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Statistics of Rainfall Rate at 60 minutes Integration Time in Malaysia

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ABSTRACT

Background: This paper presents the statistics of rainfall at 60-minute integration time in Malaysia for the period of 12 months from January to December 2009. **Objective:** To analyze the statistics and characteristics of rainfall intensity measurement at KLIA, Malaysia. To study the behavior of measured rainfall intensity and represent the annual distribution of the measured rainfall through cumulative distribution functions together with different types of rainfall that occurred in 2009. **Results:** The results obtained show the cumulative distribution functions and amount of the rainfall rate for that particular year. The results also show the different cumulative distribution functions for four different rainfall types that occur in 2009. **Conclusion:** The study of the 12-month tipping bucket data has given the characteristics of the collected rainfall. From the results obtained, it shows that Malaysia is within equatorial region with the characteristics of two distinguishable rainfall rates that occurs during the whole year.

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INTRODUCTION

Recently, the scope of service offered by communication networks has changed to data-centric services and trail behind video and multimedia services. There is a need to adequately provide excellently optimized wireless services to cater the increasing demand of high-speed data and multimedia services in Malaysia. One of the major concerns for propagation in tropical region is precipitation especially high intensity of rainfall rates during the convective events. It is a major problem encountered in the deployment of microwave and milimetric wave communication systems (Crane, 1996).

Therefore, excellent link service must be sustained regardless of any atmospheric condition including rainfall. Rainfall is a form of hydrometeor and has been recognized as a major problem in signal propagation. Heavy rainfall can sporadically and suddenly disrupts transmission links that will cause extreme fading in wireless communication systems (Ajayi *et al*., 1996). Analysis of the rainfall behavior for a specific region is important in order to find the solution for various problems in signal propagation (Crane, 1978).

Malaysia is a country that located between 3° and 7° of the equator. Malaysia's climate is categorized as equatorial. Malaysia experience hot and humid throughout the year with average of rainfall 2000 to 2500mm in a year and the average temperature is 27°C (Saw, 2007). Malaysia has two parts i.e. Peninsular and East and the climates of these two parts are slightly different. The climate of the peninsular is directly affected by the wind from the mainland but the East experiencing more maritime weather. Furthermore, Malaysia is also exposed to the El Nino effect that reduces rainfall rate in the dry season. Extreme climate change in Malaysia is likely to have significant effect on Malaysia i.e. increasing sea levels and rainfalls will increase the flooding risks and leading to large droughts (Barr *et al*., 2007).

Located within the equatorial region, Malaysia faces two monsoon winds i.e. Southwest Monsoon (May to September) and Northeast Monsoon (November to March) every year. The Northeast Monsoon is originating from China and the north Pacific brings high rainfall intensity compared to the Southwest Monsoon that is originating from the deserts of Australia. The transition months for these two monsoons occur in March and October every year (Mandeep, 2011).

There are various type of equipments used to collect the rainfall rate all over the world. These equipments are subject to different accuracy that depends on their type and functionality. Malaysia Meteorological Department (MMD) uses tipping bucket type for measuring rainfall rate in Malaysia. This tipping bucket is

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located at every rain gauge station that has been specified by MMD. This paper presents the rainfall rate measurement data acquired from rain gauge station located at KLIA.

In order to meet the system's operational reliability for equatorial region, the characteristics of rainfall in this region must be investigated thoroughly in every design of communication links. It is common knowledge that rainfall rate cumulative distributions vary greatly from region to region. This paper presents the rainfall rate measurement at KLIA, Malaysia over a period of twelve months, from January to December 2009.

Statistical analysis using Cumulative Density Functions (CDFs) has contributed to research in the area of microwave link planning and budgeting. This paper presents CDFs of the measured rainfall rate at KLIA in the year of 2009.

System Set-Up:

The ground truth measurement data were collected from the rain gauge located at MMD station KLIA with 2° 44' N and 101° 42' E, about 5km from the airport and 16.3m above mean sea level. The rain gauge used by MMD consists of standard tipping bucket in order to collect the measured rainfall values. The tipping bucket rain gauge follows the standard by World Meteorological Organization (WMO). This tipping bucket collects data every 60 minutes. Therefore, integration time for the measured data is 60 minutes.

The tipping bucket comprises of two components; funnel-shaped at the top supported by a cylindrical-shaped at the bottom. This funnel has a water filter at the end of the funnel opening. As rain falls it lands in the funnel of the tipping bucket rain gauge. Water flowing into the funnel will be screened and will be collected by two metal water collectors (tipping buckets). The raindrops is poured into the cylinder when one of the collectors receives the raindrops of amount 0.2mm and the next rain will then fall to the other metal collectors. This process is repeated and this repetition process is connected to a computing system (counter) that will count the number of times the rain that falls into the water collector metal. The amount of rainfall rate is calculated based on multiplication of the number of times the precipitation that falls on the metal rain collector with 0.2mm of rain droplets. Maximum rainfall amount that can be obtained is 200mm/hr. Table I summarized the specifications of the tipping bucket rain gauge operated by MMD and Fig.2 shows the tipping bucket that is located at KLIA. Fig. 3 shows the overall system setup for the study that includes terminal Doppler weather radar. However, this paper presents only the study of the measured ground truth rainfall rate at the rain gauge station KLIA not inclusive radar data. Radar data will be used for further analysis together with the rain gauge measurement data.

