MODIFICATION OF ITU-R RAIN FADE SLOPE PREDICTION MODEL BASED ON SATELLITE DATA MEASURED AT HIGH ELEVATION ANGLE

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ABSTRACT: Rain fade slope is one of fade dynamics behaviour used by system engineers to design fade mitigation techniques (FMT) for space-earth microwave links. Recent measurements found that fade slope prediction model proposed by ITU-R is unable to predict fade slope distribution accurately in tropical regions. Rain fade measurement was conducted in Kuala Lumpur (3.3□ N, 101.7□ E) where located in heavy rain zone by receiving signal at 10.982 GHz (Ku-band) from MEASAT3 (91.5□ E) on 77.4□ elevation angle. The measurement has been carried out for one year period. Fade slope S parameter on ITU-R prediction model has been investigated. New parameter is proposed for the fade slope prediction modeling based on measured data at high elevation angle, Ku-band.

ABSTRAK: Cerun hujan pudar adalah salah satu dinamik tingkah laku pudar yang digunakan oleh jurutera sistem untuk mereka bentuk teknik-teknik pengurangan pudar (FMT) bagi link gelombang mikro ruang bumi. Ukuran baru-baru ini mendapati bahawa cerun pudar ramalan model yang dicadangkan oleh ITU-R tidak mampu untuk meramalkan pengagihan cerun pudar tepat di kawasan tropika. Pengukuran hujan pudar telah dijalankan di Kuala Lumpur (3.3□ N, 101.7□ E) yang terletak di kawasan hujan lebat dengan menerima isyarat pada 10,982 GHz (Ku-band) dari MEASAT3 (91.5□ E) pada sudut ketinggian 77.4□. Pengukuran telah dijalankan untuk tempoh satu tahun. Parameter cerun pudar S pada model ramalan ITU-R telah disiasat. Parameter baru adalah dicadangkan untuk pemodelan cerun pudar ramalan berdasarkan data yang diukur pada sudut paras ketinggian, Ku-band.

KEYWORDS: *fade slope; ITU-R; fade mitigation techniques; sampling time interval*

1. INTRODUCTION

In satellite communication on frequencies above 10 GHz, rain attenuation is great propagation phenomenon that influence large variations in received signal levels. Rain attenuaton is inordinately degraded received signal. That is why many mitigating approachs have been developed to reduce fading outage of communication links.

Rain attenuation behaviours are extensively studied and measured but dynamic aspect of rain attenuation still has sparse study. Knowledge on rain fade dynamics is noticeable important in the design of new satellite communication systems. Adaptive power control (APC) and Uplink power control (ULPC) are ones of rain countermeasure techniques relies on rain fade dynamics parameters by increasing transmitted power to compensate rain fading on propagation path. fade slope is one behaviour of fade dynamics characteristics that assesses tracking speed contributing factor to fade mitigation techniques (FMT) [1, 2]

Various researchers have studied and proposed parameters and prediction models for rain fade slope. Most studies have based on temperate region measurements [1, 3-7]. ITU-R P.1623 [8] has recommended a prediction model for fade slope based on Van De Kamp model [3, 4] measured at Netherlands receiving signal from Olympus satellite (El = 26.78˚) on 12.5 - 30 GHz. The model was examined using data from other sites in the UK, France, Belgium, Italy, and the US [1]. However, some measurements [9] in tropical zones have indicated the model is required to improve in order to correspond to different climate zones.

This paper analyses rain fade slopes characteristic on different sampling times and comparing between available model and measurement in Kuala Lumpur, Malaysia. Fade slope S parameters has also been focused and proposed on high elevation angle as a function of different fade levels.

2. EXPERIMENTAL SETUP

Experimental system has been monitored signal from MEASAT 3 (geostationar

E) at 10.982 GHz frequency (Ku-Band), vertical polarization with QPSK modulation provided 15 channels for Malaysian direct broadcast satellite (DBS) pay television service (Astro). The received signal level has been collected for 12 months perio

. Fig. 1 and Table 1 have summarized experimental setup and system parameters, respectively at Satellite Communication lab, IIUM.

