Comparison of Microwave Path Lengths between Temperate and Tropical Region Based on Effects of Rain

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Abstract— Rain is a major source of attenuation for microwave propagation above 7 GHz. The problem of rain attenuation prediction has been studied along the years. In spite of the effort developed in different parts of the world, there are yet some points to be clarified. This problem is quite difficult to be solved, mainly due to the complexity of rain structure. This clearly suggests that reduction factor is the major yardstick for comparing rain attenuation prediction models. However, important parameter need to consider in the path reduction factor is the maximum effective path length for a particular link at specific operating frequency. This paper presents the summary of allowable path length for designing terrestrial microwave link at particular operating frequency at temperate and tropical region. The objective of this paper, to establish the maximum path length or hop length for terrestrial link on line of sight point to point communication at 99.99% of availability. Various frequency band such as 7 GHz, 15 GHz, 23 GHz, 26 GHz and 38 GHz been investigated using the ITU-R path reduction model. From the studies conducted, there are significant differences in path length between temperate region and tropical region. The differences are 22 km, 10 km, 5 km, 4 km and 3 km in the path length for operating frequency 7 GHz, 15 GHz, 23 GHz, 26 GHz & 38 GHz. This paper will provide useful information for microwave engineers and researchers in making valuable decision on path length for any terrestrial links point to point communication operating in a temperate and tropical region in future.

1. INTRODUCTION

The radio waves propagating through the earth atmosphere will be attenuated due to the presence of atmosphere particles, such as water vapour, water drops and the ice particles. The atmospheric gases and rain will both absorb and scatter the radio waves, and consequently degrade the performance of the link [1]. Rain is a major source of attenuation for microwave propagation above 5 GHz [2]. In tropical and equatorial regions, the rain intensity is higher and designing terrestrial and earth-to-satellite microwave links are very critical and challenging. The problem of rain attenuation prediction has been studied along the years. Many researcher's [3–5] stated path reduction factor is the major yardstick for comparing rain attenuation prediction model. However, important parameter need to consider in the path reduction factor is the maximum path length for a particular link at specific operating frequency. The path length been determine using the received signal level (RSL) or the Fris's equation, by considering the free space loss and rain attenuation in free space [6]. The rain fall rate and the regression coefficient for the drop size distribution (DSD) of rain is important factor in establishing the path length of any microwave link [7]. DSD varies from the geographical factor of a location. Various frequency band can be investigated using the most common ITU-R [2] path reduction model for terrestrial point to point communication. There a few models available besides the ITU-R model, such as Global Crane model, Revised Moupfouma model, Revised Silva Mello model, Lin Model and others but due to ITU-R model is known as Global model, this model been used as a reference in many research work conducted.

2. METHODOLOGY

Five experimental microwave links at 7, 15, 23, 26 and 38 GHz were installed at UTM Campus in Johor Bahru, Malaysia. The rain rate were measured for four years (Jan. 2003 to Dec. 2006) at the same location with one minute integration time . The maximum transmit power, antenna gain and received threshold for 10^{-6} BER with 2×2 Mbps traffic for all five experimental links are given in Table 1. The fade margins for 7, 15, 23, 26 and 38 GHz frequency bands are predicted based on one minute rain rate measurements for four years at UTM Skudai, Johor Bahru. The availabilities of terrestrial microwave links are also investigated based on rain attenuation data collected from

Table 1: Measured rainfall rate at UTM, Skudai, Johor Bahru from Jan. 2003 to Dec. 2006.

% of Time Rain Rate Exceeded	0.1	0.01	0.001
Measured Rain Rate in mm/hr	59	125	175

Table 2: Specification of the experimental links.

