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Determination of window frequency in the millimeter wave band in the range of 58° north through 45° south over the globe

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Abstract

The radiosonde data available from British Atmospheric Data Centre (BADC) for the latitudinal occupancy of 58° north through 45° south were analyzed to observe the variation of temperature and water vapor density. These two climatological parameters are largely assumed to be the influencing factors in determining the millimeter wave window frequencies over the chosen range of latitudes in between the two successive maxima occurring at 60 and 120 GHz. It is observed that between temperature and water vapor density, the later one is influencing mostly in determining the window frequency. It is also observed that the minima is occurring at 75 GHz through 94 GHz over the globe during the month January–February and 73 GHz through 85 GHz during the month July–August, depending on the latitudinal occupancy. It is observed that the large abundance of water vapor is mainly held responsible for shifting of minima towards the low value of frequencies. Hence, it is becoming most important to look at the climatological parameters in determining the window frequency at the place of choice.

Keywords: Window frequency; Radiosonde; Millimeter wave; Propagation; Satellite communication; Radio navigation

1. Introduction

The ever increasing demand in exploiting radio spectrum at the lower frequency has resulted in increased activity in the millimeter wave band, particularly for communication systems. Hence, the significant revision of the International Table of Frequency allocation above 40 GHz was urgently needed (Katzenstein et al., 1981).In fact, the allocation is made for satellite services such as amateur, fixed and mobile satellite communications; broadcasting and radio navigation.

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In the millimeter wave band (30–300 GHz), one can enjoy the wider bandwidths, smaller size, and low cost system possibly due to the use of solid state technology, narrow antenna beam width and light weight. However, the most important point is the increased communication capacity and high data rates. For example, we may take some operational and experimental systems wherein the RF carrier capacities is from 1 to 1000 telephone channels and bandwidth ranges from a KHz to hundreds of KHz. But at these frequencies the atmospheric attenuation remains the biggest stumbling block and hence creates problems of transmission fidelity, reliability and cost also. However, this may be surmounted by using low cost with short range repeaters which is of the order of few kilometers. In fact, short ranges systems may be of 8–12 km with small outage time are possible even in adverse weather,

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with large range being available in good weather (Tsao et al., 1968). In this context, we can look at the millimeter wave band radio systems (Chang and Yuan (1980)) such as Mobile Intercept-resistant Radio (MISR).

Looking at this highly emergent and useful radio spectrum (millimeter wave band) we need to find out the window frequencies where the atmospheric attenuation is least at the particular place of choice. However Button and James (1981) indicate that the attenuation rate (dB/km) also called the specific attenuation exhibits minima around 30, 94, 140 and GHz. But at a given frequency, the atmospheric absorption coefficient is a function of three basic parameters namely temperature, pressure and water vapor density. The water vapor absorption is essentially dependent on water vapor density and like wise the oxygen absorption is dependent on to pressure and temperature. Since, water vapor density and pressure decrease exponentially with increasing altitude, the major contribution in finding the zenith opacity (dB) is provided by the layers closest to the surface (Ulaby et al., 1981). Hence, it is expected that the zenith opacity will vary linearly with the surface water vapor density which is supported experimentally by Waters (1976).

Keeping all these in mind, the present authors attempted to find out the window frequency lying between the two maxima occurring at 60 and 120 GHz which are eventually happened due to oxygen present in the atmosphere.

For this purpose, we have chosen eight places out of which four is from the northern latitude and the other four from southern latitude over the globe. The latitudinal occupancy is presented in Table 1. In doing so, it was kept in mind that Chongging, China and Porto Alegre, Brazil lies at same latitude, amongst which China is from northern latitude and Brazil is from southern latitude.

The radiosonde data over the above said places were made available to the authors by the British Atmospheric Data Centre (BADC), UK. It is to be noted that since the data from corresponding meteorological stations were not available to the present authors, the liberty has been taken to use the surface data from BADC pertaining to the present study although BADC provides the vertical profiles of the atmospheric data.

For clarity, the absorption spectra up to 200 GHz over Srinagar, has been presented in Fig. 1, using the updated Millimeter Wave Propagation Model (MPM) as described by Liebe (1985). In fact, from 1990 onwards, ITU-R has adopted the MPM model in somewhat truncated form to describe the absorption behavior of millimeter wave propagation in which the surface values of atmospheric parameters like temperature, pressure and humidity were used as input parameters to determine the specific attenuation profile in the millimeter wave band.

Table 1
Latitudinal occupancy of eight places.

Place	Country	Latitude (°)
Kolkata	India	22.65 N
Chongging	China	29.0 N
Srinagar	India	34.0 N
Aldan	Russia	58.0 N
Lima Callao	Peru	12.0 S
Porto Alegre	Brazil	29.0 S
Paraparaumu	New Zealand	40.0 S
Comodoro Rivadavia	Argentina	45.0 S

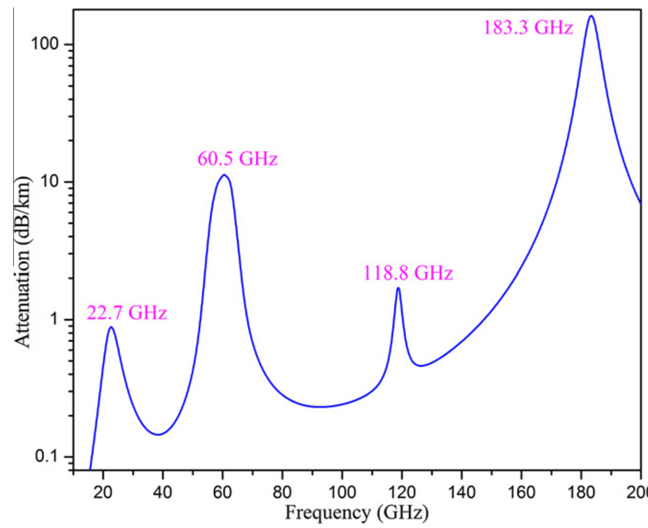

Fig. 1. Variation of specific attenuation with frequency at a height of 1585 m, pressure 846 mb, temperature 280.5 K, dew point temperature 271.5 K at Srinagar for the date 01-02-2005.

2. Analyses and results

Radiosonde data, available from BADC (UK) is consisting of vertical profiles of temperature t (h) in degree centigrade, pressure P (mb), and dew point temperature (t_d) in degree centigrade over the places of choice. Using these data for the year 2005 we have computed the water vapor pressure e (mb) and saturation water vapor pressure e_s (mb) using the following relations, respectively (Buck, 1981):

$$e(\text{mb}) = 6.105\exp\{25.22[1 - 273/T_d] - 5.31\log_e[T_d/273]\} \quad (1)$$

$$e_s(\text{mb}) = 6.1121\exp\{(17.502t)/(t + 240.97)\} \quad (2)$$

Here, T_d is the dew point temperature in Kelvin and t is ambient temperature in degree centigrade.

Water vapor pressure, e and water vapor density, ρ (g/m^3) are related by the relation

$$\rho = 217e/T\ (\text{K}) \quad (3)$$

The relative humidity, RH (%) is given by the relation

$$\text{RH} = (e/e_s) \times 100 \quad (4)$$

Now using an updated millimeter wave propagation model as prescribed by Liebe (1985) and pressure, temperature, and dew point temperature as the input data, the total attenuation i.e., water vapor attenuation plus oxygen attenuation in dB/km were calculated. It is to be noted here