Paper

Characteristics of Measured Rainfall Rate at Ogbomoso, Nigeria for Microwave Applications

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Abstract—Characteristics of rainfall rate useful in the estimation of attenuation due to rain are presented. Rain data collected at Ogbomoso between January–October, 2009 were used in the analysis. Result shows that power law relationship exists between the equiprobable rain rates of two different integration times. The value of conversion factor C_E and C_R obtained for Ogbomoso are 0.28(60) and 0.64(90) respectively. Our result then shows that different conversion factor is required for different location even within the same climatic region.

Keywords—characteristics, Ogbomoso, rainfall.

1. Introduction

With the rapid development currently being witnessed in the field of information technology there is an increasing demand for broadband satellite services and this has called for satellite system that can provide rapid and reliable transmission of information from one end to another. Attenuation due to rain is one of the factors that limits the path length over which reliable radio communication systems can be established. It also limits the usage of higher frequencies for terrestrial microwave point to point as well as satellite communication. As the frequency increases, so does the impact of atmospheric conditions on the radio wave propagation [1], which causes reduction in the quality of signal in the case of analog transmissions, and increase in the bit error rate in the case of digital transmission.

In this paper, some characteristic of tropical rainfall as measured at Ogbomoso are discussed using rainwise rain-guage between January–October 2009. The effect of integration time on the rain rate and cumulative distribution functions are examined. Rain rate duration characteristics are also discussed.

2. Measurement System

The precise knowledge of rain attenuation on any communication link improves the estimation of link availability which provides accurate knowledge of outage time excepted. Most attenuation prediction models required at least 1 min rain rate statistic [2]–[4]. Rain rate statistics is specified on a percentage of time basis, that is the percentage of time in a year or a month that the rain rate equals or exceeds a specific value.

The experimental set-up for this measurement of rain rate characteristic is located at Ladoke Akintola University of Technology, Ogbomoso. The rain rate are measured using rainwise tipping bucket rain guage of 0.5 mm per tip at different integration time. The cumulative distributions of rain rate for different integration times are generated from rain data base.

3. Results of Rain Rate Measurement in Ogbomoso

3.1. Integration Time

The relationship between rain rate statistics with different integration times has been studied from the results obtained from the rain gauge. The cumulative distribution of the rain rate from the different integration times generated from the rain gauge data is shown in Table 1 and the corresponding graph in Fig. 1.

Table 1
Time rain rate exceeded for different integration times

Rain rate [mm/hr]	Percentage of rain rate is exceeded for integration time			
	1 min	5 min	10 min	20 min
210	0.0064	0.0206	0.0386	0.110
180	0.00704	0.0123	0.0193	0.0787
150	0.0094	0.0185	0.0579	0.0866
120	0.0200	0.0699	0.143	0.236
90	0.0276	0.0864	0.135	0.307
60	0.0745	0.302	0.394	0.551
30	0.871	2.366	2.812	4.567

At the low availabilities, the probability of raining is an important parameter determining the annual outage time percentage, below which the rain attenuation has to be considered in the link to be designed [5]. From the cumulative distribution above, a table from which the relationship between equiprobable rain rates for the different integration times is established. This involves developing a conversion method for time probability of one minute rainfall rate from that for integration time great than one-minute. The result is shown in Table 2 and Fig. 2.

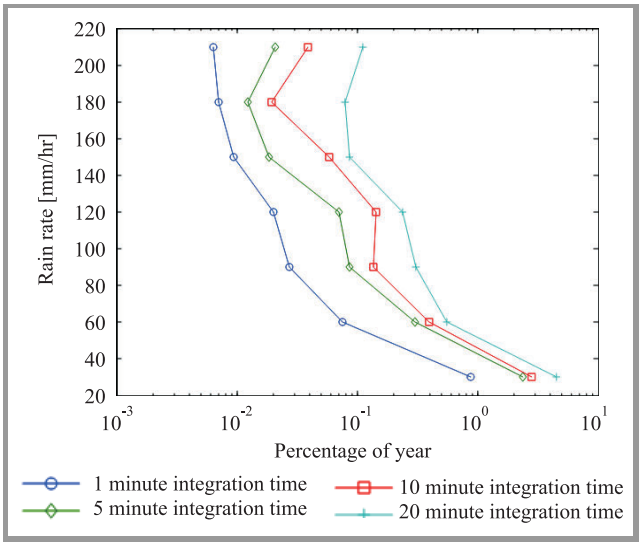

Fig. 1. Cumulative distributions of rain rate at Ogbomoso for different integration times between January and October 2009.

