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RAIN FADE MITIGATION USING FREQUENCY DIVERSITY TECHNIQUE

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Abstract— The radio waves propagating through the earth atmosphere is attenuated due to the presence of atmosphere particles, such as water vapor, water drops and the ice particles. The atmospheric gases and rain both absorb and scatter the radio waves, and consequently degrade the performance of the microwave link. Rain is a major source of attenuation for microwave propagation above 7 GHz [1]. In tropical and equatorial regions, the rain intensity is higher and designing terrestrial and earth-to-satellite microwave links are very critical and challenging for high frequencies. This paper presents the summary of rain effects studies for lower operating frequency such as C band compare to higher operating frequency such as Ka band in tropical environment. The main objective is to justify the literature findings on the effect of rain at lower and higher operating frequency in microwave link and solution to overcome it by implementing Switching Circuit as Fade Mitigation Technique (FMT). An experimental test bed has been set up for 5.8 GHz and 26 GHz terrestrial point to point data communication link. The received signal strength (RSS) data and rain fall intensity data were recorded for 24 hours daily over period of 12 months (Jan 2013 – Dec 2013) at 1 minute interval. The collected rain rate data has been analyzed with some prediction models. The main outcome of the research shows that there is negligible effect of rain for 5.8 GHz link whereas it very strong on the 26 GHz link. It was observed 15 dB to 35 dB attenuation during measurement period. The FMT used in this research for dual frequency by shifting the operating frequency to lower band (5.8 GHz) while heavy rain and shifting back to normal position at higher operating frequency (26 GHz) using the threshold level as reference seems to be one of the solution in future. This findings will be useful resources of information for researchers or telecommunication engineers mitigate rain fade in tropical regions using measured data

Index term - Rain attenuation, Received Signal Strength, Fade Mitigation Technique

INTRODUCTION

Signal attenuation due to rain fade is severe, and in order to achieve high levels of link availability, rain fade counter measures are required. The technique used to overcome this is known as Fade Mitigation Technique (FMT) [2][3]. The usage of fade mitigation technique to permit operations under lower fade margins is imperative. There are three major classes of Fade Mitigation Techniques (FMT) known as Effective Isotopic Radiated Power (EIRP) control techniques, Adaptive transmission techniques and Diversity protection scheme. These are countermeasures intended against rain fades. Almost all these techniques are being investigated by various Ka-band system planners and operators to find out the most suitable optimum technique to overcome the large rain fade attenuation in Ka-band [4],[5],[6],[7]. This chapter investigates frequency diversity technique and it's capability to

EXPERIMENTAL SET-UP

A link of path length 1.30 km was set up in UTM campus at Johor Bahru, Malaysia. Both the transmitter and receiver operate at two frequency bands: lower 5.8 GHz and higher 26 GHz. The received signal levels were sampled every minute. One year precipitation data with 95% of validity of all time, were collected from the tipping bucket rain gauge model TB 3 installed at the measurement site (June 2011 – May 2012). These data have been used to investigate the link. The precipitation data and rain attenuation data was recorded at the same period of time. The rain gauge used is a tipping bucket type and it has sensitivity of 0.2mm. 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 12 mm/h or 0.2mm/min. Table 1 and 2 shows the link specifications measured data, while figure 1 and figure 2 shows the actual test bed and experimental test bed for rain rate measurement..It was observed at 0.01% of time, the rain rate was 120 mm/h and the rain attenuation was 34 dB recorded.

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Table 1. Specifications of the 26 GHz link

Link location	Hop length (km)	Frequency band (GHz)	Maximum transmit power (dBm)	10^{-6}BER (2X2 Mbs) received threshold	Antenna for both transmit and receive side	
					Size (m)	Gain (dBi)
Johor Bahru	1.30	26	+18.0	-84.0	0.6	41.0

Table 2. Measured cumulative distributions of rain rate and rain attenuation.

