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Attenuation of Signal at a Tropical Location with Radiosonde Data Due to Cloud

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Abstract

Cloud attenuation is calculated from cloud liquid water content (LWC). Cloud liquid water content (LWC) is derived from the radiosonde data using the Salonen model, show a prominent linear variation with the attenuation contribution due to cloud at a tropical location. In this paper, the attenuation contribution due to cloud liquid water content (LWC) and attenuation contribution due to cloud ice water content is studied at different frequencies in the tropical region. Cloud liquid water content shows a greater contribution compared to Cloud ice water content in causing attenuation of signal due to cloud in troposphere.

Keywords: *We would like to encourage you to list your keywords in this section*

1. Introduction

Cloud attenuation contribution is important to decide on the fade margin for low availability and low elevation satellite communication systems. Experimental measurements of cloud attenuation over earth-space path are comparatively much less available than rain attenuation measurements, particularly in the tropical region. Also, determination of cloud attenuation from propagation measurements is not always easy, especially at Ku/Ka-bands where most of the satellites are presently operating. The other way of determining the cloud attenuation is to use the data of cloud liquid water content, more abundantly available with a number of techniques. However, to accurately determine the cloud attenuation, the profiles of liquid water density and temperature within the cloud are required. The profile of liquid water density is not easily measurable information. Usually, the total liquid water content (LWC) or a reduced liquid water content [1] is used to obtain the cloud attenuation.

Radiosonde data can indicate the presence of cloud liquid water depending on whether relative humidity exceeds the critical humidity as defined by Geleyn [2]. The phase of water within the cloud is determined by the temperature. (If the temperature is greater than 0° C, the water is completely in the liquid phase, and if temperature is less than -20° C only ice exists. The temperature in between 0° C and -20° C yields a mixture of liquid water and ice.) Salonen [3] proposed a model for cloud water density in terms of temperature and height from cloud base that can be used to obtain the liquid water density profile within cloud. There

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can be a significant variation of water density within the cloud. The pure ice does not cause any attenuation of radio signal, but supercooled water can cause very significant attenuation.

Also, In the tropical region, the data on cloud liquid water and cloud attenuation are quite inadequate, particularly in view strong seasonal dependence associated with the monsoon. In the present paper, LWC has been obtained from radiosonde measurements at a tropical location to indicate its behaviour in relation to the ITU-R model [4]. Cloud attenuations derived by considering the profiles of liquid water density and temperature have been studied which are useful for designing futuristic satellite communication systems at frequencies greater than 20 GHz in the tropical region.

2. Theoretical Background

According to the Salonen model [3], the water density within the cloud, which is detected when the relative humidity exceeds the critical humidity, is given as a function of temperature (t) and height (h) of the layer by the expression:

$$w(t, h) = w_o \{(h-h_b)/h_r\}^a (1+c.t) \qquad t \geq 0^0 \text{ C}$$
$$= w_o \{(h-h_b)/h_r\}^a \exp(ct) \qquad t < 0^0 \text{ C} \quad \dots\dots\dots\dots (1)$$

where, w_o =0.17 g/m^3 , c = 0.04 per ^{0} C, h_r = 1500 m, h_b =cloud base height in m, a(=1.0) is the parameter for height dependence. The cloud water is completely in liquid phase when temperature, t, is greater than 0^0 C and in completely solid phase when $t < -20^0$ C. The fraction of liquid water, $p_w(t)$ that exists when $-20^0 \text{ C} < t < 0^0\text{C}$ is given by

$$p_w(t) = 1 + t/20, \qquad -20^0 \text{ C} < t < 0^0\text{C} \quad \dots\dots\dots\dots (2)$$

The specific attenuation due to cloud can be expressed in terms of the frequency, f, and the complex dielectric permittivity, ε , as [4]

$$\gamma_c(h) = \frac{0.819 f_w(h).10^3}{\varepsilon''(1+\eta^2)} \quad \dots\dots\dots\dots (3)$$

where, $\varepsilon = \varepsilon \; + \varepsilon''$,

The constant ε is given by

$$\eta = \frac{2+\varepsilon'}{\varepsilon''} \quad \dots\dots\dots\dots (4)$$

The complex permittivity, ε , can be obtained using a double-Debye model which is a function of frequency and temperature [5].

Hence, the specific attenuation, $\gamma_c(h)$, being a function of temperature and liquid water density, varies within the cloud yielding a height profile. The total cloud attenuation can, therefore, be obtained by integrating $\gamma_c(h)$ along the earth-space path within the cloud from the heights of the base to the top of the cloud layer

3. Data

Radiosonde measurements obtained twice a day by the Indian Meteorological Department at Kolkata, India (22°34' N, 88°29' E), a tropical location, during the period January to December 2005, have been used in the present letter. Cloud attenuations over an earth-space path at Kolkata with an elevation 63^0, a typical value for geostationary satellites (~95^0 E) at this location[2], have been determined from the radiosonde data.