Frequency Band in GHz	Maximum Transmit Power in dBm	10^{-6} BER (2×2 Mbps) Rx Threshold in dBm	Tx and Rx Gains in dBi
7	25	−95	20
15	18	−84	37
23	20	−83	40
26	18	−82	41
38	15	−79	45

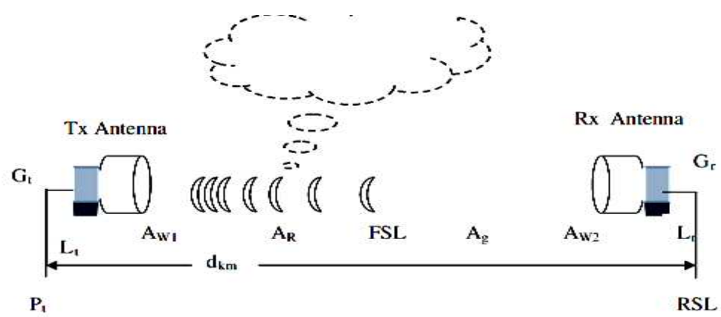

Figure 1: Link budget for a terrestrial line-of-sight radio link.

this five operational microwave links more than one year. From the measured rain fall for four years, the cumulative distribution frame at 0.01% of time, the rain rate recorded was 125 mm/hr. Table 2, summarize the specification of the experimental links. The drop size distribution (DSD) or regression coefficient on rain fall for the tropical region like Malaysia proposed by Din [6] was used.

Figure 1, shows the example of experimental test bed for each links in the studies. The rain attenuation is calculated based on the data collected thru the experiment. The rain fall rate also been recorded using Casella rain gauge using one minute time integration. These data have been used to investigate the link. The gauge is a tipping bucket type and it has sensitivity of 0.5 mm. It records the total rainfall occurring in each minute without recording non rainy events; therefore the rain rate is recorded as an integral multiple of 30 mm/h or 0.5 mm/min.

The Fris's equation been used to calculate the free space loss and other losses for the link including the rain attenuation loss which is very critical for tropical country like Malaysia. The maximum path length for a particular operating frequency is calculated base on the maximum signal can been captured by the system. The received signal level (RSL) is calculated using the equation below:

$$RSL = P_t + G_t + G_r - FSL - A_g - A_R - A_W - L_T - L_t \tag{1}$$

whereby, P_t — Transmit power, G_t & G_r — Transmit and received antenna gain, FSL — Free space loss, A_g — Losses in gaseous absorption, A_R — Losses due to rain attenuation, A_W — Losses due to wet antenna, L_T — Losses in receiving system, L_t — Losses in transmit system.

In this study, we assume at Fresnel zone, the path loss is only considering the free space loss (FSL) & rain attenuation factors, the rest is ignored. Un faded RSL can be calculated using the equation,

$$Unfaded\ RSL = P_t + G_t + G_r - 32.45 - 20\log_{10}(d_{\mathrm{km}}) - 20\log_{10}(f_{\mathrm{MHz}}) \tag{2}$$

Faded RSL due to rain,

$$Faded\ RSL = Unfaded\ RSL - kR_{\%}^{\alpha} \cdot r_{\%} d_{\mathrm{km}} \tag{3}$$

As per known, ITU-R rain attenuation model as per stated below:

$$A_{0.01} = \alpha R_{0.01}^{b} r_{0.01} d \tag{4}$$

whereby path reduction factor, r

$$r_{0.01} = 1/(1 + d/d_0) \tag{5}$$

$$d_o = 35e^{-0.015 R_{0.01}}, \quad R_{0.01} \leq 100\,\text{mm/hr} \tag{5a}$$

$$d_o = 35e^{-1.5 R_{0.01}}, \quad R_{0.01} \geq 100\,\text{mm/hr} \tag{5b}$$

ITU-R model was used to calculate rain attenuation due to it is used as global model for rain attenuation studies in world wide. R is the rain fall rate, a and b regression coefficient, r is the path reduction factor and d is the path length. Further analysis were done by comparing the results on the tropical region for the maximum path length achievable or allowable against the temperate region using the same set-up but regression coefficient values and the rain fall rate used are different based on the geographical factor. Temperate region, ITU-R model characteristic of precipitation for modeling [8] and specific attenuation [9] model for rain rate was used. Rain rate used for temperate region was 35 mm/hr at 0.01% of time. Based on the rain rate for the temperate region at 35 mm/hr it covers most of the country in Europe such as United Kingdom, Sweden, Finland, Norway, Republic Czech, Poland, Germany, France, Netherland and Iceland [8].