Probability Level (%)	0.2	0.1	0.05	0.03	0.02	0.01	0.005	0.003	0.001
Rain rate (mm/h)	20	48	62	83	96	120	132	144	168
Attenuation (dB)	4	16	22	28	31	34	39	42	49

Figure 1: Test Bed for measurement

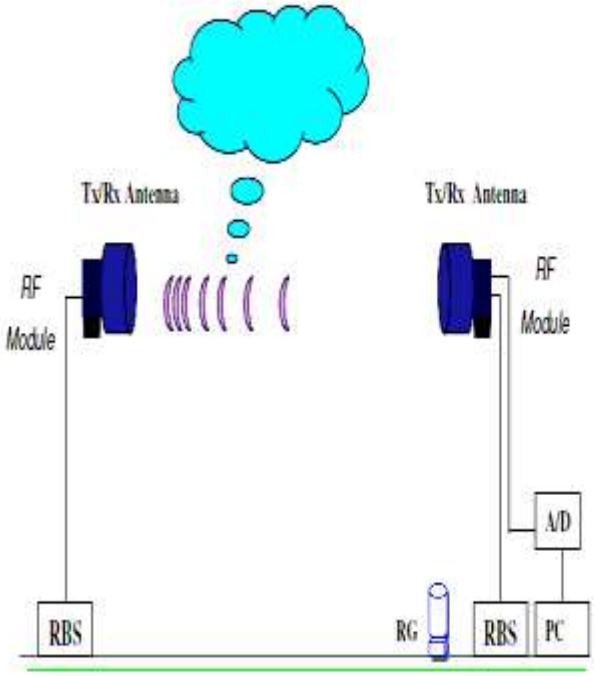

Figure 2 : Diagram of Experimental Setup and rain rate measurement

SWITCHING TEST

Basically two sets of frequency was used for lower (5.8 GHz) and higher (26 GHz) frequency range. The 5.8 GHz link functions as a backup link for the 26 GHz link at rainy periods. The objective of implementing this technique was for obtaining consistent link reliability under any worst rain condition at higher operating frequency in a microwave communication system. The switching will take place based on the threshold level of a radio trans-receiver unit. Automatic Gain Control (AGC) in terms of voltage will be captured and transferred to power (dB) using equation (1).

$$RFin = 40\,(AGC\ level\ in\ volts) - 120 \qquad (1)$$

The 26 GHz data is always logged to the data logger on a daily basis. A switching circuit was built and connected to the data logger. It will only log the 5.8 GHz data whenever switching takes place. Whenever the threshold level is below the required value for the 26 GHz link which is below -82 dBm or below 1.0 V, the circuit will shift from 26 GHz link to 5.8 GHz link. Once the threshold is below -82 dBm or greater than 1.0 V volt, the circuit will shift back from 5.8 GHz link to 26

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GHz link. In other words the 5.8 GHz link acts as a redundancy link for 26 GHz link at rainy periods where the link is connected at most for rainy events.

TEST RESULTS

A switching circuit was designed and tested in this research. Figure 3 shows the switching events during the rainy period using the switching circuit. Table 3 describes the data been captured for a particular worst day in a month, for example in this table for the month of April in the year 2013. The data been captured using data logger model DT80 for every one minute duration in a day. The value of power received, voltage at 5.8 GHz and 26 GHz also been recorded via this data logger. For the normal situation, non rainy event the typical voltage and threshold value for 5.8 GHz are 1.7 V and -92 dBm meanwhile for 26 GHz the value are 1.7 V and -82 dBm. The rain rate was captured using the rain gauge model TB3 and connected to the data logger. The data presented in the table 3 only for the rainy events which took place in particular day of the month. Link reliability during the measurement was 95% in this month.

This data is connected to the switching circuit act as a mitigation tool by deploying the frequency diversity technique. When rain above 100 mm/h possibility for the link to cut-off is high at operating frequency 26 GHz. At this time the threshold voltage value will drop beyond 1.0 V or -82 dBm. At this particular situation the switching circuit will trigger to shift the signal from 26 GHz link to 5.8 GHz link and shift back to original situation once the threshold value above back to normal (1.7 V and below -82 dBm). Figure 3 shows the shifting of signal /data transmitted from 26 GHz link to 5.8 GHz link during heavy rain events It will shift the link to the 5.8 GHz through the switching circuit and the data will be logged using data logger. Once the threshold of the 26 GHz link is back to normal, the 5.8 GHz link will be shifted back to 26 GHz as normal. The shifting tolerance is set at plus minus one minute. At this particular of the time, the rain fade or the rain attenuation observed for the 5.8 GHz link is much lesser with an average between 1 to 3 dB only. Whereby, for the 26 GHz link the rain attenuation recorded in between 25 to 35 dB. The rain attenuation is almost ten times greater at 26 GHz compare to the 5.8 GHz. The main limitation of the measurement is the validation of the link at most of the measuring time and the data logging process need to be consistent in order to have good results and findings throughout a year and more.

Table 3. Data logging for rainy events at 5.8 GHz and 26 GHz.

