Lorawan Sensor Network Operating Link Margin Analysis For Smart Agriculture Application

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***Abstract*— In this paper, LoRaWAN sensor network operating link margin analysis for smart agriculture application is resented. Secifically, Weissberger model-based link budget analysis is usd to determine the operating link margin of the LoRaWAN sensor network designed for smart agriculture application is presented. According to the Weissberger model, the estimated total path loss is a combination of the path loss in the vegetation covered areaand the free space path loss. Hence, the link budget determines the received signal power of the LoRa transceiver based on the transmitter power and the Weissberger model estimated total path loss. The computation of the path loss was conducted for different foliage depth, from 500 m to 2500 m and 2.5 km free space path length. The results showed that the total path loss according to Weissberger model is 139.1 dB at foliage depth of 500 mwhich increased to a value of 158.3 dB when the foliage depth increased to 2500m. When the foliage depth and free space path length are fixed, with (path loss = 139.1 dB and received signal strength =-121.1 dB for all the spreading factors (SF 7 to Sf 12) then results showed that the link margin increased with increase in SF from 2.9 dB at SF =7 to 15.9 dB at SF =12. Furthermore, at a foliage depth of 720 m the link margin for SF of 7 became zero while that for SFof 12 occurred at foliage depth of 2060 m. That means with spreading factor of 12 a foliage depth of 2060 m can be effectively covered whereas with SF of 7 only 720 m of foliage depth can be accommodated in the link.**

Keywords*— *Weissberger Model, Lorawan , Link Budget Analysis, Smart Agriculture, Sensor Network

1. Introduction

Communication technologies have evolved over the years; from the twisted cable to fibre optic network and today we have 5G wireless network [1,2, 3,4, 5,6,7, 8,9,10, 11,12,13, 14,15, 16,17, 18,19,20,21]. The wireless technologies have promoted satellite communication and prompted the emergence of wireless sensor networks, Internet of Things and smart systems which depends on different transceiver technologies [22,23, 24,24, 25,26, 27,28, 29,30, 31,32, 33,34, 35]. Today, LoRa transceiver technologies have become the most popular transceiver technologies applied in various wireless sensor networks and Internet of Things applications [3,37,38,39,40]. It has been widely used in terrestrial wireless networks and in recent times it has also been employed in direct earth-to-satellite communication links [41,42]. Irrespective of the application, LoRa-based wireless sensor communication systems are subjected to of the propagation challenges [43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60], as well as path loss and interference [61,62, 63,64, 65,66, 676,68,69,70,71, 72]. As such proper estimation of the pathloss is required in the design and link budget analysis of a LoRa-based wireless communication link.

Accordingly, in this paper, Weissberger model-based link budget analysis of LoRaWAN sensor network for smart agriculture application is presented [73,74,75]. In this case, smart agriculture application entails vegetation covered propagation environment. For such environment, foliage model like Weissberger model is employed to estimate the path loss. Specifically, in this paper, the focus is to conduct link budget analysis whereby the expected link margin is determined for a given communication range [76,77,78]. Furthermore, the study compares the link margin obtained for different spreading factors used in the LoRa transceiver modulation scheme.

2. Methodology

2.1 Path Loss Computation Based on Weissberger Model

Basically, wireless communication link budget is meant to account for all the gains and losses in the wireless link. The main loss in the link is the path loss. In this paper, the path loss is computed using the Weissberger model.

Notably, Weissberger model is suitable for estimation of path loss in a vegetation covered area. The total Weissberger model estimated path loss, $Pl_{TW}(dB)$ is a combination of the path loss in the vegetation covered area, $Pl_{W}(dB)$ and the free space path loss, $Pl_{FSP}(dB)$ as follows;

$$Pl_{TW}(dB) = Pl_{FSP}(dB) + Pl_{W}(dB) \quad (1)$$

Where

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

$$Pl_{W}(dB) = \begin{cases} 0.45f^{0.284}(d_f) & for \quad 0 \le d_f \le 14\mathrm{m} \\ 1.33F^{0.284}(d_f)^{0.588} & for \quad 14 \le d_f \le 400\mathrm{m} \end{cases} \quad (3)$$

Where d (path length for free space in km), d_f (foliage depth in m) and f (frequency in GHz).

