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Conversion Methods for Rain Radar's Rainfall Rate Integration Time

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Abstract: Radio signal operating above 10 GHz tend to suffer signal losses, mostly due to hydrometeors such as rain. This phenomenon also called Rain fade. Radio engineers typically rely on sets of models and recommendations by ITU to predict rain fade and assign proper fade margin for radio network planning, but those models are extremely limited. Alternatively, engineers and radio planners can use meteorological data such as rain radar data to obtain spatial and temporal information on rainfall rate. One of the main issues is the temporal sampling or integration times of rainfall rate from rain radars. This paper studies the different established methods of converting different rainfall rate integration times into one-minute time, suitable for radio network planning and optimization. The methods wil be tested on NIMROD rain radars from UK.

Keywords: Rain fade, rainfall rate, rain radar, integration time.

1. INTRODUCTION

Microwave links operating beyond 10 or 20 GHz (beyond Ka and Ku band) will experience significant radio loss, mostly due to scattering and absorption by hydrometeor particles such as rain, cloud, fog and sleet in the atmosphere. Among all the hydrometeor types, rain is the largest fade mechanism that greatly affects high frequency radio links in space and time. This phenomenon also known as "rain fade"(Crane, 1996). Extreme rain fade, either due to higher frequency operation of radio links or more intense rain events can lead to a complete loss of signal or "outage". This is truly problematic for radio engineers as channels becoming crowded due to increasing number of users and the increasing complexity of multimedia. These factors produce the demand for higher data rate and bandwidth, which lead to the increasing demand to explore higher frequency bands for wireless communication. However, atmospheric radio absorption losses due to hydrometeor such as rain limit the opportunity for exploring higher region of frequency spectrum for wireless links (Bei, 2008).

In order to resolve this issue, radio engineers have to rely on the rainfall rate parameter, or the intensity of the rain events to predict and estimate radio signal loss in dB. The rainfall rate parameter, usually expressed in mm/hr is extremely useful when designing or planning high frequencies radio networks. Higher rainfall rate means more losses in dB for radio links.

Radio engineers usually utilise models from International Telecommunication Union or ITU for rain and rain fade prediction, when performing planning for radio networks. ITU releases set of recommendations or models that include prediction for rainfall rate (ITU-R 687), for terrestrial microwave link or point-to-point (ITU-R 530) and for satellite link (ITU-R 618). Although such models exist, they only offer limited information, i.e. simple annual statistics, rather than the more advance information such as "when" or "where" will the rain occur. In addition, the models only works for individual radio links, instead of more complex networks of radio links (Hafiz, 2012).

The alternative solution would be utilising meteorological data that have rainfall rate such as rain gauges, rain radars and from weather satellite. Rain gauges provide the best rainfall rate estimation since they use direct measurement but suffer in terms of spatial coverage. Rain radars is the second best source for rainfall rate and cover large areas but have sampling time between scans from 5 to 15 minutes. Rain radars operate by measuring the reflected radio waves at C or S band. Weather satellites offer global coverage of rainfall rate but their measurements rely on analysing cloud temperatures by using IR or microwave, which are more indirect form of measurement compared to rain radar (Hafiz, 2012).

For this research, we focus on the utilisation of rain radars, particularly NIMROD rain radar managed by UK meteorological office for predicting rainfall rate and rain fade. The problem with rain radars is the sampling time as mentioned on the previous paragraph. Ideally, we want 1 minute integration or sampling time for

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proper prediction. To resolve this, radio engineers use statistical conversion methods to statistically convert various integration times to 1 minute.

2. NIMROD RAIN RADAR

NIMROD, managed by UK Meteorological office, operates 15 rain radars at C band level (5.4 GHz) that span the whole of UK. The spatial resolution is 1 km and temporal resolution is 5 minutes between two consecutive scans. The British Atmospheric Data Centre (BADC) stores single-site and composite Nimrod rain maps. Figure 1 shows a typical composite Nimrod rain map over UK.