4. Result

Figure 1 to Figure 10 gives the variation of cloud attenuation vs. cloud liquid water content at different frequency.

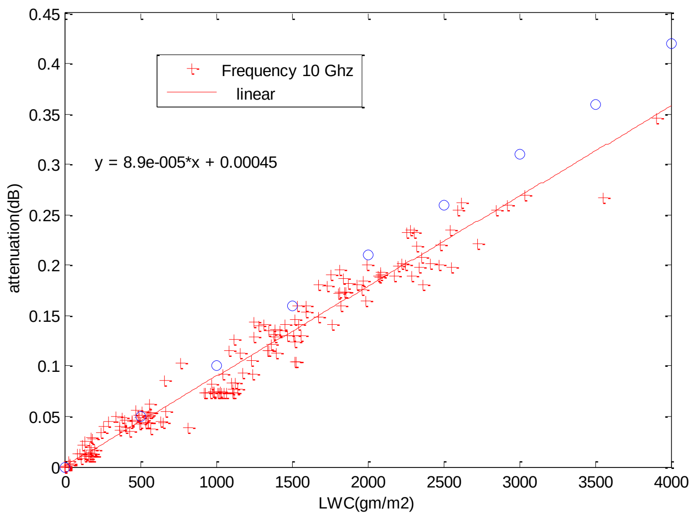

Figure 1. Cloud Attenuation vs. Cloud Liquid Water Content at 10 GHz at Kolkata

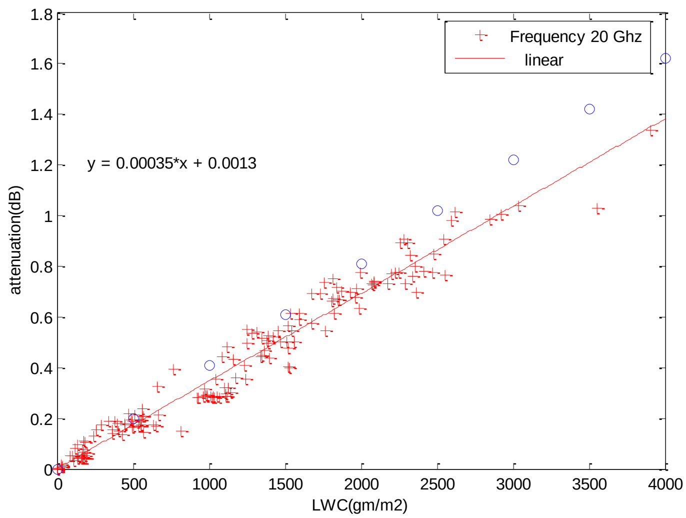

Figure 2. Cloud Attenuation vs. Cloud Liquid Water Content at 20 GHz at Kolkata

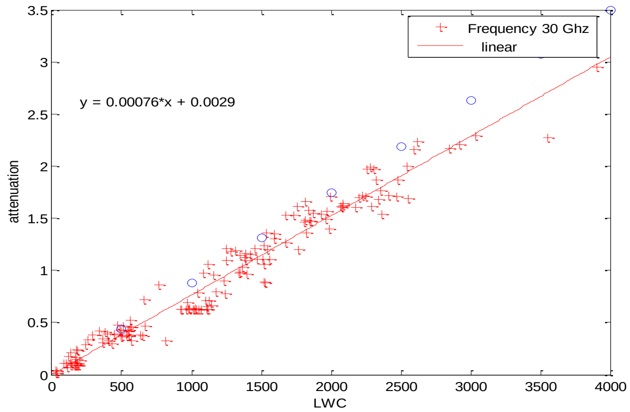

Figure 3. Cloud Attenuation vs. Cloud Liquid Water Content at 30 GHz at Kolkata

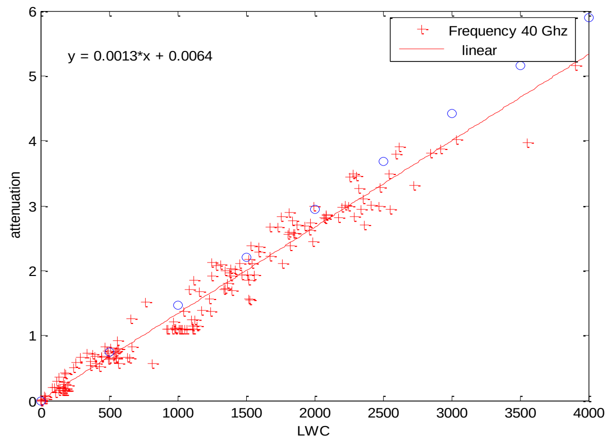

Figure 4. Cloud attenuation vs. Cloud Liquid Water Content at 40 GHz at Kolkata

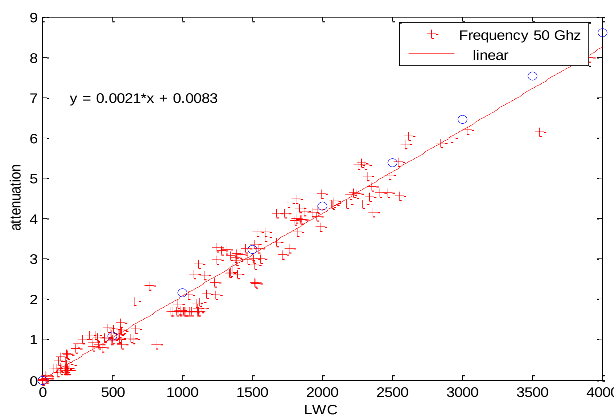

Figure 5. Cloud attenuation vs. Cloud Liquid Water Content at 50 GHz at Kolkata

The entire figure suggests a linear relation exists between cloud attenuation and cloud liquid water content. Above zero degree isotherm cloud contribution to attenuation is mainly due to cloud liquid water content.