Table 1: Specifications of Tipping Bucket Rain Gauge

Item	Specifications
Location (Latitude, Longitude)	KLIA, Sepang (2° 44' N and 101° 42' E)
Distance from KLIA	±5km
Receiving collector	203mm ±0.2mm
Accuracy	±1% to 200mm/hr
Bucket capacity	0.2mm
Dimensions	300mm height 230mm body diameter 280mm base diameter
Physical	5.5kg net weight

Fig. 1: MMD tipping bucket at KLIA

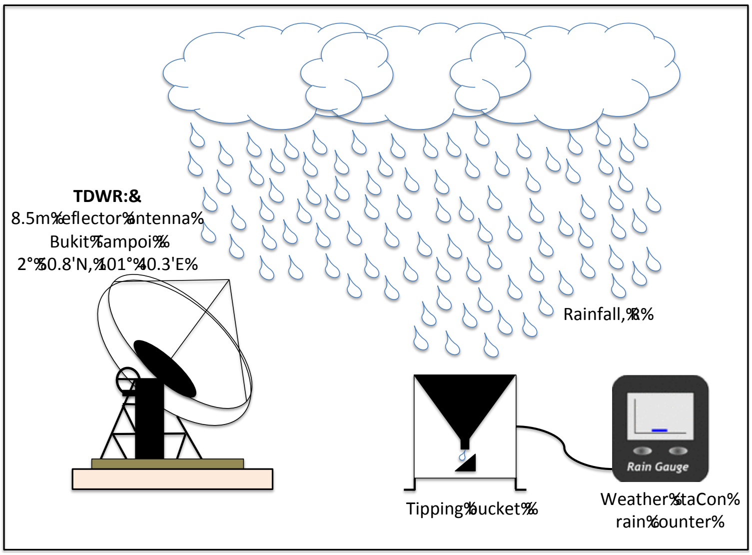

Fig. 2: Overall system setup

Fig. 3 also shows the location of the Terminal Doppler Weather Radar that is located at Bukit Tampoi. Radar data that consists the information of rainfall rate at KLIA are also required in order to compare with the rain gauge measurement data. However, this paper will only present the statistics and behavior of the rainfall at KLIA. The radar data will be used in future works to find the correction of radar reflectivity to rainfall rate relationships.

Analysis of Rainfall Intensity Measurement:

The hourly collected data by tipping bucket rain gauge at KLIA has a sampling time of 60-minute and measures in real-time quantities such as rain rate and rain accumulation. The measurements were taken over a one-year from January to December 2009.

The 60-minutes sampled data obtained from the tipping bucket rain gauge were classified under four types of rain events based on the maximum rain rate recorded in a single rain event. A total of 871 rain events with corresponding 94 rain rates samples were obtained. Table II shows the summary of the rain events recorded at KLIA. The highest rainfall rate for this particular year is 71.8mm/hr, while the lowest rainfall rate is 0.0mm/hr.

Table 2: Summary of Rain Events Recorded at KLIA 2009

Rain Event	Low (0mm/hr-5mm/hr)	Moderate (5mm/hr–10mm/hr)	Heavy (10mm/hr–40mm/hr)	Thunderstorm (>40mm/hr)
Number of Events	754	63	49	5
Rain Accumulation (mm)	477.8	421	939.0	261.4

The following assumption has been taken during the filtering and processing of the acquired data: (1) Rain rate sample of -33.3mm/hr was assumed as 0.0mm/hr, and (2) A minimum duration of five minutes was assumed as the interval between two independent rain events.

The acquired rain samples were then separated into four different rainfall types: (1) low rainfall with 0.0mm/hr to 5mm/hr, (2) moderate rainfall with 5.0mm/hr to 10.0mm/hr, (3) Heavy rainfall with 10mm/hr to 40.0mm/hr, and (4) thunderstorm rainfall with rainfall rate greater than 40.0mm/hr. The highest of rainfall rate in each event was considered and then grouped according to the listed rainfall types.

