*J. Appl. Environ. Biol. Sci.*, 7(10)71-77, 2017
© 2017, TextRoad Publication

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
*www.textroad.com*

# Impact of Cloud Attenuation on Ka-Band Satellite Links in Karachi, Pakistan

**Syed Nauman Ahmed[1], Aamir Zeb Shaikh[2], Shabbar Naqvi[3], Talat Altaf[4]**

[1]Assistant Manager, PTCL, Karachi. Pakistan
[2]Assistant Professor, Dept. of Telecommunications Engineering, NED University of Engineering & Technology, Karachi
[3]Associate Professor, Dept. of Computer Systems Engineering, Balochistan University of Engineering & Technology, Khuzdar, Pakistan.
[4]Professor, Dept. of Electrical Engineering, Sir Syed University of Engineering & Technology, Karachi. Pakistan.

*Received: May 2, 2017*
*Accepted: July 9, 2017*

**ABSTRACT**

Space communications is perceived as one of the major technologies to be incorporated for successful implementation of 5G communications. However, successful links can only be established through computation of link budget equation. These equations depend on accurate prediction of various attenuation and fading parameters. In this paper, cloud attenuation is computed for satellite links over Ka Band in Karachi. The attenuation is predicted through approximate ITU (International Telecommunication Union) model for cloud attenuation. The predicted results show a trend of lower frequency bands and higher elevation angle for preferred method of operation for the said links.
**KEYWORDS**: *Elevation angle, cloud attenuation, Liquid water content of cloud*

## I. INTRODUCTION

The bandwidth requirement is surging at an impulsive rate. The major reason behind this growth is the extensive use of multimedia applications by the users. The bandwidth utilization in 2010 surged more than five times in comparison to the estimates given by International Telecommunications Union (ITU) in 2005[1]. Besides, it is foreseen that the data requirements may further increase multiple times in coming decades [1]. The new evolving standard of wireless communications i.e. 5G standard promises to solve spectrum requirement issue by exploiting exciting technologies such as cognitive radio[2-5], pervasive networks[6], dynamic adhoc heterogeneous wireless networks[7], massive MIMO[8], mobile femtocell, visible light communication[9], green communications [10, 11] and satellite communications into terrestrial domain [12][13]. From these technologies, satellite communications into terrestrial services gives a vast new era into the space communications domain itself. This exciting era is supported by the award of license by Federal Communications Commission (FCC) for directly supporting 4G services [13]. Additionally, efforts put forth by NASA to provide worldwide Wi-Fi service through launching its own satellites for this purpose are also commendable[12]. Tele-density numbers of Pakistan are also one of the highest in the region with a plan to auction 4G license for US$300 million. This is in addition to the US$ 1.1 Billion earned in 2014 by the auction of 3G and 4G licenses. As the price of spectrum is surging, all the countries including Pakistan will look for exploiting other avenues. Space Communications operate on many bands including less than 10 GHz as well as greater than 10 GHz. These days, the focus of research is on greater than 10 GHz bands because those bands provide ample unused RF spectrum to exploit. Hence, Ka band communication is the band of interest for several applications. Exploiting these RF bands requires the accurate computation of link budgets. The link budget computations show that weather has strong negative impact on transmitted RF waves through parameters such as water vapor, oxygen, rain, fog, cloud, dust and scintillation. These parameters, present in air independently or in combination produce reasonable amount of attenuation into waveforms [14] that results in deterioration of data transmission. From this list of factors, rain attenuation[15] causes significant impact on transmission over the said band; however, clouds are present under more than 95% of time. Hence, accurate prediction of cloud attenuation is also a mandatory step towards successful utilization of RF spectrum bands. Hence, prediction of both rain attenuation [16-18] and cloud attenuation[19] is preliminary for operating over Ka bands. Additionally, models are presented that combine the impact of rain and cloud attenuation [18]. To overcome the deteriorating impact of weather conditions, fade mitigation techniques are employed. These techniques include frequency diversity, site diversity and orbital diversity[20].

Frequency diversity refers to the communication links operating on more than one communication frequency. That means in absence of good channel conditions for one communication (frequency) channel, the data may be routed through another frequency channel with better transmission quality. For example, the frequency diversity can be implemented through Ka/EHF and X/Ku bands. In this example, the former channel can serve as a primary channel of transmission and the later can serve as a backup channel. Thus, under bad channel conditions, the data can be transmitted through backup channel to exploit diversity into the system. Thus, uninterrupted data can be transmitted through two frequency channels [20].

