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Prediction of Cloud attenuation for 6B Arabsat Satellite Link at Ku, Ka, and V Bands over Libya Based on ITU-R P.840-5 Model

Nafaa M. Shebani[#1], *Abdalnaser F. kaeib*[*2], Amer R. Razek[*3]

[#]*Electrical & Electronic Eng. Department, Sabratha University*
Sabratha, Libya

[1]nafah@yahoo.com

[*] *Electrical & Electronic Eng. Department, Zawia University*
Zawia, Libya

[2]naser.kaeib@gmail.com

[3]anas_az94@yahoo.co.uk

Abstract— **In this paper, the cloud attenuation is computed in three sites in Libya for 6B Arabsat satellite link. ITU-R** P.840-5 **model is used to estimate the cloud attenuation at Ku (12 to 18 GHz) and Ka (24 to 40 GHz) bands based on the variation of the operating frequency with changing the columnar liquid water content of the cloud that are 0.2 kg/m^2 and 0.4 kg/m^2, also based on the visible range of geostationary satellites for each site, the cloud attenuation and elevation angle are computed. And to evaluate the earth-space link performance at V band (40-75 GHz), the cloud attenuation is estimated at V band uplink and downlink frequencies with variation of the longitude of geostationary satellites, and the surface temperature.**

***Keywords*— ITU-R P.840-5, cloud attenuation, satellite link, liquid water content, Ku, Ka, and V bands**

I. Introduction

Propagation impairments produced by the troposphere are a limiting factor for the effective use of the frequency bands above about 10 GHz for satellite communication applications. In general, propagation impairments of the troposphere increase in severity with the increase of frequency. The rapid growth of satellite services using frequency bands above10 GHz has highlighted a need for estimating propagation factors that are normally considered benign or negligible at the lower frequency bands [1].

Satellite communication is normally thought of as a robust means of communication, not sensitive to environmental impacts. This perception is not totally accurate. Satellite communication can be and is affected by the environment in which it operates. Space environmental effects on satellite communication can be separated into (1) effects on the space element (i.e. the satellite), (2) effects on the ground element (i.e. the Earth station), and (3) effects on the signals propagating through the Earth's lower and upper atmosphere. The propagating signal may be affected by its passage through the ionosphere (upper atmosphere) or the troposphere (lower atmosphere). These effects depend significantly on frequency, but include signal absorption, scintillation, Faraday rotation and bandwidth decoherence. Geographic location and signal propagation path can also determine the extent to which the signal is affected [2].

Accurate prediction of impairment statistics is very important for the design and deployment of satellite systems. Although raindrops have been found to be the most significant hydrometeors affecting radio wave propagation for frequency above 10 GHz, the influence of clouds and fog are very important on earth-space paths links at Ku, Ka, and V bands. But cloud attenuation, that may cause deep fades in these bands, is one of the components that need to be considered for low availability satellite links owing to its higher probability of occurrence [3].

To measure the impact of cloud attenuation there are various models to incorporate. Several models were recommended into literature [2]. DAH model segregates different cloud types based on their properties, these include water content, horizontal and vertical extent and probability of occurrence. This is valid for transmission carrier frequencies up to 35 GHz. A better and more accurate modelling technique can be performed through Salonen and Uppala work. This model is also known as Teknillinen KorkeaKoulu (TKK) model. 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 840.4 [4] 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 [5].

This paper aims to estimate the cloud attenuation based on ITU model for 6B Arabsat satellite link at Ka and Ku bands for several locations in Libya, the cloud attenuation is computed based on the variation of the operating frequency. Additionally, by changing the longitude of the satellite location, the cloud

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attenuation and the elevation angle are determined for earth station. Additionally, it determined at uplink and downlink frequencies in V band in visible range to geostationary satellite of each stations.

II. ITU-R P.840 MODULE

The ITU-R provides a model to calculate the attenuation along an earth-space path for both clouds and fog in Recommendation ITU-R P.840 . The model was originally adopted into Recommendation P.840 in 1992 and has been updated in 1994, 1997, and 2012. It is valid for liquid water only and is applicable for systems operating at up to 200 GHz. The input parameters required for the calculations are: f is Frequency in (GHz), θ *is* the elevation angle (degrees), T is a surface temperature in (K), and L is the columnar liquid water content (kg/m^2)

An intermediate parameter required for the calculation is the inverse temperature constant, ϕ determined from

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

Where T is the temperature in K.

