Rainfall Rate from Meteorological Radar Data for Microwave Applications in Malaysia

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***Abstract*—This paper present the rainfall rate obtained from the analysis of a meteorological radar data in Malaysia. Rainfall rate is an important parameter for a microwave link because it enables the attenuation due to rain to be determined. An important parameter in rain attenuation studies is the rain rate for 0.01% of the time or $R_{0.01}$. Design and system engineers use this value to construct communications system such that the link is available for 99.99% of the time. This result is obtained by utilizing the radar data from the Malaysian Meteorological Department. Knowing the rainfall rate, rain attenuation can be calculated. This information is useful for microwave link applications.**

***Index Terms*—microwave, radar data, rainfall rate**

I. INTRODUCTION

Wireless communication has seen a tremendous amount of growth. No doubt that the advancement in RF technology and the miniaturization of handheld devices has popularized the appeal of such devices among public and commercial users. Microwave links are an important part of telecommunication.

However, a major concern for microwave links is the attenuation due to rain. For a tropical country like Malaysia, rain occurs almost yearound and in most instances, the rainfall rate is much higher when compared to temperate regions. Thus, a proper model based on local study is needed to predict the rainfall rate in order to estimate the rain attenuation. This information is useful for microwave applications such as microwave link budget planning.

A source of data suitable for this kind of study is the radar data. The Meteorological Department of Malaysia operated several meteorological radars throughout the Malay Peninsular, Sabah and Sarawak. These radar data can be utilized to extract the rainfall rate in Malaysia. However, in this study, only the Kluang radar data, located in the southern part of the Malay Peninsular is utilized.

II. RADAR DATA

A. *The Kluang Meteorological Radar*

The ability of a radar to scan a wide area around the radar site and not just a particular path made it a very attractive for many types of investigations. A radar will actively probes a specific region. The ability to scan a large area continuously makes radar measurement technique very attractive. This enables a large amount of data to be collected in a short period of time. A large database can be used to provide statistical information by simulating particular systems. Compared to a rain gauge network, radar observes larger variability of precipitation characteristics over a short period of time, and at a faster rate [1]. Radar provides valuable information that is relevant in modelling rain-induced propagation effects [2]. Radar also provides spatially and temporally continuous measurements that are immediately available at one location. Through technology and computer software advancement, radar can scan 3-D space, seeks out region of rain, and acquire a quasi-photograph of the precipitation structure. Goldhirsh [3] has noted that researchers have demonstrated that a summer's database of radar reflectivity enabled the prediction of rain rate distribution, which agreed in shape to the distribution acquired using 10 years of continuous rain gauge data. Lahaie *et al* [4] suggested the use of 1000 virtual links to an attenuation model. Seed *et al* [5], utilized a month of radar data for his study. Wilson [6] used radar data that covered a period of 19 days, while Jatila *et al* [7] used radar data taken during summer of 1969.

Thus, by using radar, adequate rain attenuation statistics can be obtained in a shorter or limited period of time. Radar can be used to measure the rainfall rate indirectly. This is achieved by knowing the radar reflectivity and then converting them into rainfall rate. The S-band frequency of the meteorological radar ensures that propagation effects such as attenuation are negligible [2]. Radar will emit a pulse towards a target. If the pulse hit the target, some energy will be scattered back to the radar. The backscattered or average power received by the radar depends on the radar parameters, on the shape, size, number and dielectric constant of raindrops. If these parameters are known, the radar reflectivity factor Z can be calculated. An empirical relationship can be established between Z and the rainfall rate R. By knowing R, specific attenuation can be determined.

In its normal operational mode, the Kluang radar will do a

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composite PPI scan every 10 minutes, and a volumetric scan every 30 minutes. The PPI scan will lasts for a minute where the revolution or rotation of the antenna is 3 rpm. The displayed composite PPI scan is a combination of 3 scan-angles 3.5° (0 – 30 km), 2° (30 – 100 km), and 0.5° (100 – 500 km). The STC for Kluang radar station is up to 230 km.

For volumetric scan, the antenna beam will pass or rotates azimuthally 15 times in the duration of 5 minutes. After each pass or rotation, the antenna beam is elevated to a higher elevation angle. These angles are also known as 'volumetric elevation angles' as it is done in the volumetric scanning. Since the antenna does 15 rotations, there will be 15 volumetric elevation angles. The range of the Kluang radar station is from 4 km up to 512 km in a radial direction. The range bin is 2 km for the composite PPI scan and 1 km for the volumetric scan. Scanning is done for every angle in the azimuthal plane. The mechanism of the radar system is such that for a 1-km range bin resolution, it will send 8 pulses in every 250-meter range. The reflected power is then averaged. Four averaged readings will again be averaged for four 250-m ranges making a reading for 1-km range bin. Thus, 32 pulses are averaged for a 1-km range bin.

For this study, the 1-km range bin is more useful and thus, the volumetric scan. Operation of Kluang Radar Station was altered so that it will do volumetric scan for every 10 minutes instead of every 30 minutes. This generated enough amount of data that was used in this study. The period of the radar data is from 2 January 1998 at 4:23 (Universal Time Constant - UTC) up to 10 March 1998 at 1:03 (UTC). From 2 January to 8 January, the volumetric scanning was done at 30-minute interval, and from 8 January (1:03 UTC), the volumetric scanning was done in a 10-minute interval. Total scans where rain is detected are 7998 scans.