2.2 LoRaWAN sensor network Link budget

The link budget determines the received signal power (P_{rx}) of the LoRa transceiver based on the transmitter power (P_{tx}), the transmitter and receiver antenna gains G_{tx} and G_{rx} respectively and the path length, (L_{Path}), as follows;

$$P_{rx} = P_{tx} + (G_{tx} + G_{rx}) - L_{Path} \quad (4)$$

If G_{tx} and G_{rx} are set to 0, then,

$$P_{rx} = P_{tx} - L_{Path} \quad (5)$$

$$P_{rx} = P_{tx} - Pl_{FSP}(dB) - Pl_{W}(dB) \quad (6)$$

The value of P_{rx} can also be determined based on the link margin (L_{MG}) and the LoRa receiver sensitivity, (S_{LS}) as follows;

$$P_{rx} = L_{MG} + S_{LS} \quad (8)$$

Hence,

$$L_{MG} = P_{tx} - Pl_{FSP}(dB) - Pl_{W}(dB) - S_{LS} \quad (9)$$

3. Results and Discussion

The path loss and link margin are computed for the LoraWAN sensor network based on the Weissberger model and the LoRa transceiver sensitivity data presented in Table 1. The computation of the path loss was conducted for different foliage depth, df (m) at a free space path length of 2.5 km and the results are presented in Table 2, Figure 1 and Figure 2 for a LoRa transceiver operating with spreading factor (SF) of 7. The foliage depth was varied from 500 m to 2500 m and the results for SF of 7 shows that at 500m foliage depth and 2.5 km free space path length, the total path loss according to Weissberger model is 139.1 dB Table 1 and figure 2) which increased to a value of 158.3 dB when the foliage depth increased to 2500m.

Table 1 The receiver sensitivity for LoRa transceiver operating with bandwidth of 125 KHz

Spreading Factor, SF	Receiver Sensitivity (dB) for BW of 125 KHz
7	-124
8	-127
9	-130
10	-133
11	-135
12	-137

Table 2 The results on the path loss based on the Weissberger model for different foliage depth and fixed free space path length of 2.5 km

	df (m)	d(km)	$Pl_{FSP}(dB)$	$Pl_{W}(dB)$	$Pl_{TW}(dB)$
1	500	2.5	126.9	12.2	139.1
2	1000	2.5	126.9	18.3	145.2
3	1500	2.5	126.9	23.3	150.2
4	2000	2.5	126.9	27.6	154.5
5	2500	2.5	126.9	31.4	158.3

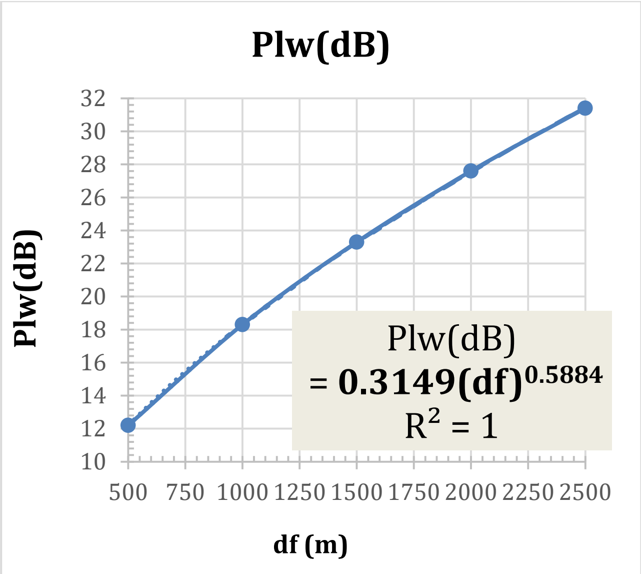

Figure 1 The Weissberger model path loss estimation for the vegetation covered path versus the foliage depth