***Corresponding Author:** Aamir Zeb Shaikh, Assistant Professor, Dept. of Telecommunications Engineering, NED University of Engineering & Technology, Karachi, Ph. +92 21 99261261 Email:aamirzeb@neduet.edu.pk

Site diversity refers to the communication system with two earth stations connected to a single satellite. In this type of communication, the location of two separate earth stations depends on the fact that the effect of rain should be different at the two sites. This distance is typically kept as 10 to 15 km so the probability of rain occurring jointly on two sites becomes reasonably low [20, 21]. Hence, the given transmission may be considered as independent. In this case, the earth station with lower bad weather impact will be considered as good and could be selected for communication purpose.
Orbit diversity or Satellite diversity refers to the communication link having an alternate satellite for communication purpose [22]. Thus, the ground station has two paths with satellites. Thus, this technique provides an alternative of diversity. The results show that site diversity performs better than orbital diversity [20]. Thus, these mitigation techniques provide good means of uninterrupted communication under challenging wireless channels.
To measure the impact of cloud attenuation there are various models to incorporate. The initial efforts into this domain were put forward by Mie and Rayleigh, in terms of recommending the mathematical models. However, later the efforts were made to produce empirical models for the same. This was initiated by [23]. Then, several other models were recommended into literature [24]. DAH model segregates different cloud types based on their properties, these include water content, horizontal and vertical extent and probability of occurrence [25]. This is valid for transmission carrier frequencies up to 35 GHz. A better and more accurate modeling technique can be performed through Salonen and Uppala work. This model is also known as Teknillinen KorkeaKoulu (TKK) model [26]. The model requires input data to predict the accurate cloud attenuation results. This model is a global model that can predict the attenuation regardless of the geographical location of use and uses liquid water content (LWC) to predict the same. Additional parameters required are input vertical profiles of pressure, relative humidity and temperature. Another, approximate model is also presented by ITU R i.e. ITU-R 840.3 (rev. 1999) and ITU-R 840.4(rev. 2009) to compute the cloud attenuation for communication links operating over 10 GHZ band. The specific attenuation is calculated in accordance with the SU model, additionally, LWC is also required as an input to compute cloud attenuation for a communication link. This model is used in this paper to predict cloud attenuation for Karachi city.
In this paper, cloud attenuation is computed for Satellite-Earth links for Ka band in Karachi, Pakistan. These estimations will be highly useful to design accurate and reliable satellite communication links over these highly useful frequency bands. Additionally, this will help to incorporate space links in future 5G based standard and services in Pakistan.

This paper is organized in following sections: Computation of cloud attenuation for Karachi is presented in Section II. The simulation and numerical results are discussed in section III. The paper concludes in Section IV.

## II. Cloud Attenuation On Ka-Band Satellite Links In Karachi

In this section, cloud attenuation is computed using ITU-R method presented in[27]. Computation requires following parameters[28]:

f: Carrier Frequency (GHz)
θ: Angle of Elevation (°)
T: Temperature (Surface) (K)
L: Total columnar liquid water content (kg/m2)

Inverse temperature constant is determined using equation (1). This parameter is required for computing the final value of cloud attenuation.

$$\phi = \frac{300}{T} \qquad (1)$$

In equation (1), T is the surface temperature in K, which is assumed to be 273.15 K for cloud attenuation as in [28]

*Step 1:* Relaxation frequencies are calculated in GHz using equation (2) and (3) as presented in [28]. The principal relaxation, $f_p$, using Double-Debye model[29]for the dielectric permittivity (DP) of water can be calculated as:

$$f_P = 20.09 - 142(\phi - 1) + 294(\phi - 1) \qquad (2)$$

The secondary relaxation frequency, $f_s$, for the Double-Debye model for the DP of water can be calculated as:

$$f_s = 590 - 1500(\phi - 1) \qquad (3)$$

- Part of this paper is submitted towards ISP at TC, NED University, Khi.

