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Results on 0°C isotherm height over Port Blair, Vishakhapatnam and Jodhpur for satellite communication and radar propagation

S K Sarkar*, N C Mondal** and A B Bhattacharya***

*Radio and Atmospheric Sciences Division, National Physical Laboratory, Dr K S Krishnan Road, New Delhi-110 012, India

**National Institute of Science Communication, Dr K S Krishnan Road, New Delhi-110 012, India

***Department of Physics, Kalyani University, Kalyani-741 235, West Bengal

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Abstract The results on rain height in relation to 0°C isotherm height, which is one of the important parameters to estimate rain attenuation over earth space path are presented in this paper The seasonal variation of rain height has been found to be appreciable over the station located in desert, while seasonal variation is not significant at lower and intermediate probability levels over the stations located in Indian south east coast and island Based on observed rain heights and rain rates, the attenuations of radiowave in frequencies from 10 GHz to 300 GHz for different probability levels over Indian desert have been deduced

Keywords Rain height, 0°C isotherm height, radiowave attenuation

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The radio attenuation over earth space path over a location can be estimated with good degree of accuracy provided the measured results on rain rates and rain heights are available. Some results on rain heights over some Indian locations are available [1,2]. But, still there is dearth for results on rain height over the Indian stations. Some results on rain height in relation to 0°C isotherm height over some selected stations were reported recently by Sarkar *et al* [3] and Mondal *et al* [4].

It is important to deduce the results on the distribution of rain height and rainfall rate over as many stations as possible for rain attenuation estimation for designing highly reliable earth-space communication systems over different locations. It is well known at present that rain height can be taken as 0°C isotherm height [5-7]. The results on rain height over Port Blair, Vishakhapatnam and Jodhpur which are presented in this paper are being reported for the first

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time. Such results are derived from radiosonde observations. The radiosonde observations are taken twice daily one at 0000 GMT and the other at 1200 GMT. Port Blair (11.49°N, 92.43°E) is an island station located over Bay of Bengal side having station elevation ~ 79 m. Vishakhapatnam (17.43°N, 83.14°E) is an coastal station located in south east coast having station height ~ 3 m while Jodhpur (26.18°N, 73.01°E) is situated over Indian desert with an altitude ~ 224 m. The rain height results over Jodhpur along with the measured rain rates have been utilised to deduce the attenuation of radiowave due to rain for different probability levels. The results on rain height reported over Port Blair and Vishakhapatnam are useful to deduce the attenuation results. However, since the measured rain rate over the two locations (Port Blair and Vishakhapatnam) are not available at present, the attenuation are not estimated.

It is seen that the 0°C isotherm height in all months varies from 2.1 km to 6.8 km over these stations. The variation in 0°C isotherm height in different stations during winter is appreciable. The 0°C isotherm height varies between 2.15 km and 6.4 km over these stations during summer months. The one way attenuation over Jodhpur for 5%, 0.1% and 0.01% probability levels are found to be ~ 5 dB, 20 dB and 47 dB respectively at 20 GHz.

The results on 0°C isotherm height over Port Blair for summer, monsoon, post monsoon and winter are shown in Figure 1. It is seen that the 0°C isotherm height varies from 2.1 km to 6.8 km during all months. The 0°C isotherm height is 4.9 km at 50% probability level over Port Blair. It means that 50% of the time ordinate value *i.e.* 0°C isotherm height 4.9 km is exceeded.

