مجلة العلوم البحتة والتطبيقية
Journal of Pure & Applied Sciences
www.Suj.sebhau.edu.ly ISSN 2521-9200
Received 17/01/2020 Revised 08/05/2020 Published online 15/09/2020

Study the Effects of Dust and Sand Storms Attenuations on Satellites Link Margin over Libya

Sana Fadil,*Nassir Abuhamoud
Communication and Computer Engineering,Faculty of Engineering Sciences and Technology, Sebha University, Libya
*Corresponding author: mans.Abuhamoud1@sebhau.edu.ly

Abstract In this paper, the effect of dust and sand storm attenuation on the link margin of the satellite in geostationary orbit at X and Ku bands in the Space-to-Earth direction is studied for a satellite at 26°E longitude. A simulation model is used to predict the sand and dust storm attenuation and used to calculate thelink margin in six locations in Libya namely Benghazi, Tubruk, Tripoli, El-Kufra, Misrata and Sebha. The simulations assume 60 cm receive antenna diameter with 55% aperture efficiency. The downlink frequencies used in this study are 11.390 and 12.75 GHz for X- and Ku-bands respectively. The free space path loss, gases attenuations and scintillations fade dept are calculated for each band. Link margin, C/N and E_s/N_o (dB) is computed at X and Ku bands. The results indicate that all sites achieve link margin above the threshold level (sensitivity)by 60 cm antenna diameter in all locations . The results show that the southern regions is the most affected by dust and sand storms attenuation and cases decreasing in link margin. In comparison to the Ku-band, the X-band was the more capable to maintain a good quality satellite link in dust and sand storm intensities.

Keywords: propagation losses, downlink, model, Libya, communication.

دراسة تأثير توهين الغبار والعواصف الرملية على هامش الوصلة للأقمار الصناعية في ليبيا

سناء عبدالله فضل و ناصر* منصور أبوهمود
قسم الهندسة الكهربائية والالكترونية-كلية العلوم الهندسية والتقنية-جامعة سبها، ليبيا
*للمراسلة: mans.Abuhamoud1@sebhau.edu.ly

الملخص في هذه الورقة ، تمت دراسة تأثير توهين الغبار والعواصف الرملية على هامش الوصلة لقمر صناعي في المدار الثابت بالنسبة للأرض في نطاقي X و Ku band في اتجاه الفضاء إلى الأرض لقمر صناعي عند خط طول 26 درجة شرقاً. يتم استخدام نموذج محاكاة للتنبؤ بتوهين العواصف الرملية والترابية وحساب هامش الوصلة في ستة مواقع مختلفة في ليبيا وهي بنغازي، طبرق، طرابلس، الكفرة، مصراتة وسبها. تفترض عمليات المحاكاة أن قطر الهوائي استقبال يبلغ 60 سم بكفاءة 55٪. ترددات الوصلة الهابطة المستخدمة في هذه الدراسة هي 11.390 و 12.75 GHz للنطاقين X و Ku band على التوالي. يتم حساب فقد الفراغ وتوهين الغازات والتلألؤ في كل نطاق. بالاضافة الي حساب هامش الوصلة، C / N و E_s / N_o في نطاقي X و Ku band. تشير النتائج إلى أن جميع المواقع تحقق هامش الوصلة فوق مستوى العتبة (حساسية) بقطر هوائي 60 سم. أظهرت النتائج أن المناطق الجنوبية هي الأكثر تأثرا بتوهين الغبار والعواصف الرملية والذي يسبب انخفاض في هامش االوصلة . بالمقارنة مع النطاق Ku ، كان النطاق X أكثر قدرة على الحفاظ على وصلة القمر الصناعي أثناء الغبار والعواصف الرملية.

الكلمات الافتتاحية: انتشار، فقد، توهين، محاكاة، وصلة السماد، اتصالات، اقمار صناعية.

Introduction

The performance of earth-satellite communication links are limited by the attenuation of the signal caused by absorption, scattering and depolarization of radio waves due to the existing of atmospheric particles such as dust and rain drops encountered along the path. The effect of the atmosphere on radio waves propagating is a significant concern in the design and analysis of the performance of satellite communications systems. These effects on the earth-space link can cause uncontrollable variations in signal amplitude, phase and polarization, which result in a reduction in the quality of transmissions[1]. The atmosphere effect must be accurately accounted using a proper prediction model to ensure the reliability and availability of the system subject to various atmosphere conditions. Systems that are poorly designed lead to an increase in transmission errors, or worst, to an outage in the received signals[2]. Dust storms are significant meteorological phenomenon that occurs for a considerable percentage of time in the Libya. Recent years records show that a phenomenon rate is increasing due to the global environmental. Wireless communication networks and microwave systems have been installed in Libya, where there are dust and sand storms that may affect the microwave signal propagation[3]. When microwaves and millimeter waves pass through a medium containing precipitations like sand and dust particles, the signals get attenuated through absorption and scattering of energy out of beam by the sand and dust particles[4]. This paper aim to study dust and sand storms attenuation effects on link margin at X and Ku bands. In addition, it will predicts different types of propagation impairments as well as combining them together to determine the overall impact on satellite downlink signals . The performance of the X-band is compared to the Ku- in six locations across East, West and South of Libya using climatic and geographical data, varying heights above sea mean level as shown in **Table 1**. the study is focused on analysis the downlink of the satellite system and link margin. C/N and Es/No (dB) degradation is calculated during sand and dust storm to evaluate the system performance.