For fog attenuation, T is equal to the ground temperature. The step-by-step procedure now follows [4]

Step 1: Calculate the relaxation frequencies:

Calculate the principal and secondary relaxation frequencies, fp andfs, in GHz, as the following

$$f_p = 20.09 - 142(\phi - 1) + 294(\phi - 1)^2 \quad (2)$$

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

Step 2: Complex dielectric permittivity:

Calculate the real and imaginary components of the complex dielectric permittivity of water from

$$\varepsilon''(f) = \frac{f\,(\varepsilon_0 - \varepsilon_1)}{f_p\left[1+\left(\frac{f}{f_p}\right)^2\right]} + \frac{f\,(\varepsilon_1 - \varepsilon_2)}{f_s\left[1+\left(\frac{f}{f_s}\right)^2\right]} \quad (4)$$

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

Where $\varepsilon_0 = 77.6 + 103.3(\phi - 1)$; $\varepsilon_1 = 5.48$, and $\varepsilon_2 = 3.51$.

Step 3: Specific attenuation coefficient:

Calculate the specific attenuation coefficient, K_l (dB/km)/(g/m3), from

$$K_l = \frac{0.819f}{\varepsilon''(1+\eta^2)} \quad (6)$$

Where $\eta = \frac{2+\varepsilon'}{\varepsilon''}$

K_l represents the 'point' attenuation at the specified frequency and water vapour concentration.

Step 4: Columnar liquid water content:

Determine the columnar liquid water content of the cloud, L, in (kg/m^2). In cases where the statistics of cloud liquid water content are not available for the location(s) of interest, the ITU-R contain global maps that provide contours of cloud liquid water content. Present contours of cloud liquid water content in kg/m^2 exceeded for 20 %, 10 %, 5 %, and 1% of an average year, respectively. For a location different from the grid points, obtain the total columnar content at the desired location by performing a bi-linear interpolation on the values at the four closest grid points, as described in Recommendation ITU-R P.1144 [6].

Step 5: Earth Station Parameters:

The elevation angle for the earth station, as shown in Fig. 1, is calculated by [7]

$$\theta = cos^{-1}(R+h)/D\sqrt{1-[cos^2(\alpha_{ES})cos^2(\theta_{SAT}-\theta_{ES})]} \quad (7)$$

Where θ is the angle of elevation, R and h are 35786 km and 6378.1 km and are the distances of the geosynchronous orbit and the radius of the Earth respectively. α_{ES} is the latitude of the earth station, θ_{SAT} is the longitude of the satellite, θ_{ES} is the longitude of the earth station, and D is calculated by:

$$D = \sqrt{h^2 - 2R(h+R)[1 - cos(\alpha_{ES})\,cos(\theta_{SAT}-\theta_{ES})]} \quad (8)$$

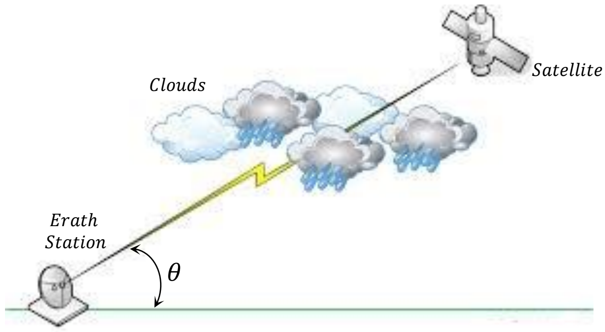

Fig. 1. Schematic presentation of an Earth–Space path

Step 6: Total attenuation:

The total cloud attenuation Ac (dB), is then found as :

$$A_c = \frac{L\,K_l}{\sin\theta} \quad (9)$$

Where $10^\circ \leq \theta \leq 90^\circ$; For elevation angles less than 10◦ the $(1/sin\ \theta)$ relationship cannot be employed, because this would assume a cloud of nearly infinite extent. Therefore, a physical limit to the path length should be imposed when performing calculations where the elevation angle approaches 0◦.