*Step 2:* Complex dielectric permittivity is computed using equation (4) and (5) as presented in [28]. The real component of the complex DP of water is determined by:

$$\eta = \frac{2+\varepsilon'}{\varepsilon''} \tag{4}$$

The imaginary component of the complex DP of water is determined by:

$$\varepsilon'(f) = \frac{(\varepsilon_0 - \varepsilon_1)}{\left[1+\left(\frac{f}{f_p}\right)^2\right]} + \frac{(\varepsilon_1 - \varepsilon_2)}{\left[1+\left(\frac{f}{f_s}\right)^2\right]} + \varepsilon_2 \tag{5}$$

In equations (4) and (5), $\varepsilon_o$ can be determined by using equation (6)

$$\varepsilon_0 = 77.6 + 103.3(\phi - 1) \tag{6}$$

Whereas, $\varepsilon_1$ and $\varepsilon_2$ have the following values:

$$\varepsilon_1 = 5.48$$
$$\varepsilon_2 = 3.51$$

*Step 3*: Calculate the Specific Attenuation Coefficient using equation (7) [28]

$$K_1 = \frac{0.819 f}{\varepsilon''\left(1+\eta^2\right)} \tag{7}$$

In above equation, $\eta$ can be determined by using equation (8) $\eta = \frac{2+\varepsilon'}{\varepsilon''}$ (8)

The specific attenuation coefficient gives the attenuation offered at a specific point at a certain frequency and water vapors concentration[28].

*Step 4*: columnar liquid water content of the cloud, L, in kg/m$^2$ is required to further the computation. It is a statistical value. ITU-R provides global maps (that give the approximate numbers) for the geographical locations, where the accurate values are not available. The value of total columnar liquid water content of cloud for Karachi, Pakistan was not available statistically hence the approximated value is derived from global map provided by ITU-R[27] for exceedance of 1% of the year is used.

*Step 5:* Calculate the total Cloud Attenuation using equation (9) as in [27, 28]

$$A_c = \frac{LK_1}{\sin\theta} \tag{9}$$

## III. Simulation And Results

In this section, simulation results are presented on the basis of the formulas provided in preceding section.

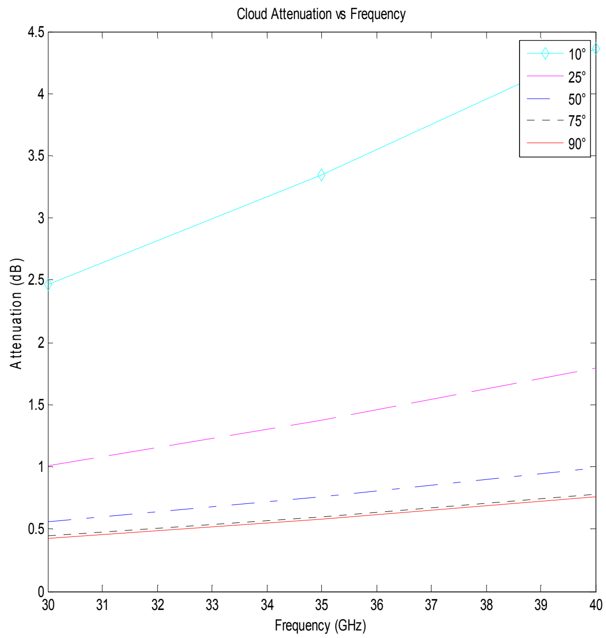


Figure 1 depicts the impact of frequency on the magnitude of cloud attenuation. In this simulation, it is assumed that the impact of the water in the cloud on the depolarization of transmitted electromagnetic wave (EM) is negligible. Hence, the statistical distribution of the transmitted EM wave is complete when received.

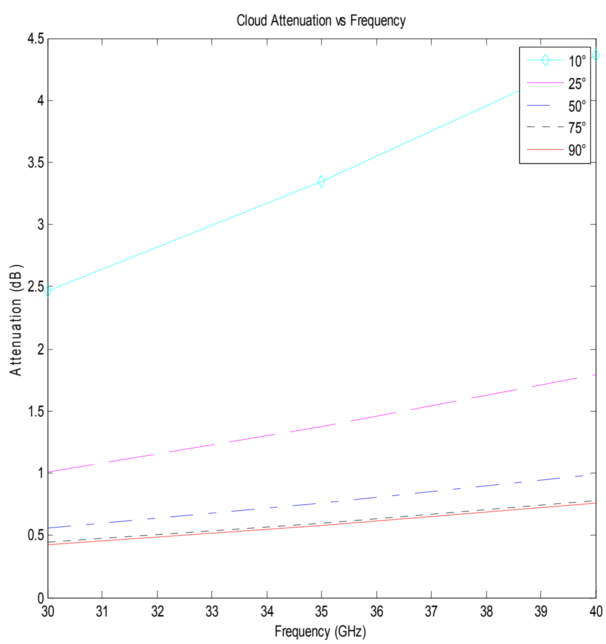


**Figure 1: Impact of frequency on Cloud attenuation**

The results show that the increase in frequency causes the cloud attenuation to be increased. The simulation is done on five different elevation angles and it is observed that for any elevation angle the cloud attenuation is directly proportional to the operating frequency. This spectrum encompasses Ka-band only. The figure illustrates comparatively low attenuation values in dB for high elevation angle. Similarly, **Table 1** presents the computation of attenuation in dB scale for different transmission parameters.