Table 1 Climatic and geographical data[5]

Regions	Temperature (K)	Relative humidity (%)	Pressure (hpa)	Duststorm visibility (km)	Station longitude	Station Latitude	height above sea level(m)
Tripoli	309	72	1016	9	13.11	32.54	25
Sebha	312	49	1014	0.004	14.26	27.01	432
Tubruk	304	67	1015	10	23.56	32.06	50
El-Kufra	312	36	1017	0.004	23.18	24.13	436
Benghazi	305	68	1016	9	20.06	32.11	30
Misurata	306	68	1017	10	15.03	32.19	32

Satellite links

A satellite link consists of an uplink (transmit earth station to satellite) and a downlink (satellite to the receive earth station).Signal quality over the uplink depends on how strong the signal is when it leaves the source earth station and how the satellite receives it. Also, on the downlink side, the signal quality depends on how strongly the satellite can retransmit the signal and how the receiving earth station receives the signal. Satellite link design involves a mathematical approach to the selection of link subsystem variables in such a way that the overall system performance criteria are met. An accounting of signal strength and noise is an important part of system design[6].

The calculation of the power an earth station receives from a satellite transmitter is fundamental to understanding satellite communications link[7].

$$P_r = EIRP - G_r - FSL - \text{other losses}\ldots\ldots\ldots \quad □□□$$

Where EIRP is Equivalent Isotropic Radiated Power from satellite, G_r is the receiver antenna gain , FSL is called the inverse of the free space loss, which represents the largest source of loss in the link, FSL[7]:

$$FSL = \left(\frac{\lambda}{4\pi d}\right)^2 \quad (2)$$

$\lambda = c/f$, where c is the speed of light and f is the propagation frequency, d is the distance from the earth station to the satellite in km.

Carrier to noise ratio C/N

The performance objectives of the satellite link is specified in terms of C/N the carrier power (C) and the noise power in the earth station receiver (N) can be represented as[7,8]:

$$\frac{C}{N} = EIRP + G_r - FSL - L_A - N \quad (3)$$

where L_A is the atmospheric losses and N is the noise power which is given by the Nyquist equation as [1]:

$$N = kTB \quad (4)$$

Where

k is Boltzman constant = - 228.6 dBw, T is the noise temperature of source in Kelvin, B the noise bandwidth.

Energy Per Symbol to Noise Density

E_s / N_o in the information channel, which carries the signal in the form in which it is delivered to the user(s). In designing a satellite communication system, the designer must ensure a minimum E_s / N_o. The energy per symbol to noise density ratio given by[9]:

$$E_s/N_0\,(dB) = EIRP + G_r - FSL - L_A - N_0 - 10\log(R_s) \quad (5)$$

(2.16)

where L_A, N_o and R_s are the atmospheric losses, noise spectral density and symbol rate, respectively.

Link Margin

The link margin is obtained by comparing the expected received signal strength to the receiver sensitivity or threshold. The link margin is a measure of how much margin is there in the satellite communications link between the operating point(satellite) and the point where the link can no longer be closed (receiver)[10]. The link margin required for the link budget calculations is usually given at the edge of the coverage area to achieve certain C/N at the receiver. The link margin can be calculated using [2]:

$$\text{Link margin} = EIRP - L_{path} + G_r - P_{min} \quad (6)$$

Where: L_{path} the total path loss, including free space loss and atmosphere loss in dB, P_{min} the receiver sensitivity or the minimum received signal level that will provide reliable operation in dBW or dBm.

Receiver Sensitivity

The receiver sensitivity is the minimum power level at the receiver input. Receive sensitivity is dependent on the noise figure and minimum required C\N of the system. System noise comprises of the low noise amplifier (LNA) generated noise and associated noises in terms of noise temperature . The required C\N is dependent on the modulation technique [11]. (2.15) The receiver sensitivity P_{min} (dBw) can be calculated from the minimal required receiver noise input power P_n (dBw) and C/N[7]:

$$P_{min} = P_n + C/N \quad (7)$$

$$P_n = F + 10\log_{10}(kT_0B) \quad (8)$$

Where

F the receiver noise figure (6 dB), K Boltzmann's constant, T_0 the absolute temperature (290K), B the receiver noise bandwidth (Hz).