III. SIMULATION RESULTS

The cloud attenuation is estimated based on the ITU-R P.840-5 model at Ka, and Ku bands for 6B Arabsat satellite with several locations in Libya that named Tripoli, Shahat, and Zuwara. The earth stations parameters are listed in Table I. The cloud attenuation for these locations are computed based on the variation of the frequency at the surface temperature of 293 K, and for two values of the total columnar content of cloud liquid water, of 0.2 kg/m2 (for 5% unavailability of an average year), and 0.4 kg/m2 (for 1% unavailability of an average year).

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Furthermore, the cloud attenuation and the elevation angle are calculated based on the visible range of each station, which listed in Table I, to geostationary satellites.

TABLE I
LONGITUDE AND LATITUDE OF EARTH STATIONS IN LIBYA AND THE VISIBLE RANGE TO GEOSTATIONARY SATELLITES

Station	Coordinates of location		Visible Range	
	Longitude (E)	Latitude (N)	West (W)	East (E)
Tripoli	13.19°	32.88°	66.3°	92.7°
Shahat	21.58°	32.80°	65.7°	94.5°
Zuwara	12.08	32.93	67.5°	91.5°

A. *Cloud Attenuation for Tripoli Earth Station*

Figures 1, and 2 show the variation of the cloud attenuation versus the operating frequency at Ku, and Ka bands respectively for Tripoli Earth station.

From Fig. 1, it can be noted that the cloud attenuation is increased by 0.0407 dB, when the frequency change from 12 GHz to 18 GHz and the liquid water content is 0.4 kg/m2. Moreover, when the liquid water content change from 0.2 kg/m2 to 0.4 kg/m2 at 18 GHz, the cloud attenuation increased by 0.04553 dB. And From Fig. 2, it can be seen that at the liquid water content is 0.4 kg/m2, the cloud attenuation is 0.188 dB at 26 GHz and it is 0.0.4331 dB at 40 GHz. Also, when the liquid water content change from 0.2 kg/m2 to 0.4 kg/m2, the cloud attenuation increase by 0.2165 dB.

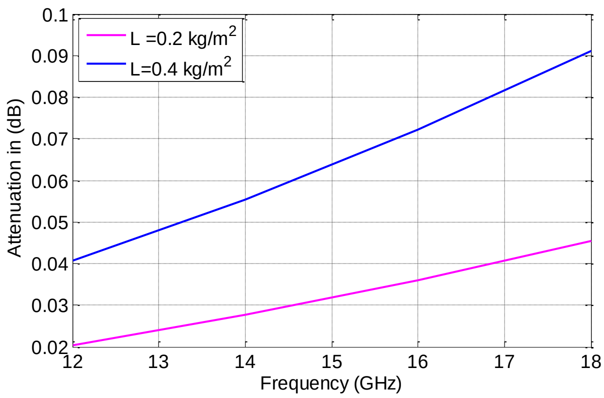

Fig. 1 Cloud attenuation vs. Frequency for Tripoli station at Ku band and T = 293 K

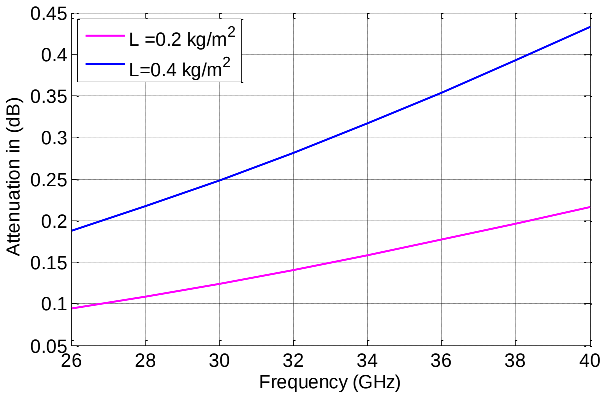

Fig. 2 Cloud attenuation vs. Frequency for Tripoli station at Ka band and T = 293 K

Fig. 3 shows the cloud attenuation and elevation angle for Tripoli earth station based on the variation of longitude of the satellite location. From the figure, it can be shown that the cloud attenuation is 0.540 dB, and the elevation angle is 23.29º for the satellite located at 65º longitude, and for the satellite that located at 80º longitude, the cloud attenuation is 1.144 dB, and the elevation angle is 10.77º.