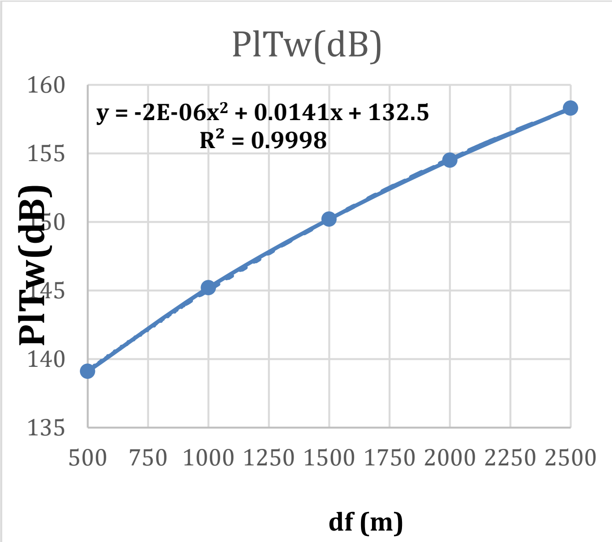

Figure 2 The Weissberger model estimated total path loss for the free space path length and the vegetation covered path

The results of the link margin computed for SF values of 7 to 12 and at df (m) = 500m and d(km) = 2.50 km are presented in Table 2 and Figure 3. The results show that because the foliage depth and free space path length are fixed, the resulting path loss (path loss = 139.1 dB) and received signal strength (RSS =-121.1 dB) are the same for all the spreading factors (SF 7 to Sf 12) while the link margin increases with increase in SF from 2.9 dB at SF =7 to 15.9 dB at SF =12.

Table 2 The results of the link margin computed for SF values of 7 to 12 and at df (m) = 500m and d(km) = 2.50 km

Spreading Factor, SF	Receiver Sensitivity, Rs (dB) for BW of 125 KHz	Lpath (dB)	Ptx (dB)	Prx (dB)	Lmg (dB)
7	**-124**	139.1	18	-121.1	2.9
8	**-127**	139.1	18	-121.1	5.9
9	**-130**	139.1	18	-121.1	8.9
10	**-133**	139.1	18	-121.1	11.9
11	**-135**	139.1	18	-121.1	13.9
12	**-137**	139.1	18	-121.1	15.9

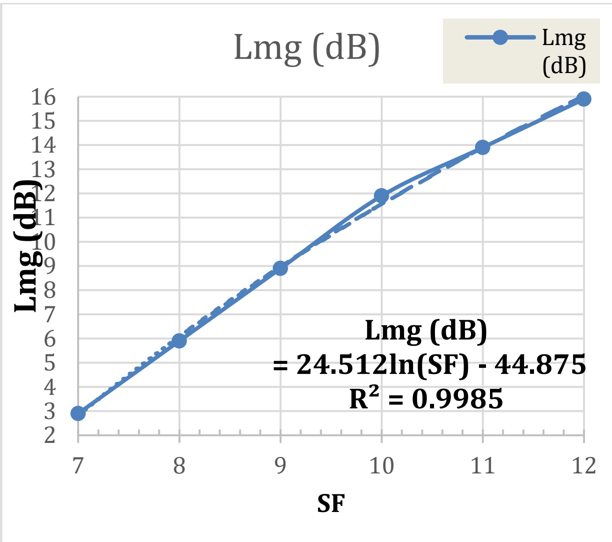

Figure 3 The graph of the link margin versus SF values of 7 to 12 at df (m) = 500m and d(km) = 2.50 km

The results of the link margin versus foliage depth for spreading factor of 7 and 12 are presented in Figure 4 and Figure 5 respectively and also in Table 3. The results show that the link margin decreases with increase in foliage depth. At a foliage depth of 720 m the link margin for SF of 7 became zero while that for SFof 12 occurred at foliage depth of 2060 m. That means with spreading factor of 12 a foliage depth of 2060 m can be effectively covered whereas with SF of 7 only 720 m of foliage depth can be accommodated in the link.