B. Z-R Relationship

Power received or returned from a scatterer depends on the radar reflectivity factor Z. The widely accepted empirical relationship of the radar reflectivity factor Z, and rainfall rate R is given by [8]-[10]

$$Z = aR^b \quad mm^6/m^3, \text{(R in mm/hr)} \qquad (1)$$

Thus, if Z can be measured and thus known, then R can be found. However, a and b varies for different types of rain [10]. The constant a and b are related to the intercept and slope of the best-fit line through a plot of R versus Z on a log-log plot. Puhakka [10] has given that if b is fixed at 1.6, then for convective rain, a has an average of 360, 196 for continuous rain, and 56 in drizzle. Reported values of a varies between 100 to 600, while b varies between 1.3 to 1.8.

Battan and other researchers [11] have noted that these parameters vary depending on geographic locality and types of rain. In addition, error in measuring the average backscattered power also contributed to the uncertainty. Wexler *et al* [12] concludes that Z-R relationship is fairly constant at low frequency (less than 3 GHz), but deviates considerably at high frequency (more that 9 GHz). However, Hunter [13] noted that the choice of Z-R relationship has small outcome in determining R. Z-R relationship is mitigated by averaging rain rate from radar data over large time and space scales. The most common values for a and b are 200 and 1.6, respectively. These are also the values used by the radar operator of the Malaysian Meteorological Department of Malaysia.

C. The Kluang Meteorological Radar

The radar data was obtained from the Kluang Radar Station of The Meteorology Department of Malaysia. The Kluang radar station is located about 61 km from the UTM, Skudai campus. For the Malay Peninsular, the Meteorology Department has five radar stations located in Kluang, Subang, Kuantan, Butterworth, and Kota Bharu. For system management and connectivity, the Meteorological Department of Malaysia uses the 3D-RAPIC software produced by the Australian Bureau of Meteorology, Observations and Engineering Branch, Radar Engineering Section. Calibration of the Kluang radar system is done every 6 months. Using this 3D-RAPIC system, data from all radar stations were integrated to give a whole radar scan of the Malay Peninsula. The specifications of the Kluang Radar Station is given in Table 1. As mentioned earlier, only data from the Kluang Radar Station were selected in this study.

TABLE 1
METEOROLOGICAL RADAR MR 781 S STESEN KAJICUACA, KLUANG WITH RAPIC TRANSMITTER EH663 V. 8.00

Station ID	3 Kluang
Station position	latitude = 2.020° longitude = 103.320°
Reflector	12 feet parabolic (3.66m)
Frequency	2800 MHz
Polarization	vertical
Gain	38 dB
Coverage	elevation: -2° to +90°; azimuth: 360°
Beamwidth	2.0°
Pulse duration	2.2 μs
PRF	278 pps
Peak power	389 kW
STC range	230 km

III. RESULT

The rain rate in the radar data is the averaged rain rate over a 1-km range-bin size. The rain rate from the radar data is as plotted in Figure 1.

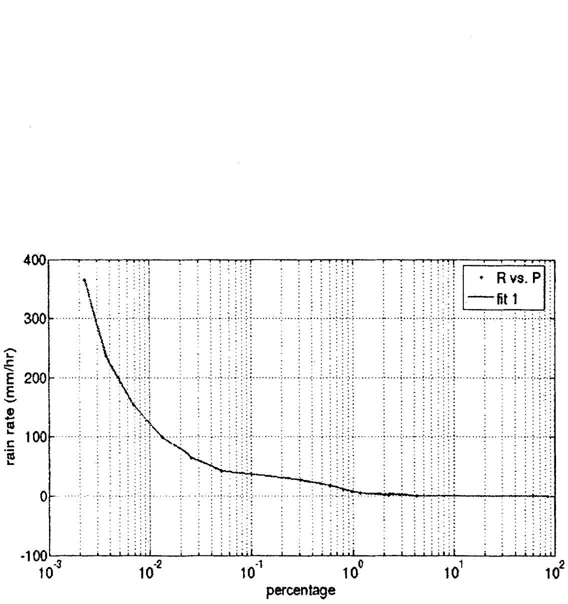

Fig 1 Rain Rate Distribution From Radar Data

An important parameter in rain attenuation studies is the rain rate for 0.01% of the time or $R_{0.01}$. The determination of the rain rate for 0.01 percent of the time or $R_{0.01}$ comes from the fact that a good system must provide at least 99.99% reliability. Design and system engineers use this value to construct communications system such that the link is available for 99.99% of the time. Systems built with this value ensure reliable microwave link and guarantee customer satisfaction. ITU-R has recommended the use of this parameter for attenuation studies. From the analysis of the curvefit line, the rain rate for 0.01 % of the time is 126 mm/hr. The $R_{0.01}$ value from the radar data is comparable to the values obtained from the Meteorological Department, which is a long-term measurement [14], and the value from ITU-R [15]. Both give the value of 120 mm/hr for $R_{0.01}$.

As a comparison, result of the rain rate from this study and the results from other researchers namely Yagasena *et al* [16], and Islam *et al* [17] are given in Table 2.

TABLE 2.
COMPARISON OF RAIN RATES.

Percentage of rain rate	Rain rate (mm/hr)		
	Metrological radar data	Yagesena	Islam
0.001	478	190	194
0.01	126	130	125
0.1	39	70	60

Table 2 shows that for $R_{0.01}$, the values obtained are similar. However, at lower percentage, the radar data gives a much higher rain rate when compared to other results, and at the lower percentage, it gives a lower value of rain rate. This may be due to the duration of data taken. A better sample of data would be to take rain rate measurements for at least a whole year.

IV. CONCLUSION

This work is done primarily using weather radar data obtained from the Meteorological Department of Malaysia. Data from weather radar have been utilized in many other studies. The biggest advantage of radar data is the large amount of data that is available in a short period of time. Radar data is also capable of providing areal precipitation where it is almost impossible to do using rain gauges.

The rain rate distribution obtained from the meteorological radar data can be used to determine the rain at the percentage of interest. This is useful for microwave link system planning and link budget estimation.

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