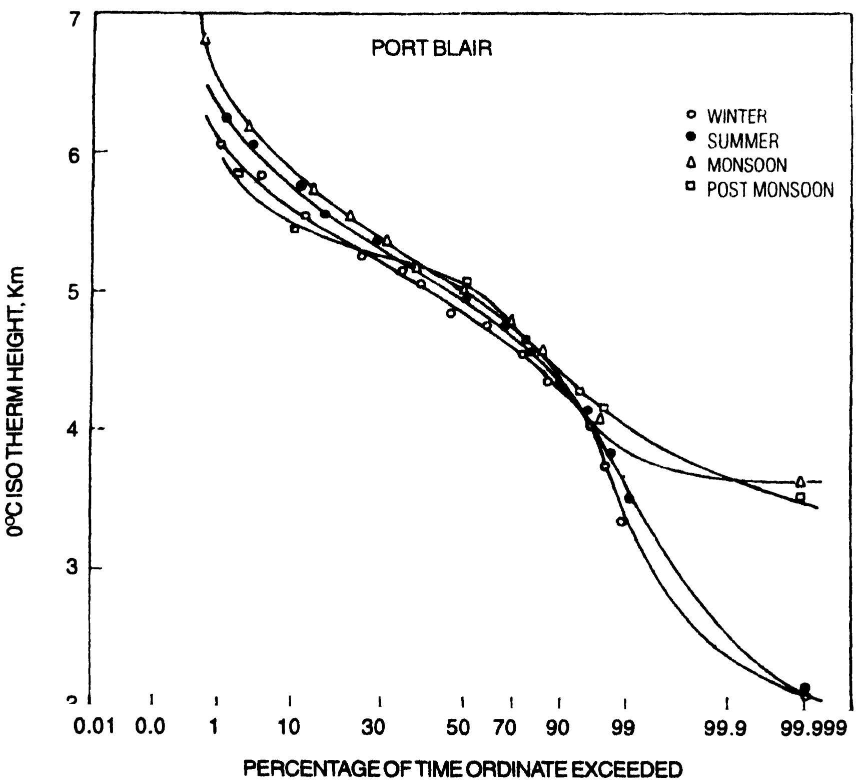

Figure 1. Distribution of 0°C isotherm height over Port Blair during different season.

The 0°C isotherm heights during monsoon months are found to vary from 2.1 km to 6.8 km, while the variation is between 6 km and 3.4 km from 1% to 99% probability levels during non-monsoon months. The results on 0°C isotherm height reported here are useful to determine the one way total attenuation and specific attenuation for satellite communication and radar propagation in frequencies varying from 10 GHz to 300 GHz provided distribution of rain rate over Port Blair is known.

The probability distributions of 0°C isotherm height for summer, monsoon, post-monsoon and winter over Vishakhapatnam (Vizag) are illustrated in Figure 2. It is seen that the 0°C isotherm height during all months varies from 2.95 km to 6.2 km. The 0°C isotherm height is 5 km at 50% probability level over Vizag. It suggests that 50% of the time ordinate value *i.e.*, 0°C isotherm height 5 km is exceeded.

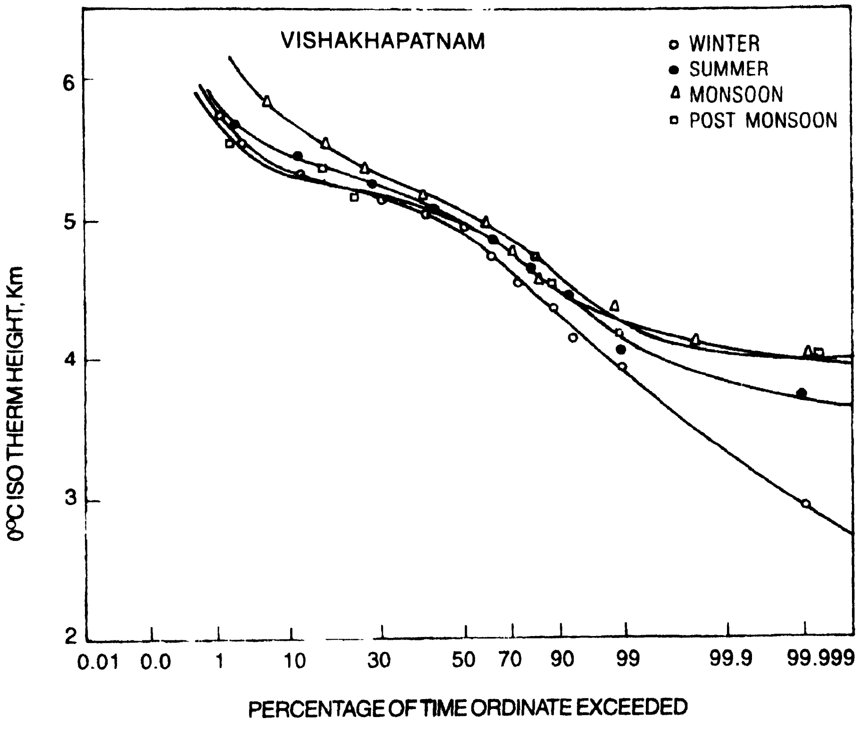

Figure 2. Distribution of 0°C isotherm height over Vishakhapatnam during different season

The 0°C isotherm heights during summer months are found to vary between 3.7 km and 5.95 km, while they vary between 5.5 km and 3.9 km from 1% and 99% probability levels during winter months.