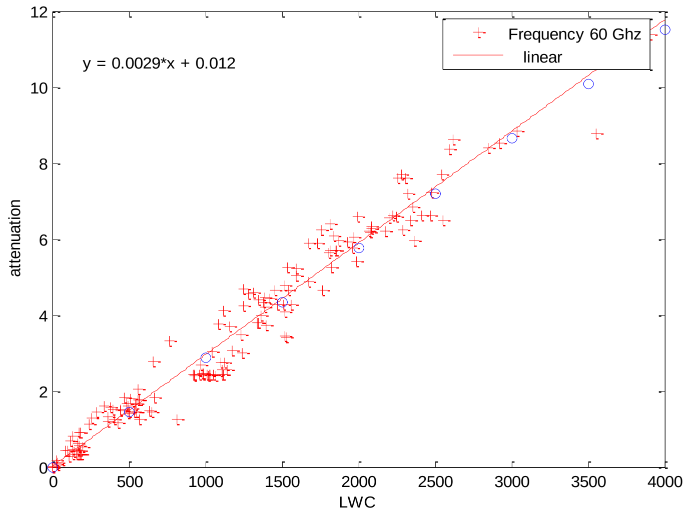

Figure 6. Cloud Attenuation vs. Cloud Liquid Water Content at 60 GHz at Kolkata

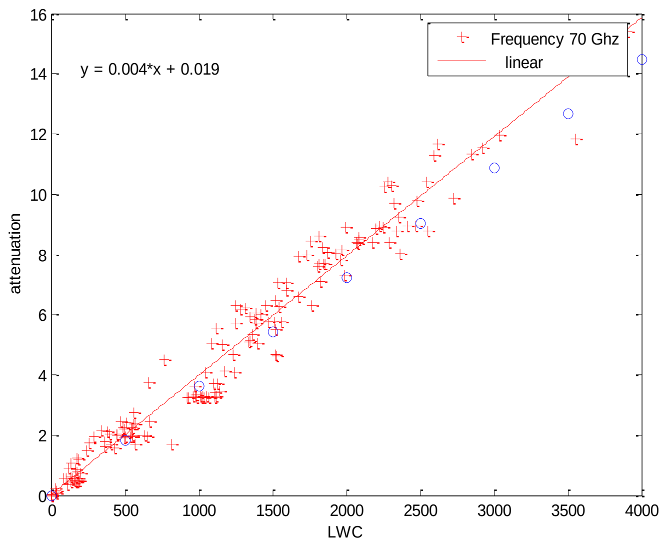

Figure 7. Cloud Attenuation vs. Cloud Liquid Water Content at 70 GHz at Kolkata

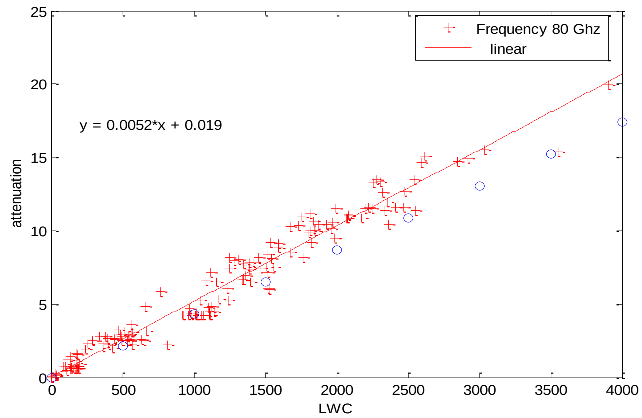

Figure 8. Cloud Attenuation vs. Cloud Liquid Water Content at 80 GHz at Kolkata

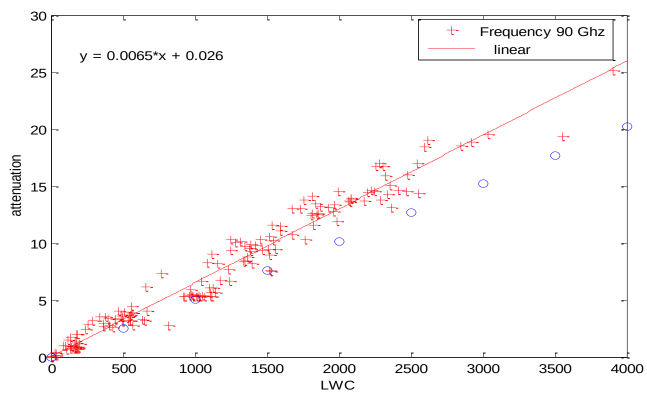

Figure 9. Cloud Attenuation vs. Cloud Liquid Water Content at 90 GHz at Kolkata

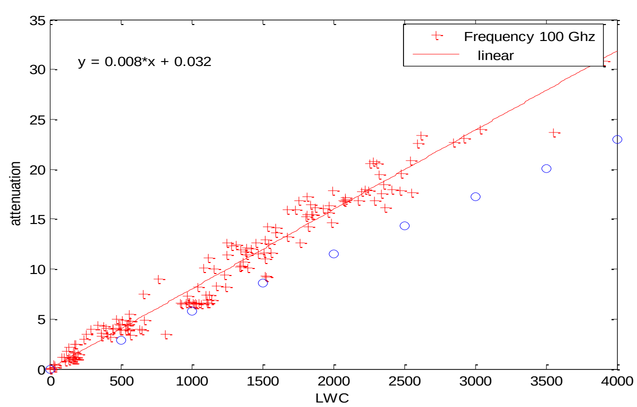

Figure 10. Cloud Attenuation vs. Cloud Liquid Water Content at 100 GHz at Kolkata

To study the effect of cloud liquid water content above zero degree isotherm cloud attenuation is plotted in Figure 11 for all the days of the year 2005. Below zero degree isotherm the contribution to cloud attenuation is mainly due to cloud ice water content. A study also been done for all the days of the year 2005 below zero degree isotherm.

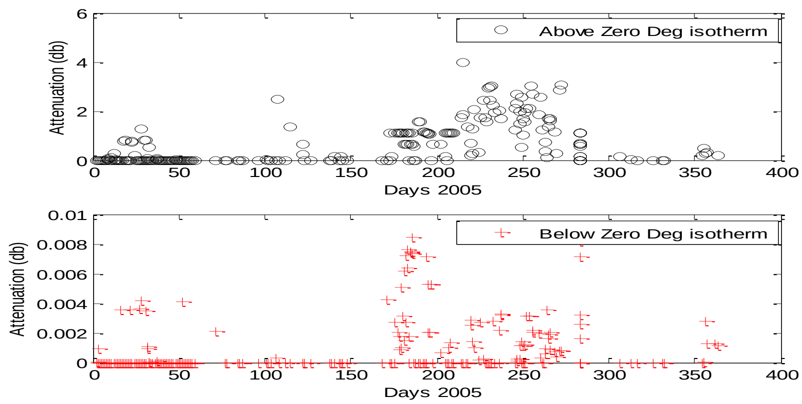

Figure 11. Cloud Attenuation Profile through the Year at a Particular Frequency at Kolkata below and above Zero Degree isotherm

The contribution to cloud liquid water content is found much higher than the contribution due to cloud ice water content. From the profile of cloud attenuation throughout the year it is seen that attenuation contribution both from cloud liquid water content and cloud ice water content is maximum at monsoon period.

5. Conclusion

Cloud attenuation due to cloud liquid water contents has been obtained from the radiosonde measurements using the Salonen model at a tropical location. The linear relationship is obtained between LWC and attenuation over the frequency range 10 to 100 GHz gives an estimate of Cloud contribution to signal attenuation if cloud liquid water content is known. Again attenuation contribution due to cloud ice water content is compared against attenuation contribution of cloud due to cloud liquid water content. Once again it is established that total contribution of cloud towards attenuation is mainly due to cloud liquid water content. So cloud liquid water content can be an estimator of attenuation due to cloud.

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