Analysis Of Rainfall Intensity Measurement:

A. Monthly Accumulated Rainfall:

According to the observation by MMD for over the rest of peninsular Malaysia with the exception of the southwest costal area, there are two obvious periods of rainfall pattern. The monthly rainfall pattern shows two periods of maximum rainfall separated by two periods of minimum of rainfall. The primary maximum generally occurs in October to November and secondary maximum generally occurs in April to May. Furthermore, the primary minimum occurs in January to February and secondary minimum occurs from June to July over the northwest region while elsewhere the primary minimum occurs in June to July and secondary minimum occurs in February.

The acquired rainfall rate measurement data are used to calculate the monthly accumulation of rain and the results is shown in the Fig. 4. The calculation for twelve months of 2009 shows that the driest month is June

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with estimated rain of 35.6mm and the worst month is March with estimated rain of 71.8mm. This information qualifies KLIA, Malaysia to be grouped under the equatorial climate classification where the criterion of average of all months have at least of 60mm is met (McKnight *et al*., 2000 and Semire *et al*., 2012).

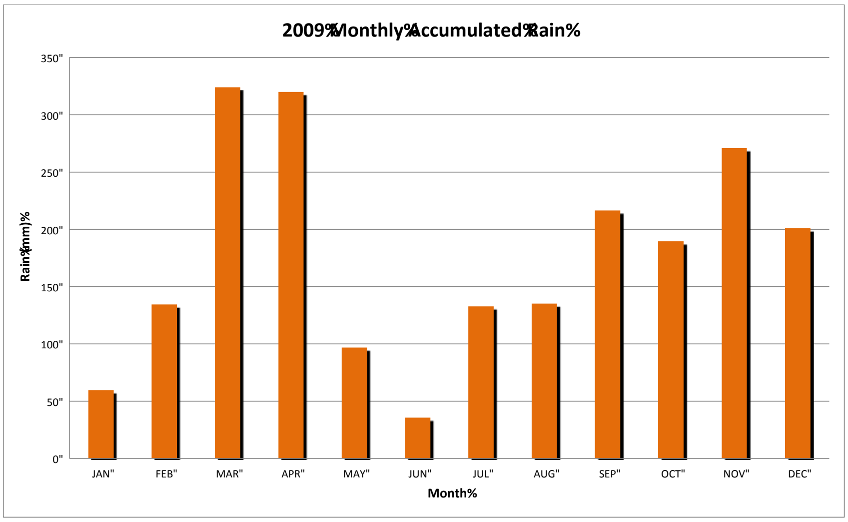

Fig. 3: Calculated monthly accumulated rainfall at KLIA, Malaysia

B. Monthly Cummulative Distribution of Rainfall Intensity:

Cumulative distribution function for each month is plotted as shown in Fig.5. The plot for each month is marked with different color to contrast each other. Fig. 5 shows that there is no specific month that dominates the time percentage within twelve months period. However, the highest measurement at 0.1% and 0.01% time exceedance occurs in March. It can be concluded that month of March are subjected to the severe rainfall intensity for the time fraction lower than 0.1% time exceedance.

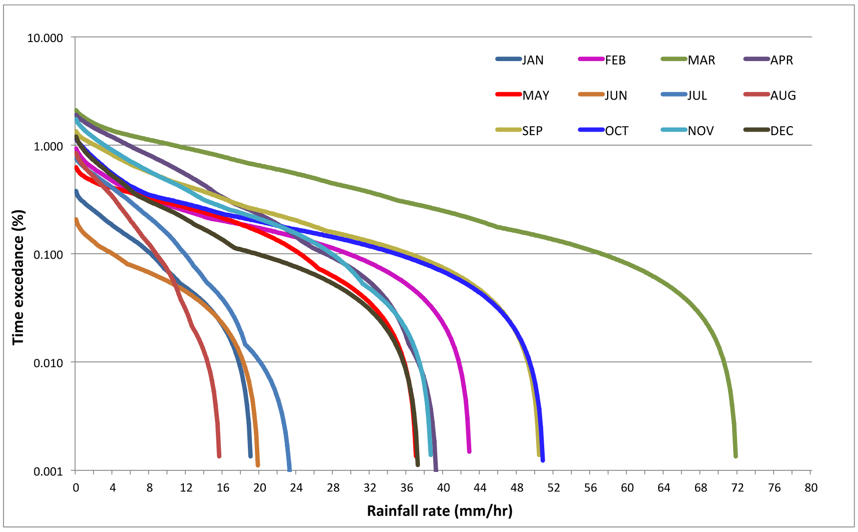

Fig. 4: Monthly cumulative distribution function of rainfall at KLIA, Malaysia

C. Annual Cummulative Distribution of Rainfall Intensity:

The annual cumulative distribution of rainfall intensity is obtained from compilation of the monthly cumulative distributions. The monthly cumulative distributions of twelve months from January to December 2009 had been presented in previous subsection. The annual cumulative distribution for the year 2009 of measured rainfall rates for KLIA is depicted in Fig. 6 below. The figure shows the annual statistics of rainfall rates for period of operation collected at every 60-minute sampling time. The figure shows the annual statistics of rainfall rates for period of operation collected at every 60-minute sampling time. The figure also shows that at 0.01 % time exceedance equivalent to 9 hours of the year, KLIA had experienced rainfall rate of approximately 54.4mm/hr.