The probability distribution of 0°C isotherm height for different periods including summer, monsoon, winter and all months over Jodhpur are presented in Figure 3. The 0°C isotherm height during all months varies from 2.5 km to 4.8 km. The 0°C isotherm height is around 4.2 km at 50% probability level. The 0°C isotherm height is found to be minimum during winter periods while it is maximum during monsoon months. The 0°C isotherm height is found to vary between

5 km and 3.4 km from 1% to 99% probability levels during summer months. It is thus seen that the variation of rain height over Jodhpur during summer months is appreciable.

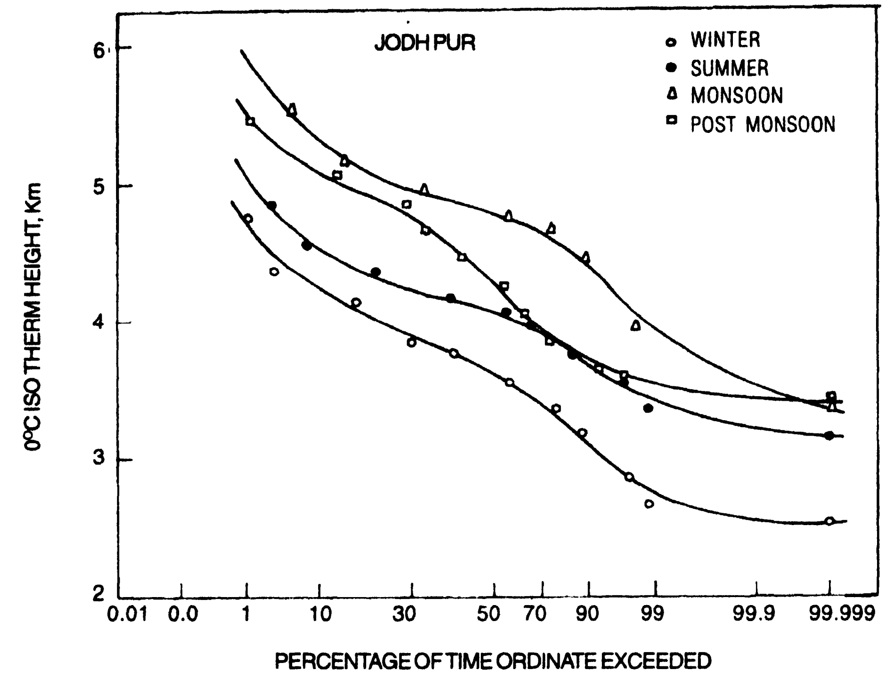

Figure 3. Distribution of 0°C isotherm height over Jodhpur during different season

The frequency range from 1 to 10 GHz is in use at present by various agencies including civilian and defence for tropospheric communication circuits in both terrestrial and earth space communication systems in India. The use of higher frequency bands for communication systems is necessary for higher channel capacities and also due to congestions in VHF and UHF bands. The higher frequency (radiowave) especially when the frequency of operation is more than 10 GHz is affected severely by rain and other hydrometeors. Rain is the most important one and it attenuates the radiowave severely.

Results on attenuations at 10 GHz, 50 GHz, 100 GHz, 200 GHz and 300 GHz for rain rates 10 mm/h, 40 mm/h and 100 mm/h over Jodhpur situated in Indian desert have been deduced. Such a study could be possible because rain rate data of six years measured over Jodhpur by a rain gauge having integration time 5 minutes were available. The results were obtained by taking the actual rain height in relation to 0°C isotherm height as reported in the previous section.

The characteristics of microstructure of rainfall including size distribution, temperature, terminal velocity and shapes of rain drops are very important for the determination of specific attenuation at a particular frequency for different rain rates. The relation between the specific attenuation, α and rain rate, R, for practical purposes is given by the following well known power law (Olsen *et al*, 1978).

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

where a and b are the constants depending on the frequency.