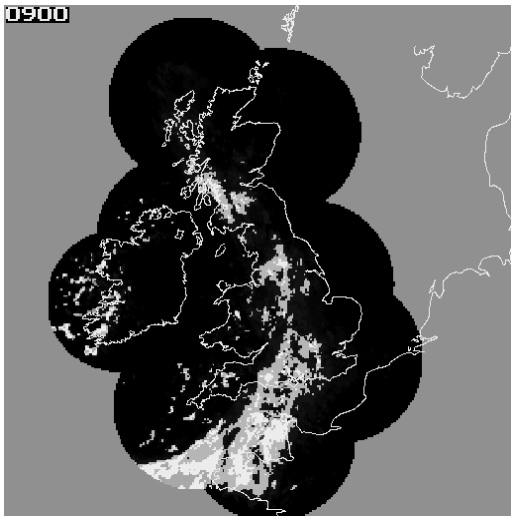


Fig 1. A sample of Nimrod rain map (Courtesy of BADC)

For this research, one-year worth of NIMROD rainfall rate data centred in Chilbolton and Sparsholt, 2004 was collected. A rain gauge data with 1-minute integration time in chilbolton, 2004 has been utilised for verification with NIMROD rain radar in terms of rainfall rate distribution. (BADC)

3. INTEGRATION TIME CONVERSION METHODS

In this section, we discuss the different methods of converting the integration time of rainfall rate distribution from NIMROD from 5 minutes to 1 minute, an ideal integration time for predicting rainfall rate or rain fade as discussed in the introduction topic earlier. The methods that we will cover are Burgueno, Segal, Joo and ITU-R P.837 models.

3.1 Burgueno *et al*. method

A mathematical model was developed by (Burgueno *et al*. 1988) for converting of rain rate distribution from different integration times into 1 minute. The model was based rain rate data collected for over 49 years in Barcelona, Spain. The principle of direct power-law fit is utilized in the equation proposed.

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

Equation (1) demonstrates the method where R_1 and $R\tau$ are rain rates at 1 minute and τ integration time respectively and exceeded with equal probability, *p%* while *a* and *b* regression coefficients. ITU-R P.837-6 (2012) utilises equation based from (Burgueno *et al*. 1988). method but with altered regression coefficients.

3.2 Segal *et al*. method

A model was built by Segal (1986) based on records of rainfall with high resolution at the Communication Research Centre in Canada. The rainfalls were recorded for at 47 stations, around 10 years using tipping bucket rain gauges. Segal articulated the conversion method as shown below:

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

Conversion factor ρτ (P) as a 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

A mathematical equation was developed by Joo *et al*. for rain rates distribution integration times conversion. The model was developed based on two years of rain rate measurement in Korea from 1998 to 2000. The rainfall rate data was acquired through the utilisation of Optical Rain Gauge (ORG) (Joo *et al*., 2002). Joo *et al*. expressed the model from τ integration time to 1 minute rain rate as shown below:

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

P_1 and $P\tau$ 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

ITU also have a model to convert different rainfall rate integration times. The model was developed based Burgueno *et al*. method and on historical meteorological measurements from different meteorological sites over some period. The regression coefficients values were acquired from measurements of rainfall rate at 14 different sites over some period. The measurements was taken mostly in Europe, Korea, China and Brazil.

Table 1. Regression coefficients for different conversion techniques

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**

3.5 Regression Coefficients

(Table 1) above shows the different values of regression coefficients including a and b for all the listed methods. The regression coefficients differ in terms of methods and integration time. For instance, to convert integration time of 5 minutes using Segal method, use a = 1.0540 and b = -0.0298 and apply it in the formula in (1).

4. RESULTS

In this section, the rainfall rate distribution from NIMROD is compared with the rainfall rate distribution from rain gauge. Data from rain gauge are considered more accurate since it measures rainfall rate more directly than rain radars. The rainfall rate distribution's integration time from NIMROD was converted to 1 minute with different methods mentioned in section 3: Integration time conversion methods and compared with the 1-minute integration time rain gauge data for further corroboration.

