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Rain Drop Size Distribution and Variability of Specific Rain Attenuation for Indian Climate

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Abstract

The demand of cellular data is expanding its capacity multifold due to exponential growth of traffic in the cellular network, which requires to achieve the very high data rate and large bandwidth by shifting from current frequency spectrum (below 10 GHz) to mm wave range (30 GHz to 300 GHz) spectrum. Rain plays a very important role in attenuation and depolarization of radio signals at mm wave frequencies due to rain drop size distribution. The rain drop size distribution in tropical climate follows the log-normal rain drop size distribution (RDSD) compared to the exponential RDSD in temperate climate. In this paper, the variability of rain drop size spectra based on the log-normal RDSD model of Indian climate have been described and compared with other tropical climatic region. The variability of the specific rain attenuation at mm wave range has been estimated based on log-normal RDSD model from 10 GHz to 100 GHz. In this paper, the variability of specific rain attenuation in mm wave region is described for Indian tropical climate, which shows less attenuation of radio signals at 100 GHz compared to 60 GHz during heavy rainfall event beyond 30 mm/hrs.

1. Introduction

Recent advancement in the device and component technology together with phased array technology for multi-beam steering antenna has given the opportunity to exploit the mm wave communication systems for short distances with the capability to handle very high data rates of the order of GBPS, which is not feasible in the microwave frequencies. The major atmospheric effect on the mm wave radio signals is the influence of various forms of precipitations such as rain, snow and hail, introducing a significant additional signal attenuation as well as depolarization. As a result, the radio signal at mm wave bands are affected mainly by rain rate, rain drop size distributions, rain drop orientations apart from radio signal polarization. Indian tropical climate follows log-normal rain drop size distribution during rain events based on the rain drop size spectra measurement carried out at various locations such as Dehradun, Shillong, Kharagpur, Ahmedabad, Trivandrum, Hassan, Eastern and Western coast such as Thiruvananthapuram, Kochi and Sriharikota [1-8].

In case of cellular broadband mobile communication for heterogeneous network, 100 m to 200 m radii of cell size at mm wave region enables very high data rates and very bandwidth. The applications for mm wave broadband cellular system for longer range or non-radio-line of sight (NLOS) dense urban environment is a new applications. Rain attenuation in the microwave and mm wave band is currently considered to be a major concern in the design of communication systems at frequencies above 10 GHz.

First raindrop size distribution (RDSD) model for Indian climate developed for Dehradun based on the measurement of rain drop size data using Distrometer during 1989-93 by considering 4200 and 1100 rain events at Defence Electronics Applications Laboratory (DEAL), Dehradun [2-4]. The measurement of rain drop size data for other locations [5-6,8] such as Shillong, Kharagpur, Ahmedabad, Trivendrum, and Hassan of Indian tropical region carried out by Indian Space Research Organisation (ISRO) during 2004-2007 provided different log-normal RDSD models. Defence Electronics Application Laboratory (DEAL) and Indian Space Research Organization (ISRO) conducted ground based measurement of Rain Drop Size Distribution (RDSD) as a part of earth-space propagation experiments over Indian region. Similarly, other organization started the study of rain drop size distribution in order to understand the rainfall characteristics of tropical climate and conducted the measurement of rain drop size distribution spectra at three locations such as Thiruvananthapuram, Kochi and Sriharikota during 2003 to 2005 [7]. It is observed from RDSD measurement that In general, with the increase of rainfall, the number of rain drops increases, but with the intense rainfall at Shriharkota and Kochi confirms the increase of rain drops in contrary to increase of rain drop sizes as well as rain drops at Thriuvanthapuram. This paper discusses various log-normal rain drop size distribution models of Indian Climate for Dehradun, Kharagpur, Shillong, Ahmedabad, Hassan and Trivandrum in respect of drop size spectra. In this paper, the variations in characteristics of rain drop spectra of the Indian climate and its effect on the attenuation of radio signal at mm wave range have been explained, which is responsible to contribute the variability of specific rain attenuation. In this paper, the effect of the presence of larger rain drop size for the Indian tropical region leading to less attenuation of radio signals at 100 GHz compared to 60 GHz for heavy rainfall events have been described.