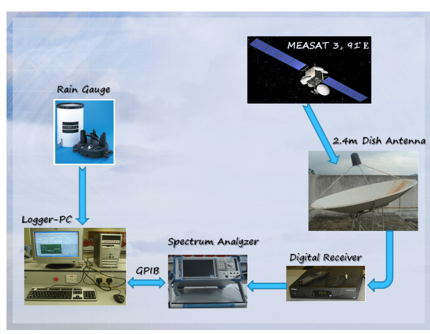


Fig. 1: Experimental setup for measurement at Ku-band signal over earth-space path at Satellite Communications Lab, IIUM.

Table 1: System parameters of the link.

Ground Station Location	3.3°N, 101.7°E
Beacon Frequency	10. 982 GHz (IF = 1.232GHz)
Satellite Position	91.5° E (MEASAT 3)
Polarization	Vertical
Azimuth	253°
Elevation Angle	77.4°
Antenna Diameter	2.4 m
NF of LNB	0.3 dB

Signal from MEASAT3 has been received by 2.4 m diameter of parabolic dish antenna with Low noise block (LNB), 0.3 dB noise figure. The signal is down converted to Intermediate Frequency (IF) as L-band with Local Oscillator (LO) 975 MHz. The subsequent IF is sent to spectrum analyzer setting post-detection bandwidth (video bandwidth) of 10 Hz [10] to monitor carrier signal and remove spurious noise. Consequent Output signal from spectrum analyzer is logged and saved in databank by using software developed with sampling time interval of 1s. In addition, rainfall rate is also measured synchronously by 0.2mm-Tipping bucket rain gauge every 10s time interval.

3. FADE SLOPE MODEL PROPOSED BY ITU-R

ITU-R has proposed statistical distribution model of fade slope developed by Van De Kamp [1, 11] that depends on cutoff frequency, attenuation and sampling time. The proposed prediction model of probability density function (PDF) is shown Eq. 1,

$$p(\xi \mid A) = \frac{2}{\pi\sigma_\varsigma\left(1+\left(\xi/\sigma_\xi\right)^2\right)^2} \quad (dB/s)^{-1} \tag{1}$$

Where σ_ξ is the standard deviation of the conditional fade slope at a given attenuation level given by,

$$\sigma_\zeta = s\,F(f_B, \Delta t)A \;\; \text{dB/s} \tag{2}$$

Where $$F(f_B, \Delta t) = \sqrt{\frac{2\pi^2}{\left(1/f_B^b + (2\Delta t)^b\right)^{1/b}}} \tag{3}$$

With b = 2.3, f_B is the 3 dB cutoff frequency of the low pass filter (Hz), and S parameter is from experiment as derived above.

4. DATA PRE-PROCESSING

4.1 Clear sky reference level

Finding out zero dB reference level from clear sky on measurement of satellite signal attenuation is a fundamental trouble requirement. Defining clear sky reference level by hourly averaging after and before raining days [12]. Raining events were determined on 10s interval time for tipping bucket type of rain gauge. The number of data points (second) during raining events used to generate fade slope for each attenuation values are shown in Fig.3. It is obvious that the number of occurrences decreases with attenuation levels.

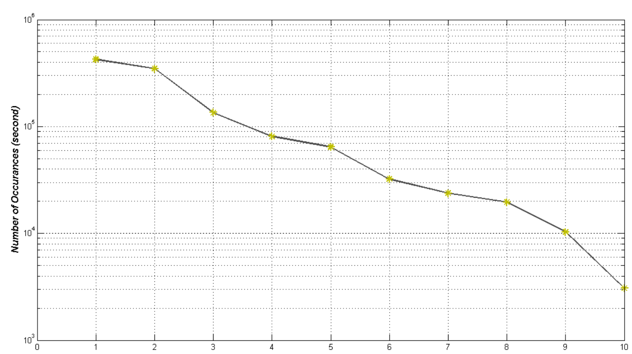


Fig. 3: Number of time series (second) extracted from data measured from July 1, 2010 to June 30, 2011.