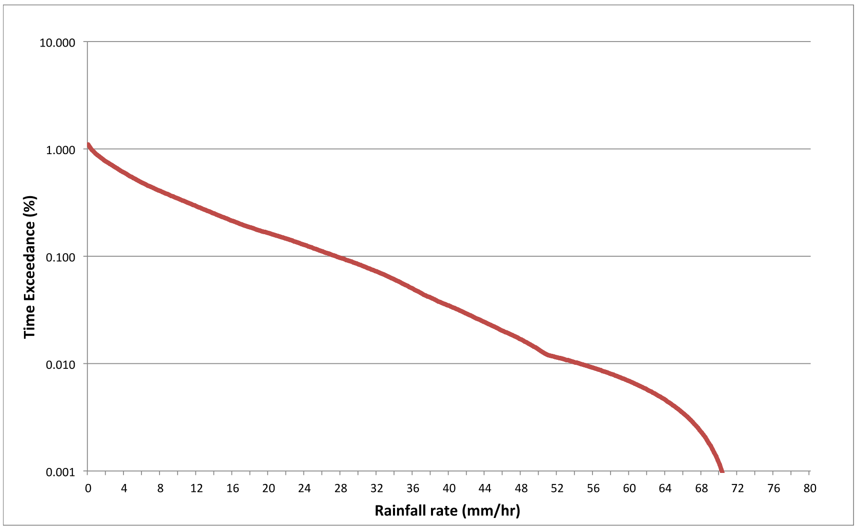

Fig. 5: Annual cumulative distribution function of rainfall at KLIA, Malaysia

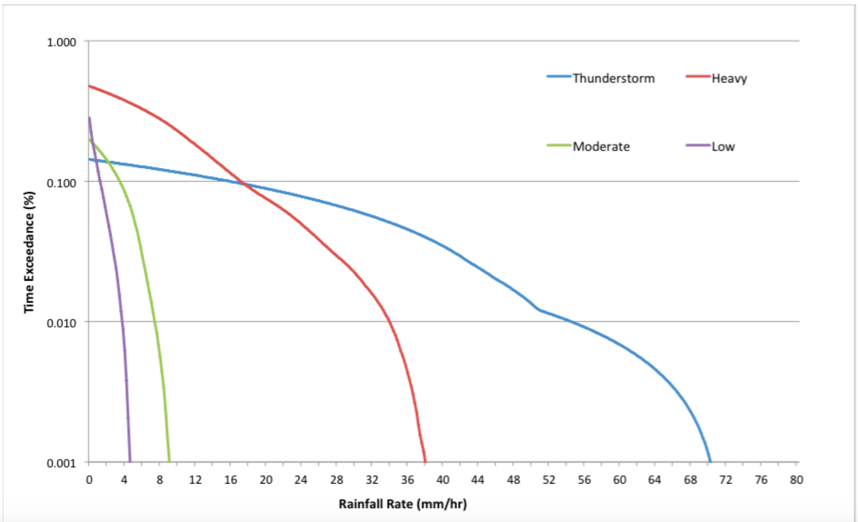

Fig. 6: Cumulative distribution function of different rainfall types at KLIA, Malaysia

The cumulative distribution function of different rainfall types at KLIA is depicted in Fig. 6. The figure shows that the highest rainfall rate exceeded at 0.01% or $R_{0.01}$ occurs during thunderstorm and the lowest rainfall rate during low rain event 54.2mm/hr and 3.8mm/hr respectively. The percentage of time exceeded at 0.1%, 0.01%, and 0.001% for each rain type are tabulated in Table III.

Table 3: Summary of Rain Events Recorded at KLIA 2009

Time exceedance (%)		0.1	0.01	0.001
Low	Rainfall rate (mm/hr)	1.2	3.8	4.6
Moderate		3.2	7.4	9
Heavy		16.6	33.8	38
Thunderstorm		17	54.2	70

Conclusion And Future Works:

The scope of this paper is limited to the study of the behaviors of the rainfall acquired at KLIA for the year 2009. The study of the 12-month tipping bucket data has given the characteristics of the collected rainfall. From the results obtained, it shows that Malaysia is within equatorial region with the characteristics of two distinguishable rainfall rates that occurs during the whole year.

However, further study and assessment need to be carried out in order to obtain annual cumulative distribution of rainfall that complies with ITU-R P. 837-6. Next investigation will involve in converting the acquired 60-minute integration time to 1-minute rainfall rate data. Then, this conversion will compare with the previously established conversion methods including ITU-R P. 837-6.

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