Date	Time	Threshold voltage (V)	Received Signal at 26 GHz (dBm)	Rain Rate (mm/hr)	Received Signal at 5.8 GHz (dBm)
2013/04/29	16:08:00	0.81108	-87.55685	150	-77
2013/04/29	16:09:00	0.68437	-92.62527	150	-78
2013/04/29	16:10:00	0.74263	-90.29475	180	-78
2013/04/29	16:11:00	0.79143	-88.34268	150	-77
2013/04/29	16:12:00	0.66497	-93.40116	180	-78
2013/04/29	16:13:00	0.69425	-92.23001	150	-78
2013/04/29	16:14:00	0.61615	-95.35394	120	-77
2013/04/29	16:15:00	0.61636	-95.34561	150	-77
2013/04/29	16:16:00	0.61634	-95.34818	90	-77
2013/04/29	16:17:00	0.61636	-95.34561	90	-78
2013/04/29	16:18:00	0.61646	-95.34179	90	-78
2013/04/29	16:19:00	0.61623	-95.35072	120	-78
2013/04/29	16:20:00	0.61634	-95.34626	90	-78
2013/04/29	16:21:00	0.61628	-95.34885	90	-78
2013/04/29	16:22:00	0.61656	-95.33987	120	-78
2013/04/29	16:23:00	0.61644	-95.34244	90	-79
2013/04/29	16:24:00	0.61642	-95.34308	90	-79
2013/04/29	16:25:00	0.61646	-95.34179	90	-78
2013/04/29	16:26:00	0.61639	-95.34435	60	-79
2013/04/29	16:27:00	0.61655	-95.33796	60	-79
2013/04/29	16:28:00	0.61644	-95.34244	60	-78
2013/04/29	16:29:00	0.61658	-95.33669	60	-79
2013/04/29	16:30:00	0.61658	-95.33669	60	-78

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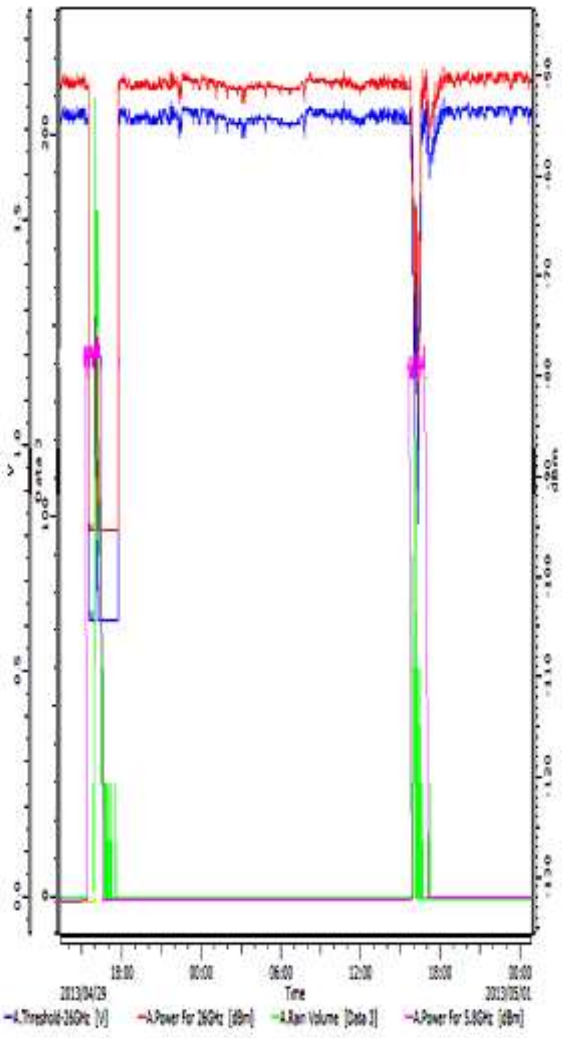

Figure 3. Receive Signal Strength for a **s**witching events during the rainy period using the switching circuit

CONCLUSION

From the research, an experimental work was conducted using the fade mitigation technique to overcome the rain fade in microwave point to point (P2P) terrestrial communication link. The frequency diversity method seems to be very economical and promising to be implemented provided a proper set up of equipment and monitoring is done when compared with other methods. In this research a circuit for the switching method was designed using protel software and fitted with a programmer chip using C++ language The circuit was tested using the threshold in terms of voltage as a sensor for shifting purposes.

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