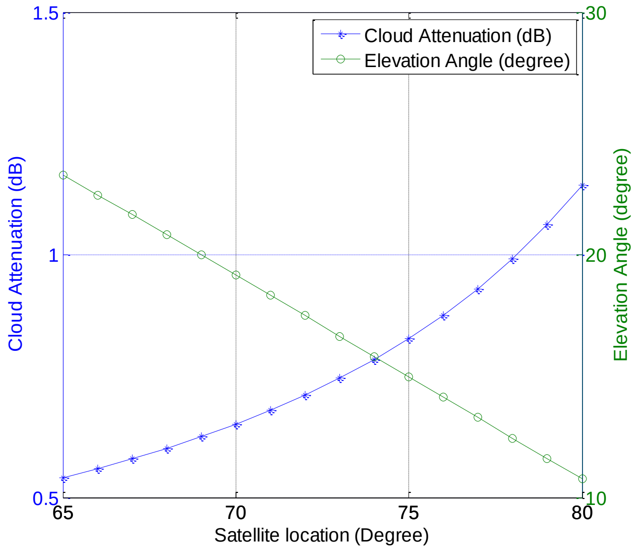

Fig. 3 Cloud attenuation, and Elevation Angle vs. longitude Satellite location for Tripoli station at f = 32 GHz, and T = 293 K.

B. *Cloud Attenuation for Shahat Earth Station*

The variation of the cloud attenuation versus the operating frequency at Ku band for Shahat Earth station is shown in Fig.4. From the figure, when the frequency change from 12 GHz to 18 GHz, it can be noted that the cloud attenuation is increased by 0.04878 dB and 0.02439 dB when the liquid water content is 0.4 kg/m2 and 0.2 kg/m2 respectively. Additionally, when the liquid water content is changed from 0.2 kg/m2 to 0.4 kg/m2 the cloud attenuation increased by 0.01971 dB and 0.0441 dB at the frequency of 12 GHz and 18 GHz, respectively.

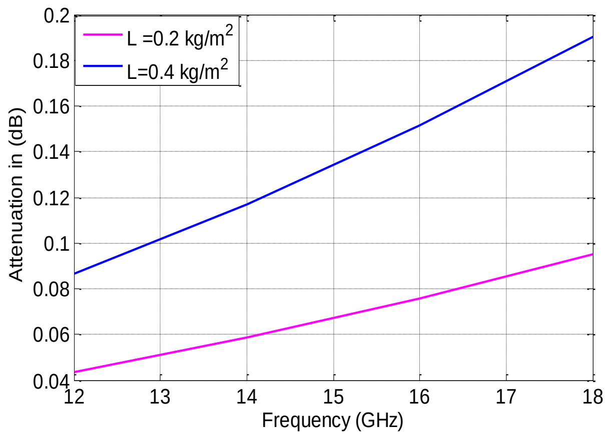

Fig. 4 Cloud attenuation vs. Frequency for Shahat station at Ku band and T = 293 K

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For Shahat Earth station, Fig. 5 shows the variation of the cloud attenuation versus the frequency at Ka band. From the figure, it can be seen that, at the liquid water content of 0.4 kg/m2, the cloud attenuation is 0.1821 dB at 26 GHz ant it is 0.4195 dB at 40 GHz; and the cloud attenuation is changed from 0.0.09103 dB to 0.2097 dB when the frequency changed from 26 GHz to 40 GHz, at the liquid water content of 0.2 kg/m2.