2. Rain Drop Size Distribution and Specific Rain Attenuation

The tropical rain drop size distribution follows log-normal distribution of rain drop sizes and can be written as [2], [3], [4]

$$N(D_i) = \left(N_T / \sigma D_i \sqrt{2\pi} \right) \exp\left[-0.5 \{ (\ln D_i - \mu) / \sigma \}^2 \right] \quad (1)$$

Where, N_T is the total number of drops of all sizes, μ and σ are the mean and standard deviation of D_i , D is drop size, i is number of drop size channel (i varies from 1 to 20 rain drop size channel) . Here, N_T, μ and σ are the functions of rain rate and can be written as

$$N_T = a_o R^b \quad (2)$$
$$\mu = A_o + B_o \ln R \quad (3)$$
$$\sigma^2 = A_e + B_e \ln R \quad (4)$$

The log-normal RDSD model developed based on the rain drop size data measurement at different locations in the Indian tropical region and other tropical countries have different value of coefficients of N_T, μ and σ given in Table-I [1-9].

TABLE I

Locations	Value of coefficient for different locations					
	a_o	b	A_o	B_o	A_e	B_e
Dehradun	169.05	0.2937	-0.05556	0.1309	0.3004	-0.0236
Ahmedabad	149.37	0.3467	-0.1380	0.1569	0.0625	0.0079
Trivandrum	176.76	0.3178	0.1934	0.1684	0.0692	0.005
Shillong	170.37	0.26	0.1925	0.1831	0.0738	0.0059
Kharagpur	140.85	0.2994	0.1417	0.1716	0.0744	0.0064
Hassan	225.99	0.3041	0.2557	0.1615	0.0683	0.0097
Calcutta	546	0.4690	-0.5380	0.0170	0.0689	0.0760
Durban (SA)	221	0.354	-0.2594	0.1504	0.0742	0.0088
Nigeria	108	0.3630	-0.1950	0.1990	0.1370	-0.0130
Brazil	391	0.0090	1.5798	0.0145	2.1592	0.0454
Singapore	276.18	0.3815	-0.4286	0.1458	0.1564	0.0091
Miami	46.0	0.55	0.451	0.264	0.409	-0.076

Medhurst Techniques are used for the estimation of specific attenuation by using the rain drop size distribution model and can be written as

$$\gamma = \sum^{D_i} [d_{D_i} / (1.885 * 10^3\ 10^3\ v_i D_i^3)]\ P_{D_i} \quad (5)$$

The general form of equation for specific attenuation based on Mie-scattering can be written as

$$\alpha = a R^b \quad (6)$$

Specific rain attenuation model can be obtained through measurement or predicted from knowledge of rain rate and drop size distribution [2, 4, and 5]. The values of coefficients of Specific rain attenuation models based on lognormal RDSD models are given in Table-II.

TABLE II

Locations	Value of Specific Rain Attenuation Coefficient				
	10 GHz	20GHz	30GHz	60GHz	100GHz
Dehradun : a	0.00719	0.07378	0.16128	0.6596	1.117172
b	1.2804	1.1239	1.07848	0.8614	0.708326
Shillong : a	0.01115	0.1329	0.3389	1.319	1.476
b	1.199	0.9289	0.8492	0.6366	0.6095
Ahmedabad: a	0.0081	0.1204	0.2932	1.214	1.386
b	1.249	0.9557	0.8922	0.6838	0.654
Trivandrum : a	0.0057	0.1106	0.2625	1.227	1.479
b	1.316	0.9723	0.9169	0.6865	0.6442
Kharagpur : a	0.0116	0.1304	0.3241	1.203	1.341
b	1.193	0.9328	0.8577	0.6548	0.6285
Hassan : a	0.006	0.1082	0.2691	1.29	1.676
b	1.289	0.9686	0.9036	0.6799	0.6259
ITU-R2005: a	0.0117	0.938	0.2347	0.856	1.3675
: b	1.2371	1.0198	0.9311	0.7571	0.6789