Table 2
Value for equiprobable rain rates for different integration times

$R_{1\min}$ [mm/hr]	R_τ [mm/hr]		
	5 min	10 min	20 min
30	22	16	10
60	42	29	22
90	61	47	35
120	79	62	49
150	97	78	64
180	114	93	79
210	131	108	95

3.2. Conversion Factors

According to G.O. Ajayi *et al.* and Watson *et al.* [6]–[7], conversion factors C_R and C_e for different integration times are considered as:

$$C_R(t) = \frac{R_T}{R_\tau},$$

$$C_e(R) = \frac{e_T}{e_\tau},$$

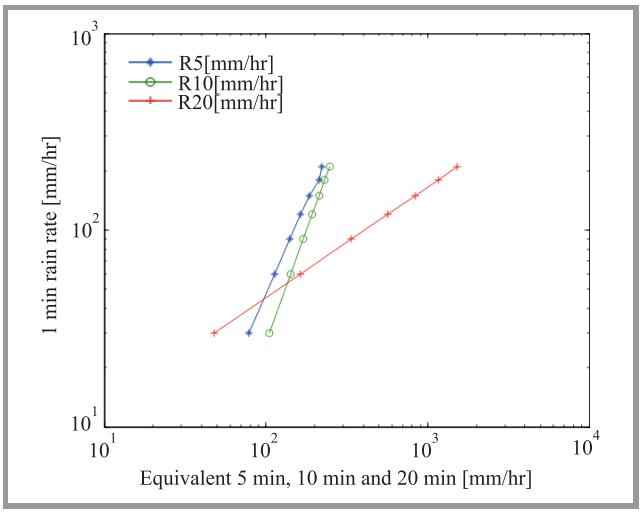

Fig. 2. Equivalent 1-min rain rate for different integration times at equal probabilities of occurrence.

where C_R is the ratio of rain rates exceeded for a given percentage of time t as measured by the rain gage with integration times T and τ, C_e is the ratio of the exceedances for a given rain rate measured using the integration time T.

The result of C_e obtained in Ogbomoso for $T = 5$ min and $\tau = 1$ min was then compared with that obtained in Ile-Ife and some countries in Europe. The result is shown in Table 3.

As shown in Table 3 there is a gradual decrease in the value of C_e with increasing rain rate for the European countries while that of Ile-Ife and Ogbomoso in Nigeria decreases rapidly with increasing rain rate. This suggests that C_e might be climate dependent as suggested in [8] which is also corroborated as according to the value obtained for Ogbomoso. The value of C_R obtained in Ogbomoso is also compared with that obtained in [7] for some stations in Europe and that of Ile-Ife, as obtained in [6]. The results obtained in Ogbomoso agrees with that obtained in Ile-Ife which are generally lower than values obtained for other European stations. On the average, the percentage difference between the values of C_R obtained for Europe and other temperate regions are generally lower than that obtained in tropical regions such as Ogbomoso and Ile-Ife. The values are depicted in Table 4.

3.3. Return Periods

Return periods for specific rain data were studied from the rain data we obtained here in Ogbomoso over the period between January and October 2009. Table 5 shows the number of occasions when rain rates of 30, 60, 90, 120, 150, 180 and 210 mm/hr had particular return periods. It is shown also in Fig. 3.