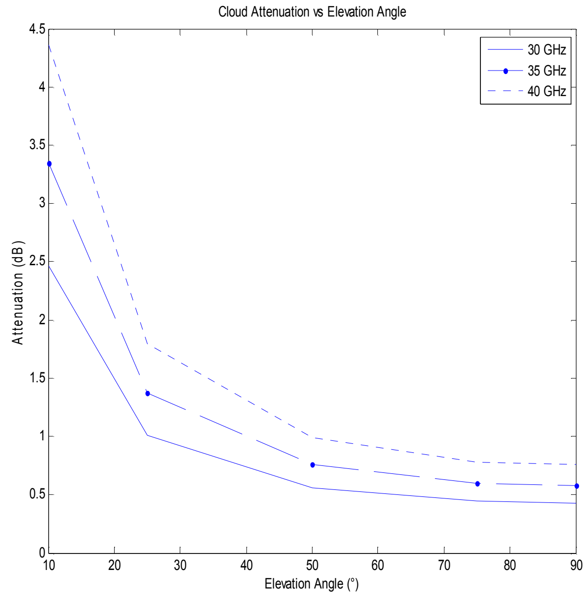


**Figure 2: Relation between Elevation angle and Cloud Attenuation**

The observation of the **Figure 2**suggests the preference of higher elevation angles. The simulation is done on three different frequencies from the Ka-Band. For elevation angle as low as $10^0$, the cloud attenuation is maximum, whereas, for elevation angle as high as $90^0$, the cloud attenuation can be seen as low as around just 0.5 dB. The graph depicts the model of exponential function for all the three frequencies considered.

**Table 1: Cloud Attenuation Measurements for Karachi**

| Frequency (GHz) | Elevation Angle (°) | Attenuation (dB) |
|---|---|---|
| 30 | 10 | 2.46537562 |
| | 25 | 1.012989789 |
| | 50 | 0.558855283 |
| | 75 | 0.443209998 |
| | 90 | 0.428107984 |
| 35 | 10 | 3.348677902 |
| | 25 | 1.375926854 |
| | 50 | 0.759083654 |
| | 75 | 0.602004626 |
| | 90 | 0.581491815 |
| 40 | 10 | 4.363353058 |
| | 25 | 1.792843272 |
| | 50 | 0.989091839 |
| | 75 | 0.784416657 |
| | 90 | 0.757688307 |

## IV. CONCLUSION

In this paper, the magnitude component of cloud attenuation for Karachi is calculated. The results propose to establish satellite-earth links with higher elevation angle and low operating frequency to limit attenuation losses offered by the atmospheric channel due to clouds. The results will be useful for future based satellite communications in Ka-Band for Karachi, Pakistan. The authors could not find the similar results in literature for Karachi, Pakistan. The results can also be used to design counter measures such as site diversity to establish an improved and reliable communications even in the presence of clouds.

## ACKNOWLEDGMENT

The authors are highly thankful to the NED University of Engineering & Technology that provided all the useful resources that were necessary for the successful completion of this paper.

## V. REFERENCES

[1] X. Hong, *et al.*, "Cognitive radio in 5G: a perspective on energy-spectral efficiency trade-off," *IEEE Communications Magazine,* vol. 52, pp. 46-53, 2014.

[2] A. Z. Shaikh and T. Altaf, "Collaborative Spectrum Sensing under Suburban Environments," *International Journal of Advanced Computer Science & Applications,* vol. 4, 2013.

[3] A. A. Khan, *et al.*, "Implementation of Cooperative Spectrum Sensing Algorithm using Raspberry Pi," *INTERNATIONAL JOURNAL OF ADVANCED COMPUTER SCIENCE AND APPLICATIONS,* vol. 7, pp. 363-367, 2016.

[4] S. Haykin, "Cognitive radio: brain-empowered wireless communications," *IEEE Journal on Selected Areas in Communications,* vol. 23, pp. 201-220, 2005.

[5] C. Cordeiro, *et al.*, "IEEE 802.22: the first worldwide wireless standard based on cognitive radios," in *New Frontiers in Dynamic Spectrum Access Networks, 2005. DySPAN 2005. 2005 First IEEE International Symposium on*, 2005, pp. 328-337.