3. Results and discussions

Fig. 1 (a) – (d) explains the variation of RDSD spectra with increase of rain rate from 1 mm/hr. to 150 mm/hr. for Dehradun, Trivandrum, Kharagpur and Shillong. It is observed from RDSD spectra that rain drop size spectra shifts towards the bigger rain drop size and increased number of rain drops with the increase of rain rate. However, RDSD spectra pattern is different for different locations with increasing rain rate. As the rain rate increases, there is shift in rain drop size spectra towards the distribution of bigger rain drops and decrease of smaller rain drops in RDSD, which plays higher attenuation by increasing rain rate. Further, it is observed that RDSD pattern is almost similar for Shillong and Kharagpur as well as Trivandrum and Hassan, which consists of bigger rain drops of 1.5 mm for the same rain rate compared to Dehradun and Ahmedabad. The presence of bigger rain drops are observed maximum for Hassan, which is followed by Trivandrum, Shillong and Kharagpur for the same rain rate. RDSD for Dehradun consists of presence of both smaller and bigger rain drops with maximum rain drops size between 0.75mm to 1.95 mm. Similarly, RDSD spectra for Ahmedabad consist of presence of rain drops between 1.1 mm and 2.25mm with maximum rain drops of 1.5 mm size. It is found that the characteristics of RDSD spectra are different for each location in the Indian tropical region. Fig.2(a)-(d) shows the variation of specific rain attenuation at Dehradun, Shillong, Kharagpur, and Trivandrum for 10, 20, 30, 60 and 100 GHz frequencies with increasing rain rate. It is observed that specific rain attenuation increases with increase of frequency and rain rate.