4.2 Rain Attenuation and Scintillation Extraction

Attenuation time series during raining events are contaminated by fast fluctuations due to tropospheric scintillation. Therefore, tropospheric scintillation is essentialy decimated prior to proceed next processes [13]. Power spectral density (PSD) is efficient technique in order to separate propagation due to scintillation and rain attenuation by specifying appropriate cutoff frequency (f_c) [14, 15]. High pass filter (HPF) order 6th of Digital Butterworth filter with cutoff frequency of 0.025 Hz [16] obtained by the PSD function and has been implemented to remove fast fluctuation due to scintillation.

5. DATA ANALYSIS AND RESULTS

Fade slopes are calculated for each attenuation level thresholds after tropospheric scintillation has been decimated. Each attenuation level (dB), A is calculated when $A - 0.5 < A(t) \leq A + 0.5\ dB$, then fade slope is calculated by Eq. (4)

$$\delta(t) = \frac{A(i + \Delta t) - A(i - \Delta t)}{2\Delta t} \qquad (dB/s) \qquad (4)$$

Where Δt is sampling time, 1s and i is sample number.

5.1 Comparison Between Measured Data and Prediction Model

Once fast fluctuation due to tropospheric scintillation has been decimated from the signal, fade slope has been calculated from Eq. 4. The prediction model has been calculated by Eq. 1 using f_B 25 mHz obtained from the experiment, Δt 1s and S = 0.01 (ITU-R proposed). Comparison of measurement and model has been depicted in Fig. 4.

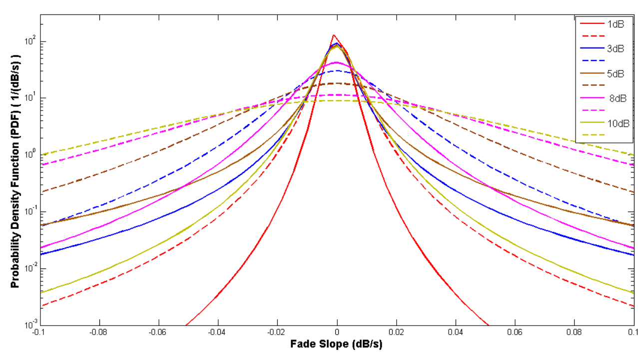
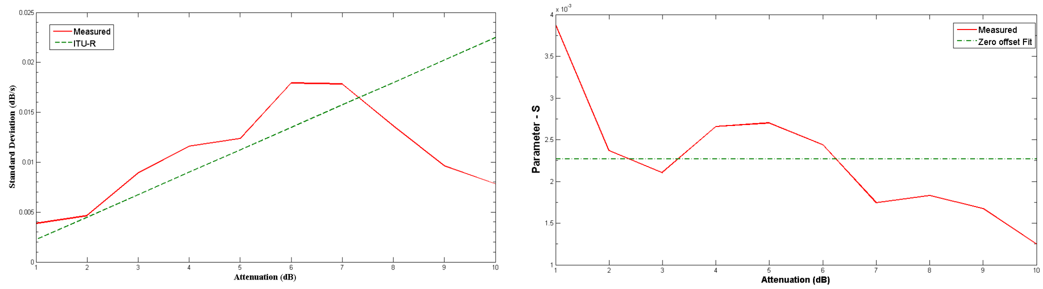


Fig. 4: PDF comparison between fitting of measured data (solid line) and ITU-R (dash line) model for 1s sampling time.

5.2 Investigation of Standard Deviation

Rain fade slope characteristic has been investigated to evaluate the parameters for ITU-R [8] based on the measured data. Principal parameters analysis was focused on standard deviation (σ_ζ) with different attenuation thresholds. The measured standard deviation and the model have been presented as a function of attenuation thresholds in Fig. 5 (a).

Measured σ_ζ indicated that keeps increasing with attenuations from 0.0038 dB/s and reaching maximum 0.018 dB/s at 6dB attenuation and subsequently reducing until 0.0079 dB/s at 10 dB. Standard deviation, σ_ζ was estimated by ITU-R prediction model indicated that σ_ζ increased linearly with attenuation levels.



(a) (b)

Fig. 5: (a)Comparison of standard deviations between measured data (solid line) and predicted by ITU-R prediction models (dash line), (b) The measured value of *S* as a function of attenuations between measurement (solid line) and Zero Offset fit (ZOF) (dash line).

