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Integration time conversion methods for Multi Precipitation Estimate rain maps

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Abstract: Rain fade is a phenomenon where rainfall causes radio signal operating at Ka or Ku Band frequencies to suffer signal degradation. To resolve this, radio engineers use annual rainfall rate distribution with 1 minute integration time to plan and design radio networks and assign appropriate fade margin. This paper aims to study the performance and impact of using several models to convert different integration times of measured rainfall rate annual distribution to 1 minute integration time. The models that will be covered in this paper are Burgueno et al, Segal, Joo et al and ITU-R 837 model for Multi Precipitation Estimate rain maps product. Comparison with rain gauge data collected in Malaysia will also be presented for further validation.

Keywords: rainfall rate, rain maps, rain fade, microwave links

1.0 INTRODUCTION

Radio signals, either point to point terrestrial or satellite links operating above 10 GHz (mostly at Ka or Ku band) tend to suffer fade effects, mostly due to hydrometeors in the atmosphere. The biggest fade contributor to high frequency radio links is rain. To overcome this problem, radio engineers utilise annual rainfall rate distribution statistics to design the networks and assign suitable fade margin to compensate the fade. The annual rainfall rate distribution statistics can be obtained, either from ITU-R 837-5[1] and 6[2] models or from measurement data, usually the latter is preferable [3].

Rainfall rate measurements are preferable to be used compared to relying on the model since the measurements can provide updated info on the climate and obviously a lot more accurate. The problem with the measurement rainfall rate data is not all of them are with 1 minute integration time since the measurement equipment, especially rain gauges with shorter integration time are expensive. Therefore, a method is needed to convert various integration times to 1 minute, necessary for radio planning and design to resolve the rain fade issue. In this paper, Multi Precipitation Estimate (MPE) which contains rainfall rate data globally will be studied and various models for converting integration time will be used on the data.

2.0 MULTI PRECIPITATION ESTIMATE

Multi Precipitation Estimate (MPE) is a meteorological product, produced and maintained by intergovernmental organization called The European Organization for the Exploitation of Meteorological Satellites or EUMETSAT. The MPE obtains rainfall rate data, measured in mm/hr through the use of meteorological satellites called METEOSAT. The temporal sampling of the rainfall data between two scans is 30 minutes and the spatial resolution is approximately few kilometers for each pixel of the rain map. MPE integrates the IR channel data from METEOSAT satellites and Special Sensor Microwave/Imager (SSM/I) microwave data from US-DMP satellites in the re-processing branch of its Meteorological Product Extraction Facility (MPEF) to estimate precipitation rate. MPE regularly uses rain gauge or radars for validation purposes [4].

3.0 CONVERSION METHODS

Since the rain maps collected from MPE have 30 minutes sampling time, it is therefore necessary to convert the time sampling down to 1 minute since all ITU-R models are dealing with 1 minute integration time. Several methods exist to convert the integration time of measured rain rates distribution to 1 minute for microwave fade link simulation. In this topic, 30 minutes sampling time from MPE and 1 hour integration time from rain gauge will be converted to 1 minute integration time using several methods such as Joo et al, Segal and Burgueno et al. method.

3.1 Burgueno et al. method

Burgueno et al.[5] developed a mathematical model for conversion of rain rate distribution for various integration times based on rain rate data collected for over 49 years in Barcelona, Spain. The principle of direct power-law fit is utilized in the equation proposed by Burgueno et al.

$$R_1(p) = a[R_\tau(p)]^b \quad \text{mm/hr} \qquad (1)$$

Equation (1) shows the Burgueno et al. method where R_1 and R_τ are rain rates at 1 minute and τ integration time respectively and exceeded with equal probability, *p%* while *a* and *b* are regression coefficients. ITU-R P.837-5 (2007) also uses the equation similar to Burgueno et al. method although with different regression coefficients values.

3.2 Segal method

Segal[6] developed a model founded on records of rainfall with high resolution prepared at the Communication Research Centre. The rainfalls were recorded for around 10 years and over 47 stations in Canada through tipping bucket rain gauges. Segal expressed the conversion method as follows:

$$\rho_\tau(P) = R_1(P) / R_\tau(P) \qquad (2)$$

Conversion factor $\rho_\tau(P)$ is expressed as power law:

$$\rho_\tau(P) = aP^b \qquad (3)$$

$R_1(P)$ and $R_\tau(P)$ are rainfall rates with 1 minute and τ minutes integration time respectively and with probability of occurrence *P* while *a* and *b* are regression coefficients.

3.3 Joo et al. method

Joo et al.[7] developed a mathematical equation to convert rain rates distribution at different integration times. The equation was based on two years of rain rates measurement in Korea from 1998 to 2000 and the rainfall rate data was acquired through the use of Optical Rain Gauge (ORG) (Joo et al., 2002). Joo et al. expressed the conversion technique from τ integration time to 1 minute rain rate as follows:

$$P_1 = aP_\tau 10^{b[\exp(-t/24.28)]} \qquad (4)$$

P_1 and P_τ are the probability of the exceedance time for 1 minute and τ minutes integration time respectively. The sampling time of rain gauge in minutes is represented by *t* while *a* and *b* are the regression coefficients.

3.4 ITU-R P.837 models

The models[1][2] were developed based on previous measurements from different meteorological sites over a long period of time. The model also based on the previous existing models such as Burgueno et al. method. Over the time, the model from ITU-R was refined, updated and improvements to achieve more accurate results are continuously been made, based from models by other researchers. Simply put, the model is the nexus for all other rain rate integration time models to be integrated and improved upon. Therefore, this model is highly likely to yield more accurate results than the others.