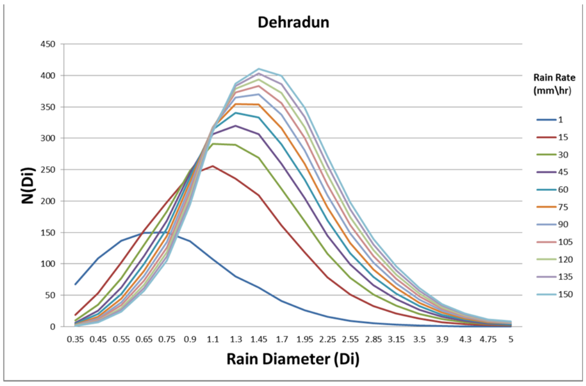

Fig. 1 (a) Variation of Rain Drop Size Spectra

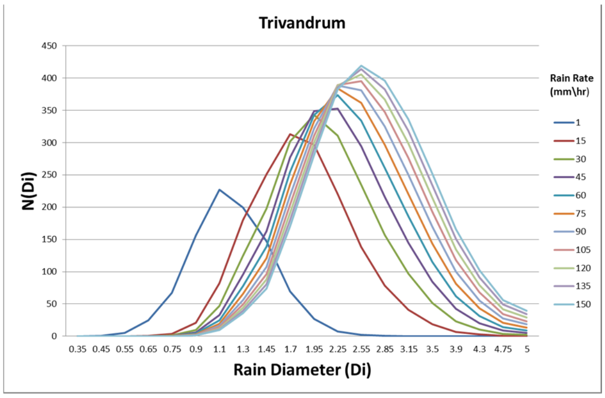

Fig. 1 (b) Variation of Rain Drop Size Spectra

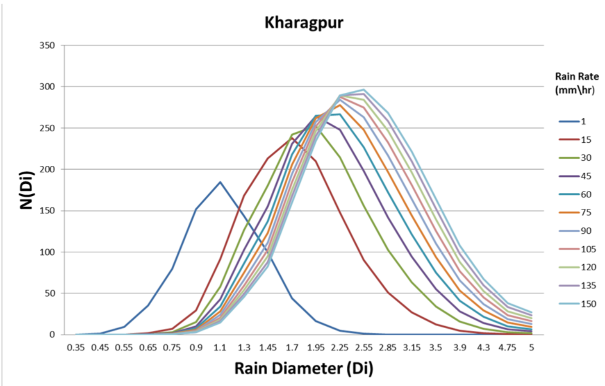

Fig. 1 (c) Variation of Rain Drop Size Spectra

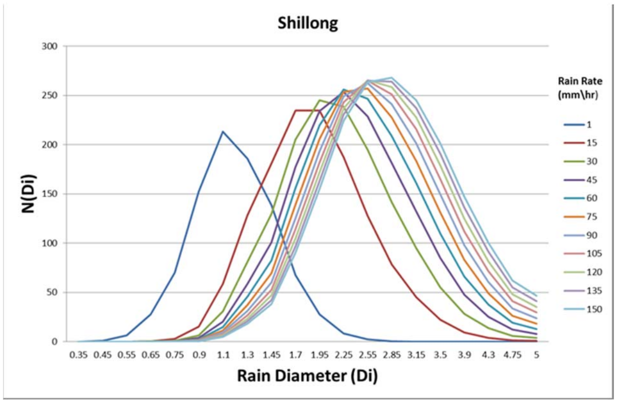

Fig. 1 (d) Variation of Rain Drop Size Spectra

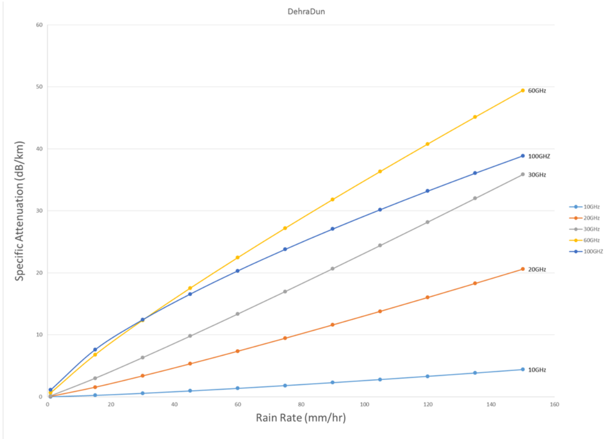

Fig. 2(a) *Specific rain attenuation at Dehradun*

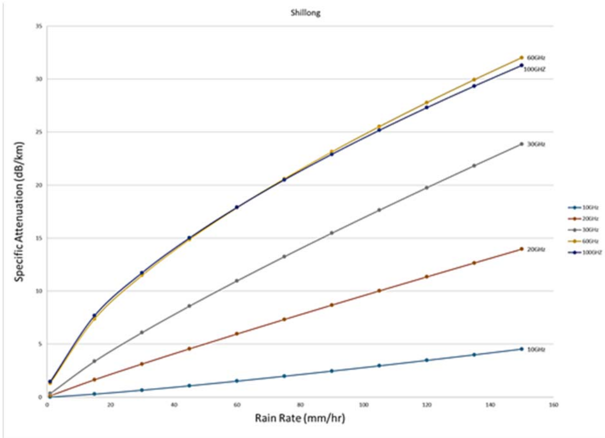

Fig. 2(b) Specific rain attenuation at Shillong

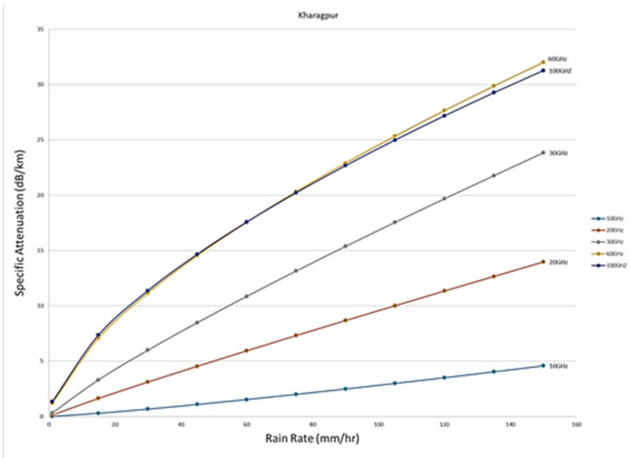

Fig. 2(c) Specific rain attenuation at Kharagpur

Further, specific rain attenuation at 60 GHz is found very close to 100 GHz for Indian region, but specific rain attenuation for Dehradun decreases for 100 GHz compared to 60 GHz after the increase of the rain rate beyond 30 mm/hr due to the presence of both smaller and bigger rain drops in RDSD spectra with mean rain drop size between 1.4mm and 1.75 mm at maximum N(Di). Similarly, it is observed from Fig. 2(b)&(c) that specific attenuation characteristics for Shillong and Kharagpur is almost very close due to similarity in the RDSD spectra. Specific rain attenuation at 100 GHz and 60 GHz is almost the same value. The value of specific rain attenuation at 100 GHz starts decreasing from 60GHz at higher rainfall rate beyond 60 mm/hrs. Similar, specific rain attenuation characteristics is observed for Trivandrum and Ahmedabad causing higher attenuation compared to Shillong and Kharagpur, and specific rain attenuation at 100 GHz decreases from 60 GHz beyond the rainfall rate of 90mm/hr. Fig.3 explains the regional