Table 3
Values of $C_e(R)$ for $T = 5$ min and $\tau = 1$ min

Location	Rainfall rate [mm/hr]									Comments
	10	20	30	40	50	60	70	80	90	
Greece							0.65	0.51		2 year data for Keffalina
Italy			0.63	0.60	0.60		0.63			2 year data from Rome
West Germany		0.80	0.74	0.73						1 year data from Darmstadt
UK	0.78	0.72	0.71	0.69	0.60		0.43			5 year data from southern UK on a network of rain gauges
Nigeria (Ile-Ife)	0.74	0.68	0.59	0.57	0.40	0.30	0.17	0.10	0.08	28-month data obtained at Ile-Ife using a fast response rain gauge
Nigeria (Ogbomoso)			0.37			0.28			0.16	10-month data obtained at Ogbomoso using a rain gauge
All results except Nigeria (Ogbomoso) was obtained from [6].										

Table 4
Values of $C_R(R)$ for $\tau = 1$ min numbers in bracket indicate the 1 min rain rate

Location	T [min]	Percentage of year		Comments
		0.01	0.001	
Italy	5	0.8(100)		2 year data from Rome
	10	0.7(100)		
	60	0.42(100)		
UK	5	0.84(20)	0.82(60)	5 year data from southern UK from a network of rain gauges
	10	0.77(20)	0.72(60)	
	60	0.59(20)		
West Germany	5	0.93(20)	0.9(40)	1 year data from Darmstadt
	10	0.81(20)		
Nigeria (Ile-Ife)	5	0.68(80)	0.64(130)	28-month data obtained at Ile-Ife
	10	0.52(80)	0.53(130)	
Nigeria (Ogbomoso)	5	0.64(90)		10-month data obtained at Ogbomoso
	10	0.53(90)		

Table 5
Values of return periods at different rain rate

Rain rate [mm/hr]	Return period	No. of occasions rain rate was exceeded
30	0.010	1484
	0.423	1150
	0.356	728
	0.222	573
60	3.311	147
	1.147	127
	2.538	102
	1.815	70
90	37.017	46
	11.574	42
	1.815	39
	7.407	35
120	6.993	37
	50.075	34
	4.237	30
150	106.383	16
	17.271	15
	11	11
180	9	9
	142.045	12
	7.134	10
	81.301	6
	51.815	5
210	9.091	14
	156.25	11
	48.543	10

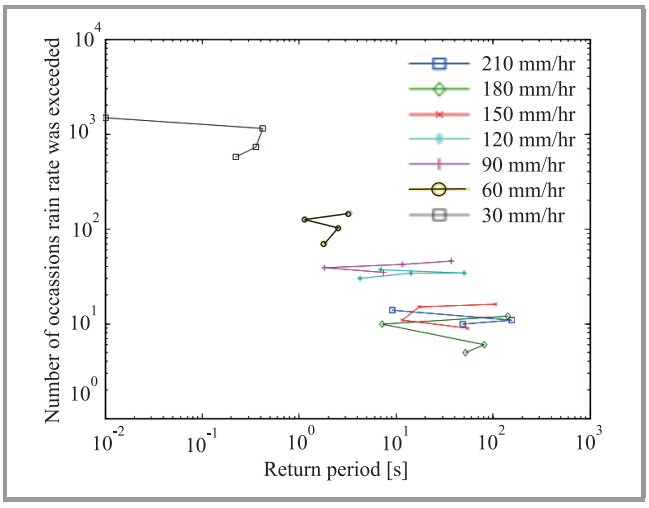

Fig. 3. Characteristics of return period of rain rates.

3.4. Rain Duration

The rain rate duration data are paramount to study the characteristics of precipitation. The data is useful in the determination of communication link outage due to rainfall. The rain duration at different rain rates is shown in Table 6 and the corresponding graphs in Figs. 4 and 5.

