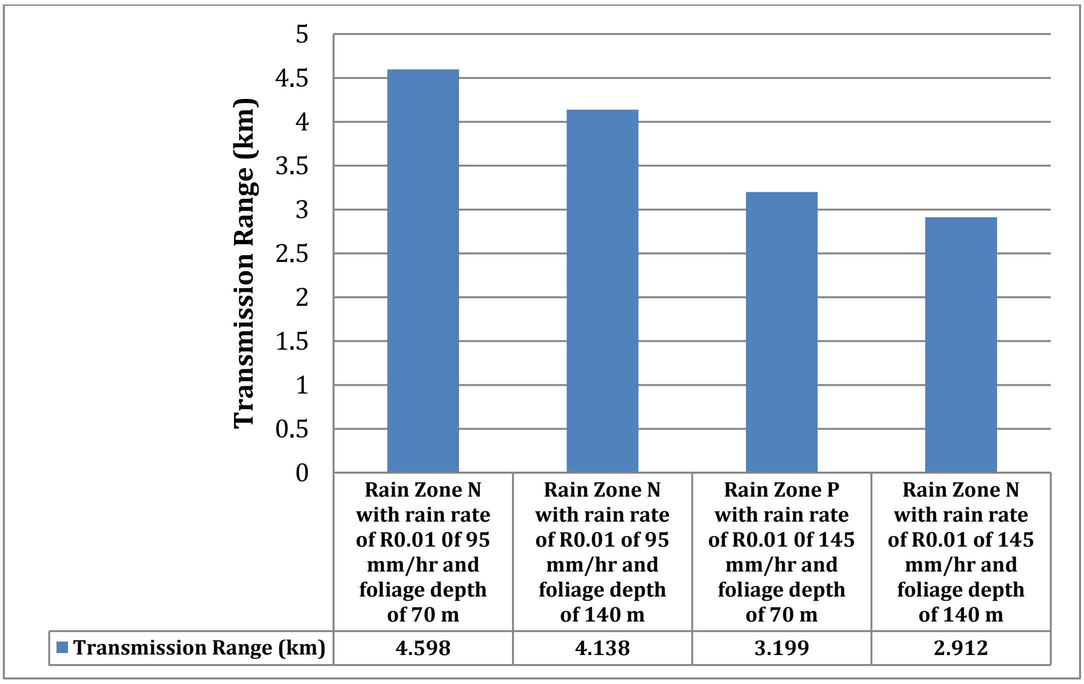

Figure 2 Comparison of the transmission range for the various cases (rain zones and foliage depths) considered in the study

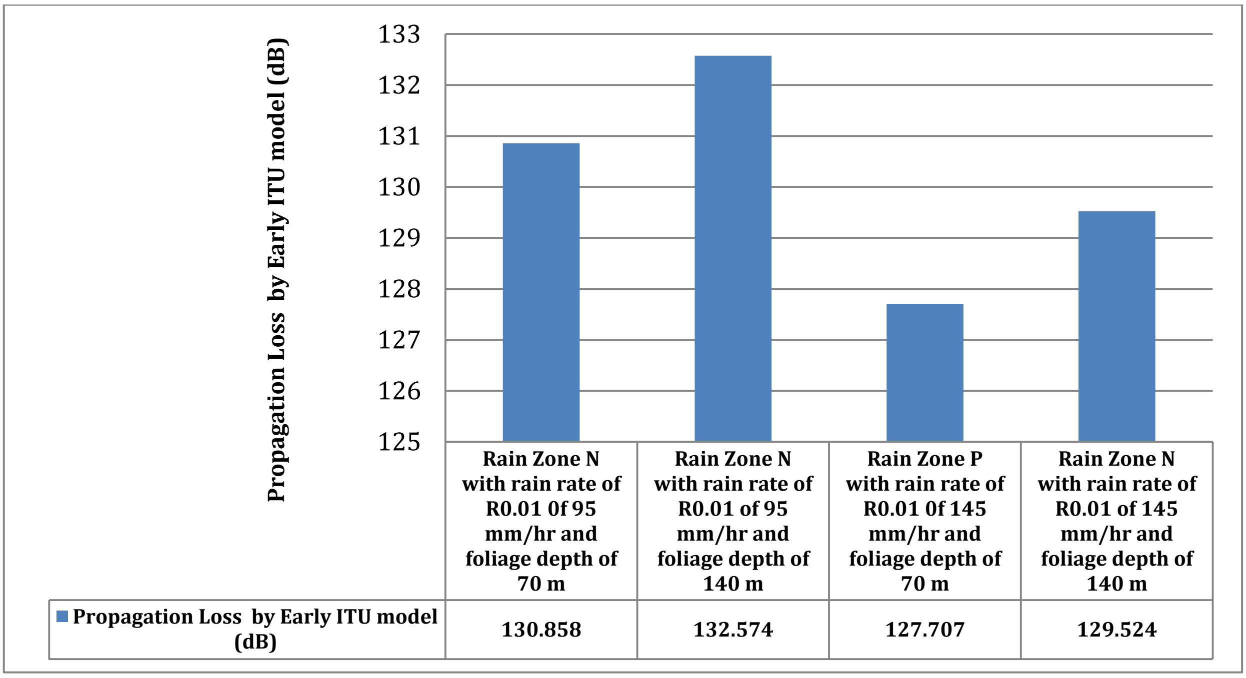

Figure 3 Comparison of the propagation loss for the various cases (rain zones and foliage depths) considered in the study

IV. CONCLUSION

Analysis of the impact of foliage depth on the effective transmission range of microwave links located in vegetation covered areas is presented. The study was conducted using Early ITU model foliage model and rain fade depth. Then, a fixed point iteration flowchart was developed and used to compute the effective transmission range of the communication link for four different scenarios, name, at rain rate of 95 mm/hr with foliage depth of 70 m, at rain rate of 95 mm/hr with foliage depth of 140 m, at rain rate of 145 mm/hr with foliage depth of 70 m, and at rain rate of 145 mm/hr with foliage depth of 140 m. The results showed that the higher the rain rate the higher the rain fading and the lower the transmission range. Also, higher fade depth leads to lower transmission range. In all, the link with rain rate of 145 mm/hr with foliage depth of 140 m had the lowest transmission range and the highest rain fade depth.

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