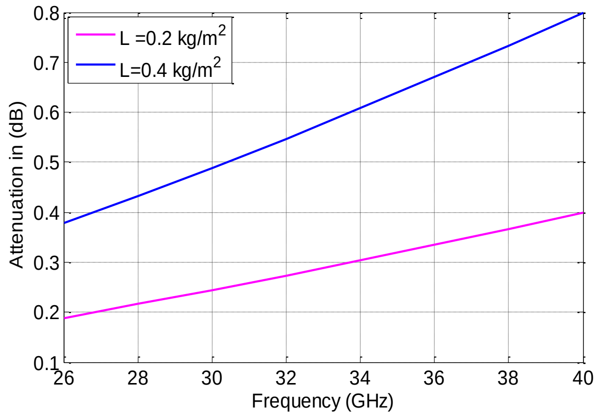

Fig. 5 Cloud attenuation vs. Frequency for Shahat station at Ka band and T = 293 K

Fig. 6 shows the cloud attenuation and elevation angle for Shahat earth station based on the variation of the longitude of satellite location. From the figure, it can be observed that for the satellite that located at 65º, the elevation angle 30.11º, and the cloud attenuation of 0.426 dB. And for the satellite that located at 80º, the cloud attenuation of 0.69773 dB, and the elevation angle of 17.84º.

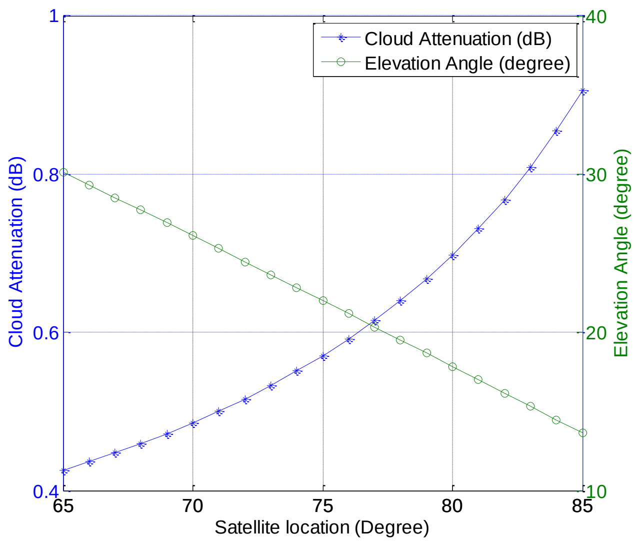

Fig. 6 Cloud attenuation, and Elevation Angle vs. longitude Satellite location for Shahat station at f = 32 GHz, and T = 293 K.

C. *Cloud Attenuation for Zwara Earth Station*

Figures 7, and 8 show the variation of the cloud attenuation versus the frequency at Ku, and Ka bands respectively for Zuwara Earth station.

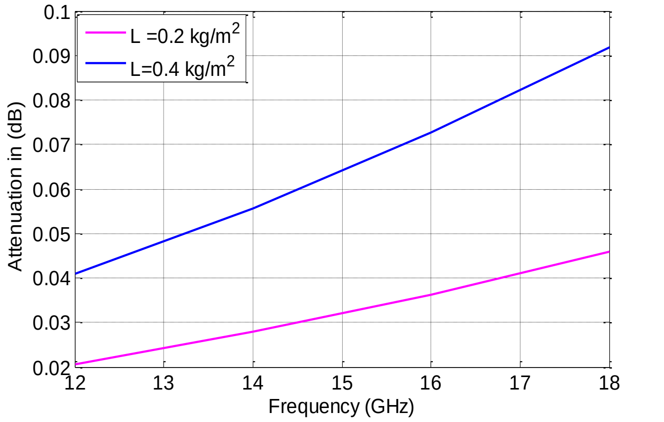

Fig. 7 Cloud attenuation vs. Frequency for Zwara earth station at Ku band and T = 293 K,

From Fig. 7, at Ku band (12/18 GHz), it is clear that the cloud attenuation is increased by 0.05002 dB and 0.02501 dB when the liquid water content is 0.4 kg/m2 and 0.2 kg/m2 respectively. Furthermore, when the liquid water content is changed from 0.2 kg/m2 to 0.4 kg/m2 the cloud attenuation increased by 0.02022 dB and 0.044523 dB at the frequency of 12 GHz and 18 GHz, respectively.