5.3 Proposed Standard Deviation

ITU-R prediction model has been proposed σ_ζ which depends on f_B, Δt and parameter *S*. Parameter *S* is a constant which depends on climate and elevation angle which affect to σ_ζ of ITU-R model. ITU-R has proposed the constant averagely at 0.01 in Europe and USA at elevation angle between 10°-60°. But there is no model proposed in tropical region and on high elevation angle. Therefore, *S* is needed to derive in order to propose for the model on this region and high elevation angle. Parameter S is obtained by Eq. (5) using σ_ζ from the experiment and has been presented by Fig. 5(b).

$$S = \frac{\sigma_\delta}{F(f_B, \Delta t)A} \tag{5}$$

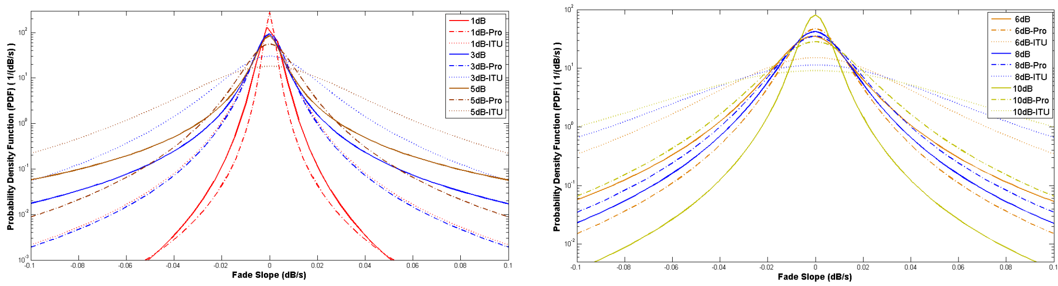
Thus, determination of empirical *S* is implemented by Zero offset Fit (ZOF) [2, 3, 4] yielded 0.0023 to propose in the model for this characteristics.

5.4 Comparison with the Model

Statistical distribution comparisons between measurement and model with different parameter S have been depicted in Fig. 6(a) and 6(b) as a function of attenuations. Figure 6 illustrates fade slope distribution comparison between measured data and the propoaed model. The models are drawn S parameters as applying Zero offset fit (ZOF) method. PDF's predicted by ZOF is closer fit with the measurement for attenuation between 1dB-6dB. For attenuation higher than 6dB, the model shows wider with attenuations while the measurement showd narrower with attenuations corresponding to standard deviations.

Table 2: Descriptive PDF Statistics comparison between measurement and models.

Attenuation (dB)		1	3	6	8	10
Mean	Measured	3.311	3.308	3.306	3.31	3.311
	ZOF	3.357	3.311	3.31	3.309	3.307
SD	Measured	17.42	13.181	7.785	8.747	12.548
	ZOF	25.123	13.626	9.345	7.921	6.929
Skewness	Measured	6.403	5.24	2.859	3.19	4.702
	ZOF	9.864	5.105	3.419	2.85	2.449
Kurtosis	Measured	43.185	28.818	7.413	9.573	22.645
	ZOF	105.662	26.963	11.22	7.316	4.996



(a) (b)

Fig. 6: PDF comparison among Measurement and model with different values of s-parameters of (a)1dB to 5dB attenuations and (b) 6dB to 10dB attenuations levels.

6. CONCLUSION

Rain fade was measured in Kuala Lumpur (3.3^0 N, 101.7^0 E) at 10.982 GHz (Ku-band) from MEASAT3 (91.5^0 E) on 77.4^0 elevation angle. The measurement has been carried out for one year period. Fade slope S parameter on ITU-R prediction model has been investigated based on data processed with 1 sec integration time. The probability distribution functions proposed by ITU-R with parameter S = 0.01 are much wider than the measurement for all attenuation levels. The value of *S* parameter is evaluated using implemention of Zero offset Fit (ZOF) with measured data. The new value of S = 0.0023 is proposed in the fade slope prediction model for high elevation angle, Ku-band in tropical regions.

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