3. RESULTS AND DISCUSSION

From the analysis using the Fris's equation, Table 3, clearly summarized and shows the path length required at temperate and tropical region. There are wider differences in path length, km at lower operating frequency compare to higher operating frequency at both temperate and tropical region. As per known in the literature, when the frequency is greater the path length will be shorter. This phenomena complies in this studies. Figure 2, shows comparison of path length required between temperate and tropical region at specific operating frequency using the ITU-R model as a references for rain attenuation.

The path length differences at various operating frequency for temperate and tropical region been analysed. For 7 GHz, the path length differences at temperate region 40% (22 km) more compare to the tropical region. Thus at 15 GHz, 23 GHz, 26 GHz and 38 GHz at temperate region 62.5% (10 km), 55.5% (5 km), 57.1% (4 km) and 60% (3 km) more compare to the tropical region. Base on the observation, at lower operating frequency the differences between the path length in the regions are small compare (40%) to the higher operating frequency (> 50%) but at higher operating frequency, the path length differences for the both regions looks more stable at average of 59%.

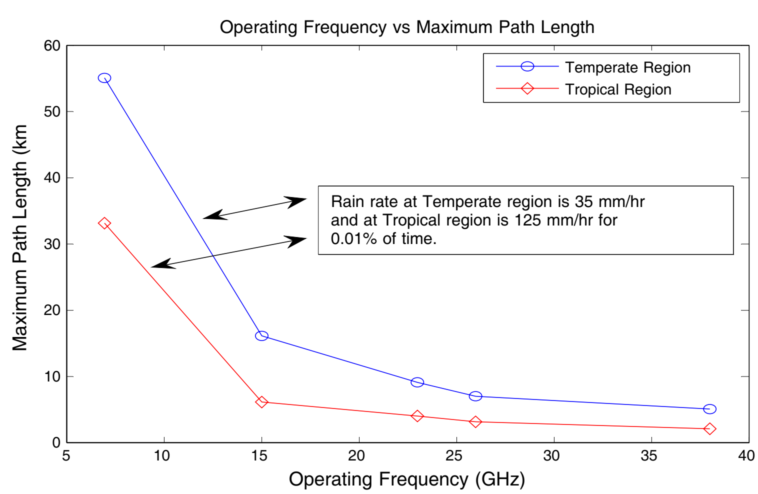

Figure 2: Comparison of path length between temperate and tropical region at specific operating frequency.

Table 3: Summary of path length required for temperate and tropical region at specific operating frequency.

Operating Frequency/GHz	Path Length for Temperate Region/km	Path Length for Tropical Region/km	Differences in Path length/km
7	55	33	22
15	16	6	10
23	9	4	5
26	7	3	4
38	5	2	3

4. CONCLUSION

Based on the results from the experiment conducted, it shows the temperate region such as European countries like United Kingdom, Sweden, Finland, Norway, Republic Czech, Poland, Germany, France, Netherland and Iceland having longer path length for all the operating frequency at 7, 15, 23, 26 and 38 GHz in the microwave communication link compare to tropical region like Malaysia, Brazil, Nigeria, Indonesia, Thailand and Singapore. This is due to the geographical location of the region, the rain fall rate and the regression coefficient for the drop size distribution (DSD) of rain which is important factor in establishing the path length of any microwave link. It's clearly indicate there are differences about 22 km ,10 km, 5 km, 4 km, 3 km differences in the length for operating frequency at 7 GHz, 15 GHz, 23 GHz, 26 GHz & 38 GHz at 0.01% of time. Further analysis will be carried out by analyzing the other frequency range for lower to higher operating frequency at temperate and tropical region at different location to validate the microwave link path length further in future.

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