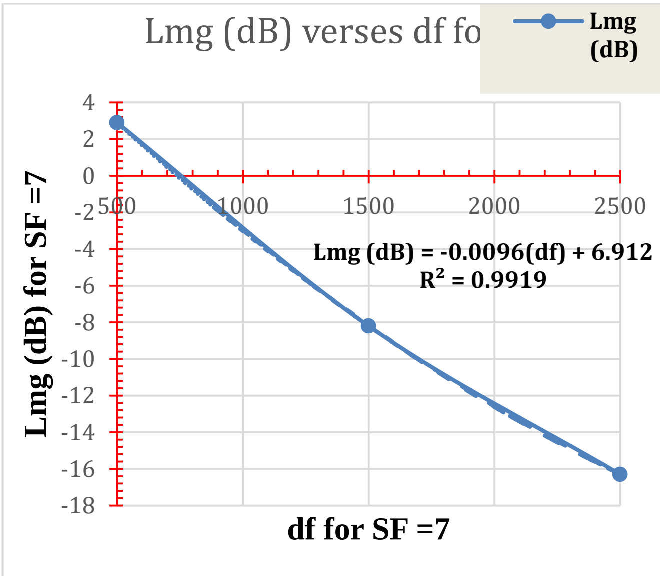

Figure 4 The graph of the link margin versus foliage depth for spreading factor of 7

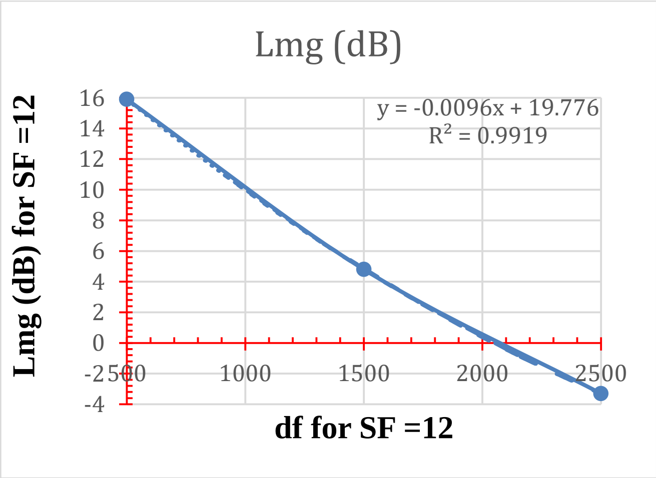

Figure 5 The graph of the link margin versus foliage depth for spreading factor of 12

Table 3 The results of the **link margin versus foliage depth for spreading factor of 7 and 12**

	df (m)	d(km)	$Pl_{FSP}(dB)$	$Pl_W(dB)$	$Pl_{TW}(dB)$
SF =12	2060	2.5	126.9	28.0	155.0
SF =7	720	2.5	126.9	15.1	142.0

4. Conclusion

Analysis of a LoRaWAN sensor network link is presented using Weissberger model. The Weissberger path loss model is designed for vegetation covered areas as it includes a foliage depth which is used to assess the impact of vegetation cover on the path loss experienced by wireless signals in such areas that have vegetation cover. The study used the link budget equation to examine the impact of the foliage depth on the path loss, the received signal strength and the link margin. The results showed that the link margin decreases with foliage depth. Also, for a fixed path length, the link margin increases with increase in the spreading factor use in the Lora transceiver.

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