From Fig. 8, it can be shown that when the frequency changes from 26 GHz to 40 GHz, the cloud attenuation increased by 0.2469 dB and 0.12343 dB at the liquid water content of 0.4 kg/m2and 0.2 kg/m2. Also, it can be observed that, when the liquid water content is changed from 0.2 kg/m2 to 0.4 kg/m2, the cloud attenuation is increased by 0.09463 dB and 0.2181 dB at the operating frequencies is 26 GHz and 40 GHz respectively.

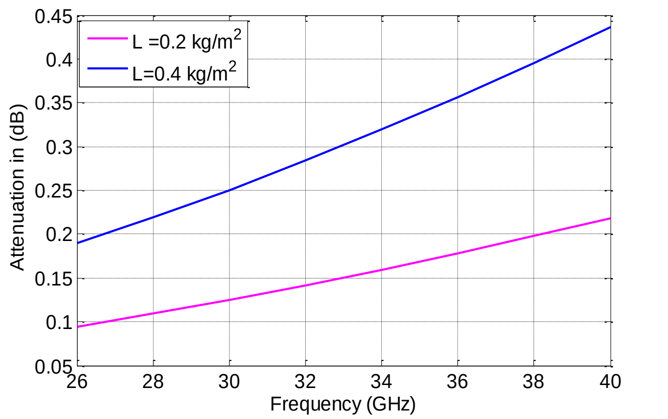

Fig. 8 Cloud attenuation vs. Frequency for Zwara station at Ka band and T = 293 K

Fig. 9 shows the cloud attenuation and elevation angle for Zuwara earth station based on the variation of the longitude of satellite location. From the figure, it can be noted that for the satellite that located at 65º, the elevation angle 22.36º, and the cloud attenuation is 0.562 dB. Additionally, for the satellite that located at 80º, the cloud attenuation of 1.253 dB, and the elevation angle is 9.82º.

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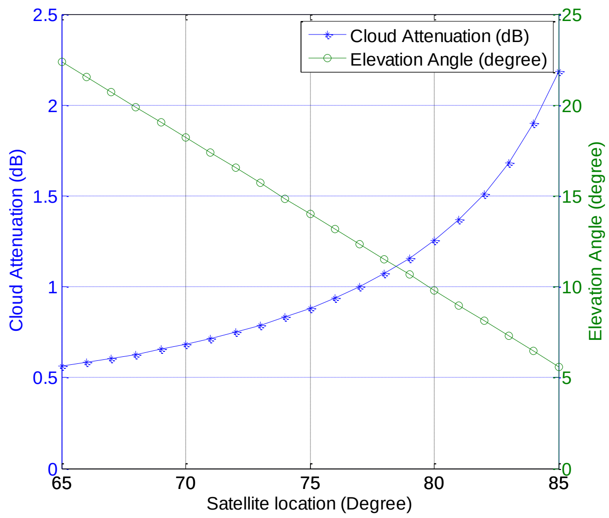

Fig. 9 Cloud attenuation, and Elevation Angle vs. longitude of Satellite location for Zuwara station at f = 32 GHz, and T = 293 K

D. Cloud Attenuation over Libya at V-Band (40 – 75 GHz)

At the surface Temperature T= 293 K, and total columnar content of cloud liquid water is 0.4 kg/m^2, the cloud attenuation is simulated at uplink frequency (50 GHz), and V band downlink frequency (40 GHz) for the three sites versus according the visible range to the longitude of geostationary satellites.

Figures 10, 11, and 12 show Cloud attenuation versus longitude of Satellite location for Tripoli, Zuwara, and Shahat earth stations respectively.