The values of a and b have been estimated by assuming the rain drops to be oblate spheroidal (CCIR, 1990 and Nowland *et al*, 1977) and is presented in Table 1. The specific attenuation can be deduced for different measured rain rate at various frequencies ranging between 1 GHz and 300 GHz. The non uniformity of rainfall in horizontal and vertical directions makes the evaluation of attenuation along earth space path complex. The model for the slant path suggests that the rain rate (R) exceeded for P% of time at ground level occurs for the same percentage of time up to the height (h_R), called rain height (Ajayi and Kolawole, 1984 ; CCIR, 1986). It is also assumed that the attenuation due to rain does not occur above h_R .

Table 1. Values of a and b

Frequency in GHz	a	b
10	0 00887	1 264
20	0 0691	1 065
50	0 479	0 868
100	1 06	0 744
200	1 42	0 690
300	1 35	0 689

The CCIR method of calculation of total attenuation along the slant path is given by CCIR, 1986 ; Ajayi and Kolawole, 1984.

$$A_R = \alpha(R).L_e ,$$

where A_R is the attenuation exceeded for P% of time, the specific attenuation and L_e the effective path length given by

$$L_e = r_p . L_s ,$$

where r_p is the reduction factor and is given by

$$r_p = \frac{90}{90 + C_p . LG}$$

and $$L_s = \frac{H_R}{\sin\theta}$$

Here, H_R is the rain height above the station elevation and is the elevation angle. The value C_p as given in the CCIR, 1986 are 9, 4, 0. 5 and 0 respectively for rains occurring for 0.001%, 0.01%, 0.1% and 1% of time. The parameter L_G is the horizontal projection of slant path.

The specific attenuation α in db/km at 10 GHz, 20 GHz, 50 GHz, 100 GHz, 200 GHz and 300 GHz for rain rates 10 mm/h, 40 mm/h and 100 mm/h is estimated. The specific attenuation at 10 GHz, 20Ghz, 50 GHz, 100 GHz, 200 GHz and 300 GHz are 1dB/km, 3.5 dB/km, 12 dB/km, 16 dB/km, 18 dB/km and 17 dB/km respectively for rain rate of 40 mm/h. It means that as the frequency increases the specific attenuation increases. The detailed results on specific attenuation at different frequencies for various rain rates are presented in Table 2.

Table 2. Specific attenuation in dB/km

Frequency in GHz	Specific attenuation in dB/km 10 mm/h	40 mm/h	100 mm/h
10	0.16	0 93	2.99
20	0.80	3.51	9 32
50	3 55	12.00	26.08
100	5 87	16 00	32.60
200	6 95	18 00	34 06
300	6 59	17 15	32.23

The distribution of rain rates observed at 0.5%, 0.1% and 0.01% during worst months are around 10 mm/h, 40 mm/h and 100 mm/h. Here, 0.1% probability level suggests that for 0.1% of the time including non rainy period, rain rate 40 mm/h is exceeded in worst months. Similarly, 0.01% probability level indicates that for 0.01% of the time rain rate exceeded for 100 mm/h in worst months.

The one way total attenuation over Jodhpur for 40mm/h which exceeds for 0.1% of time is found to be 20 dB at 20 GHz. It is seen that the measured rain rate 100 mm/h exceeds for 0.01% of time over Jodhpur and the attenuation value at 0.01% of time is 47 dB at 20 GHz. The results on one way attenuation for earth space path at 10 GHz, 50 GHz, 100 GHz, 200 GHz and 300 GHz have also been estimated for 0.5%, 0.1% and 0.01% probability levels. The details of the results on attenuation are presented in Table 3. It is seen that the one way total attenuation value increases with frequency at all probability levels. The estimated results on attenuation at 100 GHz for 0.5%, 0.1% and 0.01% levels are 34 dB, 94 dB and 165 dB respectively while attenuation results at 200 GHz are 40 dB, 103 dB and 172 dB for 0.5%, 0.1% and 0 01% probability levels.

Table 3. One way total attenuation in dB

Frequency in GHz	One way attenuation in dB 10 mm/h	40 mm/h	100 mm/h
10	1	5	15
20	5	20	47
50	20	67	131
100	34	94	165
200	40	103	172
300	38	97	163

The results on rain height in relation to 0°C isotherm height presented in this paper, are useful for estimation of one way total attenuation of radiowave due to rain in microwave and millimetrewave frequency bands for satellite communication and radar propagation. The present results on one way total attenuation can be utilised for estimation performance of earth-space communication links and radar propagation in microwave and millimeterwave frequency bands over Indian desert region. Such investigations or rain height and rain attenuation for more number of Indian locations/regions should be undertaken.

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