Table 6
Rain duration at different rain rates

Rain rate [mm/hr]	No. of occasions rain rate was exceeded	Rain duration [s]
30	6	360
Different rain events at which rain volume is greater than or equal to 100 mm	8	480
	11	660
	20	1200
	29	1740
	31	1860
	46	2760
	52	3120
	134	8040
60	1	60
	3	180
	4	240
	7	420
	8	480
	9	540
	11	660
	14	840
90	1	60
	2	120
	3	180
	5	300
	7	420
	8	540
120	1	60
	2	120
	3	180
	4	240
	9	540
150	1	60
	2	120
	4	240
	6	360

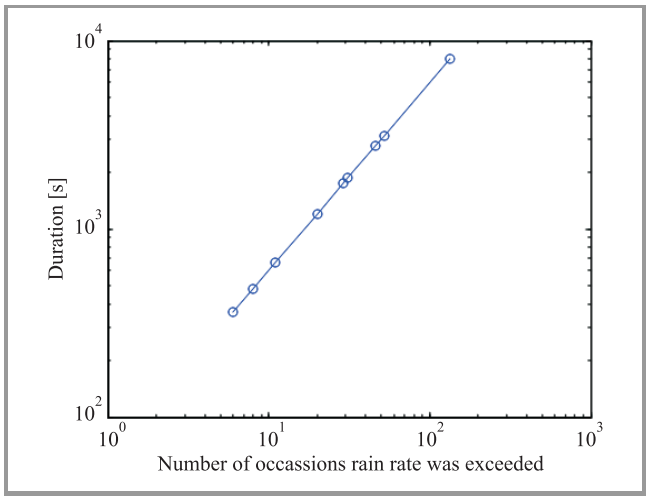

Fig. 4. Rain duration at 30 mm/hr rain rate.

4. Conclusion

In this contribution, rainfall rate data between January-October, 2009 at Ogbomoso have been used in the study of effect of integration time on the cumulative distribution of rain rate. The result shows that power law relationship exists between the equiprobable rain rates of two different integration times. Our result compared to Ile-Ife follows the same trend except that the value obtained in Ogbomoso is a little higher than Ile-Ife. Although, Ile-Ife rain rate is expected to be higher because Ogbomoso experiences Northern climatic condition. Therefore it is recommended that the work of [6] need to be revisited as a result of change in climatic condition due effect of global warming. The conversion factors C_R and C_E obtained at Ogbomoso are lower as compared to those obtained at Ile-Ife. The value of C_E and C_R obtained for Ogbomoso are 0.28(60) and 0.64(90) respectively. Our results show that different conversion factor is required for different locations even within the same climatic region for the conversion of one integration time to another. However, measurement period of 10 months may not be sufficiently enough to compare other literature results. Further detailed analysis based on longer period would be performed and presented by the authors in the future.

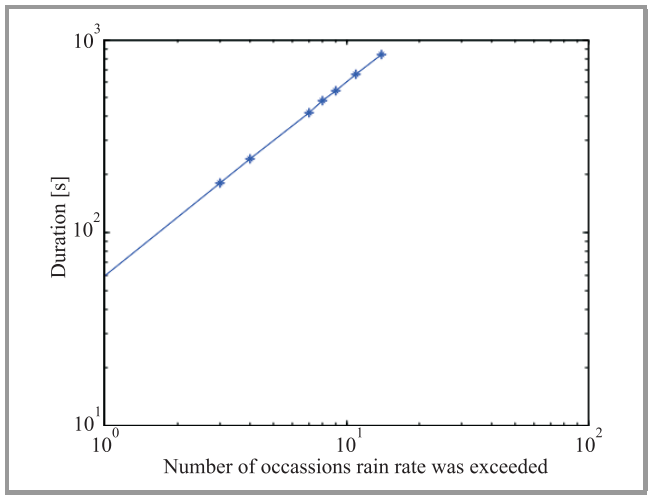

Fig. 5. Rain duration at 60 mm/hr rain rate.

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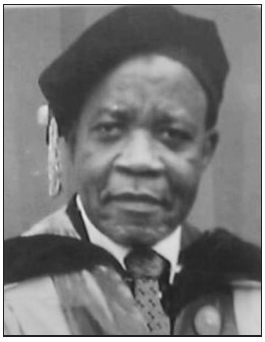

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