variability of specific rain attenuation due to variance of RDSD spectra in Indian tropical climate for frequency above 10 GHz. The regional variability for 100 GHz increases slowly with rain rate compared to 30 GHz and 60 GHz. The regional variability of specific attenuation for 100 GHz decrease from 60 GHz and 30 GHz beyond the rain rate of 45 mm/ hr. and 90 mm/hr. respectively.

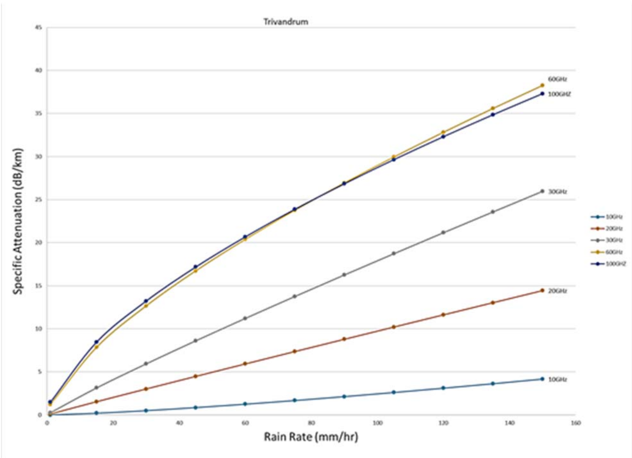

Fig. 2(d) Specific rain attenuation at Trivandrum

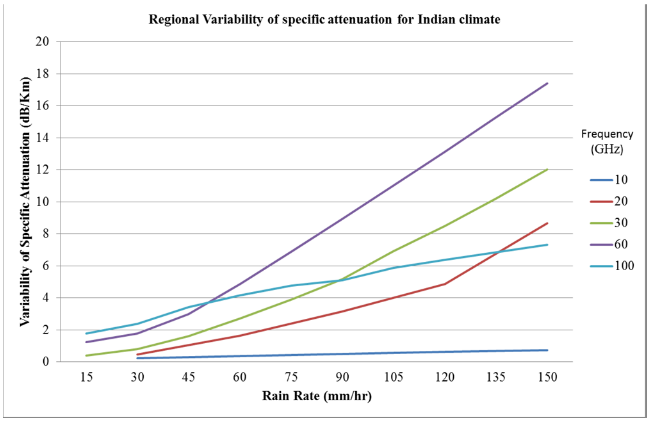

Fig.3 Regional variability of specific rain attenuation

4. Conclusion

Rain drop size distribution model for tropical climate varies from place to place and region to region and requires more measurement for the Indian tropical region at many locations in order to evolve the precise specific rain attenuation model for Indian region. The variation in the rain drop size spectra characteristics causes the regional variability of specific attenuation model due to the presence of smaller and larger rain drop sizes , which are required to cater as rain fade margin for development of very high data rate and broadband communication system to meet the upcoming demand of digital traffic in mm wave cellular system . Based on the specific rain attenuation model, it is observed that rain attenuation of 100 GHz decreases with the increase of rain rate and attenuation is less for 100GHz compared to 60 GHz at higher rainfall rate beyond 30 mm/hr depending upon the locations in the Indian tropical region, which is not observed in other countries, due to different drop size spectra

5. References

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