(Fig.2) shows the rainfall rate distribution over a year (2004) comparison between NIMROD rain radar and rain gauge. The result shows a quite consistent result with the exception for lower exceedance probability (lower than 0.1%) where the rain radar shown to be slightly lower than rain gauge distribution. This is mostly due to NIMROD rain maps have 5 minutes sampling time between two consecutive scans whereas the rain gauge data is 1-minute integration time.

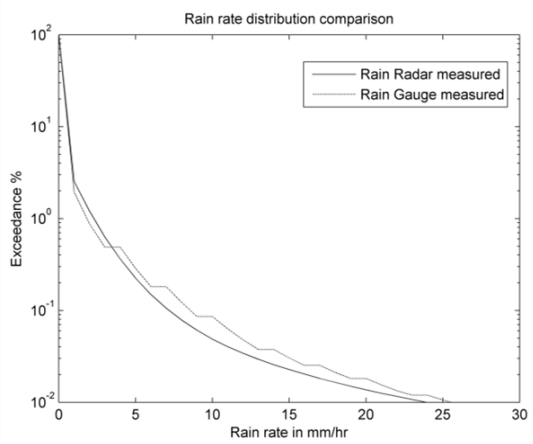


Fig. 2. Rainfall rate distribution comparison between NIMROD rain radar and rain gauge

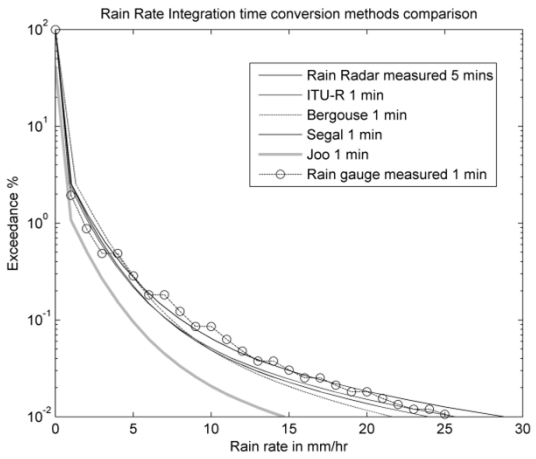


Fig. 3. Converted NIMROD rainfall rate distribution comparison with rain gauge

(Fig. 3) shows the NIMROD rainfall rate distribution that was converted with all the methods mentioned in section 3 in this paper and compared with the rain gauge data. The result shows the converted NIMROD rainfall rate distribution with Segal method offers the most plausible or consistent comparison with the rain gauge data.

5. CONCLUSION

Based from the results in Figure 3, we can conclude that Segal method is the best for rainfall rate integration time conversion method for NIMROD rain radar when comparing with the rain gauge data. This could be useful for radio engineers to utilise meteorological data, particularly from rain radars to predict and calculate rainfall rate distribution for rain fade analysis.

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REFERENCES:

British Atmospheric Data Centre's website. In: (2012) badc.nerc.ac.uk/home/index.html.

Burgueno, A. M., M. Puigcever, E. Vilar, (1988). "Influence of rain gauge integration time on the rain rate statistics used in microwave communications", Ann. Telecommun., 10, 522–527.

Crane R. K., (1996). “Electromagnetic wave propagation through rain”, John Wiley&Sons, Inc.

Hafiz, B., (2012), "Development of a Heterogeneous Microwave Network, Fade Simulation Tool", PhD thesis, Department of Engineering, University of Hull, UK.

ITU-R P.837-6 (2012). “Characteristics of precipitation for propagation modelling”, International Telecommunication Union Recommendation. Accessed https://www.itu.int/rec/R-REC-P.837-6-201202-I/en

Joo, H. L., S. C. Yong, K. P. Jeong, H. H. Eun, (2002) "Conversion of Rain Rate distribution for various Integration time" URSI Proceeding, Netherlands.

Segal, B., (1986): “The influence of rain gauge integration time on measured rainfall-intensity distribution functions”, J. Atmos. Ocean. Tech., 3, 662–671.

Zhang, X., (2008), “Fine-scale modelling of rain fields for radio network simulation”, PhD thesis, Department of Engineering, University of Hull, UK.