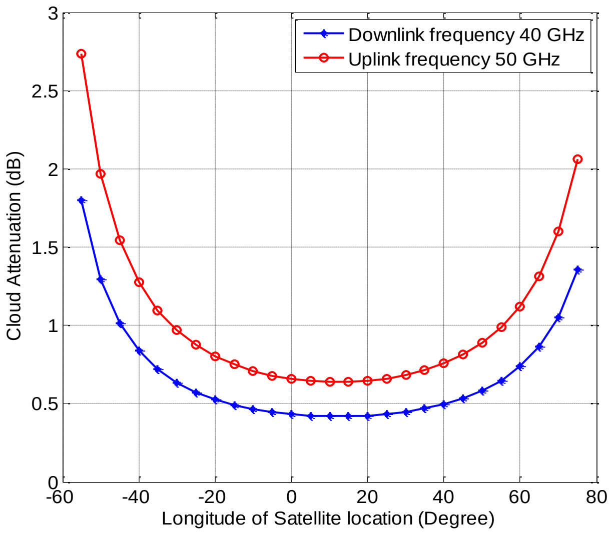

Fig. 10 Cloud attenuation versus longitude of Satellite location for Zuwara station at T = 293 K, and L = 0.4 kg/m^2

From Figure 10, in the visible range of the Tripoli earth station, it can be observed that at the V-band uplink frequency (50 GHz), the lowest value of cloud attenuation is 0.6371 dB with higher elevation angle of 51.70º for the GEO satellite located at the longitude of 12 E; and the highest values of cloud attenuation are 2.736 dB, and 2.702 dB at the GEO satellites located at the longitude of 55W and 79E respectively.

Based on the cloud attenuation for Tripoli earth station that illustrated in Figure 11 at the uplink frequency (50 GHz), it can be noted that within the visible range, the lowest value of cloud attenuation is 0.6367 dB with higher elevation angle of 51.75º for the GEO satellite located at 13 E; and the highest values of cloud attenuation are 2.758 dB, and 2.677 dB at the GEO satellites located at 54W and 80E respectively.

At the V-band uplink frequency (50 GHz), and according to the visible range of the Shahat earth station which shown in Figure 12, it can be seen that the lowest value of cloud attenuation is 0.6363 dB with higher elevation angle of 51.802º for the GEO satellite located at 22 E; and the highest values of cloud attenuation are 2.684 dB, and 2.744 dB at the GEO satellites located at the longitude of 45W and 89E respectively.

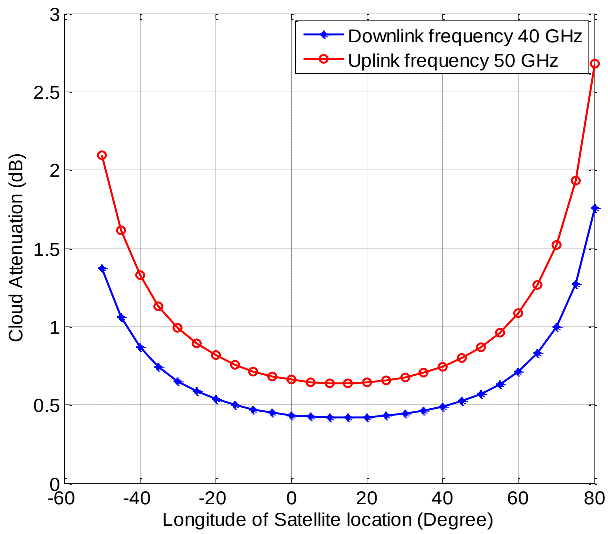

Fig. 11 Cloud attenuation versus longitude of Satellite location for Tripoli station at T = 293 K, and L = 0.4 kg/m^2

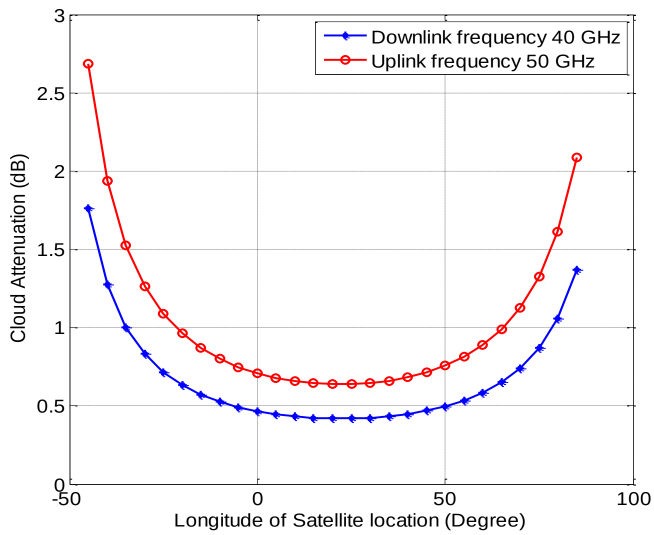

Fig. 12 Cloud attenuation versus longitude of Satellite location for Shahat station at T = 293 K, and L = 0.4 kg/m^2