The values of regression coefficients have been obtained from long-term measurements of point rainfall rate at 14 different sites, located globally including Korea, China and Brazil. Within the range from 0.01% to 0.1% of time, the average values of the absolute differences between the measured and converted 1-min rainfall rates were found to be 1.14 mm/h for the conversion from 5-min to 1-min integration times, 1.90 mm/h for the conversion from 10-min to 1-min integration times, 3.69 mm/h for the conversion from 20-min to 1-min integration times and 5.72 mm/h for the conversion from 30-min to 1-min integration times.

3.5 Regression Coefficients

Integration Time (min)	Segal (1986)		Burgueno et al. (1988)		Joo et al. (2002)		ITU-R P.837-5 (2007)	
	a	*b*	*a*	*b*	*a*	*b*	*a*	*b*
5	1.0540	–0.0289	1.3630	0.8814	0.2740	0.6530	0.906	1.055
30	1.3360	–0.0307	3.1492	0.7551	0.8392	0.7784	0.561	1.297
60	1.5390	–0.0635	6.4372	0.6170	10.2600	-8.5040	0.497	1.440

Table 1: Regression coefficients for different conversion techniques

Table 1 shows the regression coefficients of for all the mentioned conversion methods.

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4.0 RESULTS

In this section, the MPE rain maps are collected in the East (Sabah and Sarawak) and West (Peninsular) Malaysia regions from 2010 to 2012 and its 30 minutes sampling time is converted to 1 minute integration time using all the models mentioned in the previous section. The results with different models are compared.

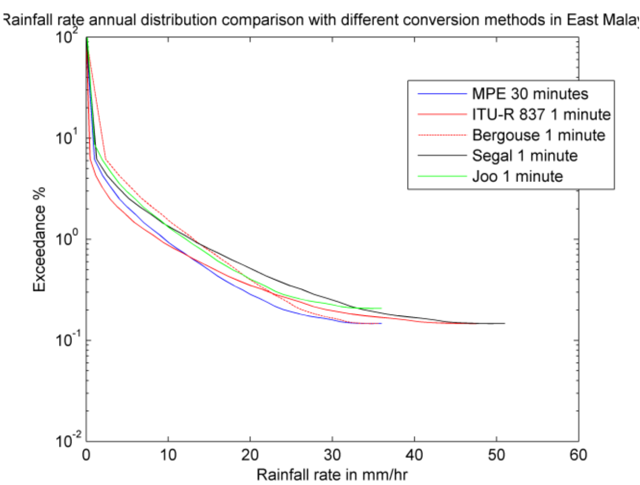

Figure 1: Rainfall rate distribution with different conversion methods comparison in East Malaysia

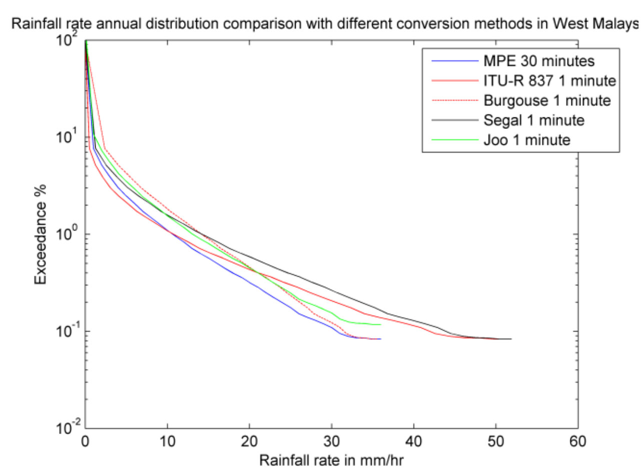

Figure 2: Rainfall rate distribution with different conversion methods comparison in West Malaysia

Figure 1 and 2 shows the comparison results when applying different conversion models for the collected MPE rain maps data. From the results shown, it appears that ITU-R 837 models yield better and more accurate results compared to the other models. This is because when reducing the integration time of a rainfall rate distribution, we expect to see lower exceedance for the low rainfall rate and the increase of exceedance for higher rainfall rate and from the results in Figure 1 and 2, ITU-R models conform the expectations.

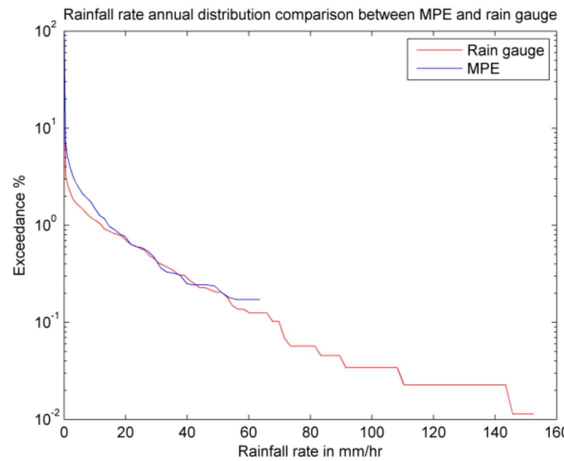

Figure 3: Rainfall rate distribution comparison between rain gauge and MPE with 1 minute integration time.

For further validation, the MPE rain maps data that has been converted to 1 minute integration time are compared with a rain gauge measurement, also with 1 minute integration time. The rain gauge measurement was collected in Petaling Jaya, near Kuala Lumpur in 2012. The result in Figure 3 shows that the ITU-R 837 model yields plausible result when compared to the rain gauge data.

5.0 CONCLUSION

As a conclusion, the power law equation model from ITU-R 837-5 is the best to be utilized when converting integration time of a rainfall rate distribution. This would be extremely useful for radio engineers to utilize any measurement rain data with integration times for radio network planning and design to combat rain fade.

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