[6] D. Estrin, *et al.*, "Connecting the physical world with pervasive networks," *IEEE pervasive computing,* vol. 1, pp. 59-69, 2002.

[7] T. Qiu, *et al.*, "Heterogeneous ad hoc networks: Architectures, advances and challenges," *Ad Hoc Networks,* vol. 55, pp. 143-152, 2017.

[8] E. Björnson, *et al.*, "Massive MIMO: Ten myths and one critical question," *IEEE Communications Magazine,* vol. 54, pp. 114-123, 2016.

[9] A. V. Jalajakumari, *et al.*, "High-speed integrated digital to light converter for short range visible light communication," *IEEE Photonics Technology Letters,* vol. 29, pp. 118-121, 2017.

[10] C.-X. Wang, *et al.*, "Cellular architecture and key technologies for 5G wireless communication networks," *IEEE Communications Magazine,* vol. 52, pp. 122-130, 2014.

[11] V. W. Wong, *et al.*, *Key Technologies for 5G Wireless Systems*: Cambridge university press, 2017.

[12] M. Jia, *et al.*, "Broadband Hybrid Satellite-Terrestrial Communication Systems Based on Cognitive Radio toward 5G," *IEEE Wireless Communications,* vol. 23, pp. 96-106, 2016.

[13] A. Ansari, *et al.*, "S-WiMAX: adaptation of IEEE 802.16 e for mobile satellite services," *IEEE Communications Magazine,* vol. 47, 2009.

[14] Y. Gataullin and R. Kozlowski, "Implementation of rain and gaseous attenuation models for 26-30 GHz Ka-Band Communication," 2009.

[15] A. Z. S. Engr. Syed Nauman Ahmed, Shabbar Naqvi, Talat Altaf, "Impact of Rain Attenuation for Satellite Links at C, Ku, K, Ka and mm Bands in Karachi," *J. Appl. Environ. Biol. Sci. 2017 7(7): 119-125*.

[16] S. Shrestha and D.-Y. Choi, "Study of rain attenuation in Ka band for satellite communication in South Korea," *Journal of Atmospheric and Solar-Terrestrial Physics,* vol. 148, pp. 53-63, 2016.

[17] S. Shrestha*, et al.*, "Rain Specific Attenuation and Frequency Scaling approach in Slant-Path for Ku and Ka-Band Experiments in South Korea," *대한전자공학회 학술대회,* pp. 625-628, 2017.

[18] L. D. Emiliani and L. Luini, "A Combined Rain and Cloud Attenuation Field Simulator and its Application to Gateway Diversity Analysis at Ka, Q and V bands," in *34th AIAA International Communications Satellite Systems Conference*, 2016, p. 5742.

[19] R. K. Crane, *Propagation handbook for wireless communication system design*: CRC press, 2003.

[20] T. A. Alawadi, "Investigation of the effects of cloud attenuation on satellite communication systems," 2012.

[21] A. Savvaris, "Accurate prediction of scintillation degredation applicable to satellite communications systems design," University of Glamorgan, 2004.

[22] Y. Karasawa*, et al.*, "Analysis of availability improvement in LMSS by means of satellite diversity based on three-state propagation channel model," *IEEE Transactions on Vehicular Technology,* vol. 46, pp. 1047-1056, 1997.

[23] K. L. S. Gunn and T. W. R. East, "The microwave properties of precipitation particles," *Quarterly Journal of the Royal Meteorological Society,* vol. 80, pp. 522-545, 1954.

[24] L. Luini and C. Capsoni, "Efficient calculation of cloud attenuation for earth–space applications," *IEEE Antennas and Wireless Propagation Letters,* vol. 13, pp. 1136-1139, 2014.

[25] A. Dissanayake*, et al.*, "Cloud attenuation modelling for SHF and EHF applications," *International journal of satellite communications,* vol. 19, pp. 335-345, 2001.

[26] E. Salonen and S. Uppala, "New prediction method of cloud attenuation," *Electronics Letters,* vol. 27, pp. 1106-1108, 1991.

[27] ""Recommendation ITU-R P.840-3"," 1992-1994-1997-1999.

[28] L. J. Ippolito Jr, *Satellite communications systems engineering: atmospheric effects, satellite link design and system performance* vol. 6: John Wiley & Sons, 2008.

[29] H. J. Liebe*, et al.*, "A model for the complex permittivity of water at frequencies below 1 THz," *International Journal of Infrared and Millimeter Waves,* vol. 12, pp. 659-675, 1991.