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For 79E satellite link with the total columnar content of cloud liquid water is 0.4 kg/m^2; Tables II, and III show the variation of cloud attenuation with changing the surface temperature at V-band uplink frequency (50 GHz) and V-band downlink frequency (40GHz) respectively. From these Tables, it can be noted that, the cloud attenuation is increased by decreasing of the surface temperature.

With the reference surface temperature is 20 ºC. From Table III, it can be founded that the cloud attenuation is increased by 22.9%, 53.3%, and 80.1%, when the temperature is decreased by 10 ºC, 20 ºC, and 28 ºC respectively. And from Table III, it can be shown that the cloud attenuation is increased by 24.7%, 59.7%, and 94.8%, when the temperature is decreased by 10 ºC, 20 ºC, and 28 ºC respectively.

TABLE III
CLOUD ATTENUATION VERSUS SURFACE TEMPERATURE AT V-BAND UPLINK FREQUENCY (50 GHZ)

Surface Temperature	Cloud Attenuation (dB)		
	Zuwara	**Tripoli**	**Shahat**
20 ºC	2.703	2.485	1.562
10 ºC	3.323	3.056	1.92
0 ºC	4.144	3.810	2.394
-8 ºC	4.868	4.476	2.813

TABLE III
CLOUD ATTENUATION VERSUS SURFACE TEMPERATURE AT V-BAND DOWNLINK FREQUENCY (40 GHZ)

Surface Temperature	Cloud Attenuation (dB)		
	Zuwara	**Tripoli**	**Shahat**
20 ºC	1.775	1.632	1.026
10 ºC	2.214	2.036	1.279
0 ºC	2.835	2.607	1.638
-8 ºC	3.457	3.179	1.998

IV. CONCLUSIONS

For fixed satellite link between 6B Arabsat satellite and three earth stations in Libya, the cloud attenuation is estimated by using ITU-R P.840-5 Model based on the variation of liquid water content at Ku, Ka, and V bands.

Depending on the simulation results, it can be concluded that, the cloud attenuation is increased as both of the operating frequency and the liquid water content increase. Based on the increasing of the longitude of satellite location in both directions west, and east, the cloud attenuation is increased, and the elevation angle is decreased. According to the variation of temperature, the cloud attenuation is increased by decreasing of the surface temperature.

The simulated cloud attenuation results were obtained will be useful to design a reliable satellite link for Libyan earth stations.

REFERENCES

[1] A. Dissanayake, J. Allnutt, and F. Haidara, "Cloud attenuation modelling for SHF and EHF applications", International Journal of Satellite Communications, pp. 335-345, 2001.

[2] H. Singh, R. Kumar, B. Bonev, P. Petkov, "Cloud Attenuation issues in Satellite Communications at millimetre Frequency Bands- State of Art", International Journal of Scientific & Engineering Research Volume 8, Issue 7,pp. 858-862, July-2017.

[3] T. Omotosho, E. Babatunde, "Study of Cloud Impact on Fixed Satellite Communication Link at Ku, Ka and V Bands in Nigeria", Australian Journal of Basic and Applied Sciences, pp. 3287-3298, 2010.H.

[4] Recommendation ITU-R P.840-5, Attenuation due to clouds and fog, P-Series Radiowave propagation, 2012.

[5] S. Ahmed, and others," Impact of Cloud Attenuation on Ka-Band Satellite Links in Karachi, Pakistan", Journal of Applied Environmental and Biological Sciences, pp. 71-77, 2017.

[6] Recommendation ITU-R P.1144-6, Guide to the application of the propagation methods of Radiocommunication Study Group 3, 2012.

[7] T Priya, and T. Nizhanthi, "A Study on the Effects of Rain Attenuation for an X-Band Satellite System over Malaysia", Progress In Electromagnetics Research B, Vol. 45, 37–56, 2012