Signal Attenuation

The total path losses component is the sum of various loss components such as: losses in the atmosphere due to attenuation by dust storms, gases and losses at the antenna at each side of the link and possible reduction in antenna gain due to antenna misalignment. This needs to be incorporated into the link equation to ensure that the system margin allowed is adequate[1].

Attenuation Due to Atmospheric Gaseous: The principal interaction mechanism between the radio waves and gaseous constituents is molecular absorption from molecules. Attenuation by atmospheric gaseous depends on frequency, elevation angle, altitude above sea level and water vapor content. The gaseous attenuation measured in dB is expressed below[12]:

$$A_{Gaseous} = \frac{A_o + A_w}{\sin\theta}$$

Where A_o is oxygen attenuation, A_w is water vapor , θ is elevation angle .

Scintillation Fade depth:

Scintillation happens when signals travels through this turbulent mixing atmosphere, it will experience alternation and scattering. The scintillation fade depth can be calculating by [13]:

$$A_s = a(p).\sigma$$

where a(p) is the time percentage factor for time percentage, σ standard deviation of the signal amplitude.

Signal Attenuation due to Dust and sand storms

The methods of predicting the signal attenuation due to rain effects can be applied for dust storm because the general model for scattering in sand and dust particle populations is essentially the same as that for a population of hydrometeors, both of them are discrete random medium. The signal attenuation due to dust storm is estimated generally by solving the forward scattering amplitude function of a single particle. The solution may be carried out using the Rayleigh approximation or Mie solutions. The method depends largely on the particle number and particle radius[14].

$$A_d = \frac{a_e f}{V}(x + y a_e{}^2 f^2 + z a_e^3 f^3) \quad (11)$$

Where a_e is the equivalent particle radius in meters, V is the visibility in kilometer or in other words the intensity of dust storms and f is the frequency in GHz and x, y and z are constants whose values depend on real (ε') and imaginary part (ε'') of the dielectric constant of the particles [15] shown in **Table 2** :

$$x = \frac{1886.\varepsilon''}{(\varepsilon'+2)^2+\varepsilon'^2} \quad (12)$$

$$y = 137 \times 10^3.\varepsilon'\left\{\frac{6\times7\varepsilon'^2+7\varepsilon'^2+4\varepsilon'-20}{5[(\varepsilon'+2)^2+\varepsilon'^2]^2} + \frac{1}{15} + \frac{5}{3[(2\varepsilon'+3)^2+4\varepsilon'^2]}\right\} \quad (13)$$

$$z = 379 \times 10^4\left\{\frac{(\varepsilon'-1)^2(\varepsilon'+2)+[2(\varepsilon'-1)(\varepsilon'+2)-9]+\varepsilon'^4}{[(\varepsilon'+2)^2+\varepsilon'^2]^2}\right\} \quad (14)$$

Table 2 Listing of dielectric constants at various frequencies[16]

Frequency	Soil Type	ε'	ε''
1 – 3	Loam	3.5	0.14
3 - 10.5	clay, silt	5.73	0.474
10.5 – 14	Sand	3.9	0.62
14 – 24	Sad	3.8	0.65
24 – 37	Loam	2.88	0.3529

CONTEXT OF STUDY

This study consists analysis of satellite communication downlink between satellite on geostationary orbit (Badr sat) in six locations in Libya namely Benghazi, Tubruk, Tripoli, El-Kufra, Misrata and Sebha, and earth station with a fixed parabolic receiving antenna and specification of the earth station is shown in **Table 3**. The simulation was done using MATLAB software. The model expressed the satellite downlink attenuation as a function of that the microwave signal attenuation due to dust storm depends on visibility, frequency, dust particle radius and dielectric constant. Sand particle average value of the diameters radius is 50μm. The climatic data were collected at the six locations in Libya for a period of fifteen year as shown **Table 1**, this data used to calculate the attenuations of dust and sand storm, gases and scintillation fade dept. Different locations of earth stations will contribute to different distance ranges according to its longitude and latitude and uses to calculate FSL as shown in **Table 4** . The atmospheric attenuations calculated in order to investigate their impact on the received signal. C/N, E_s/N_o and link margin are used to indicate and evaluate the signal quality. The receiver sensitivity is calculated according to Eq.(7) when code rate is 1/2.

Table 3 Summary of earth station specification

	X-band	Ku-band
Antenna Diameter(cm)	60	60
Antenna efficiency	0.55	0.55
Antenna gain(dBi)	34.49	35.47
Receiver noise Temperature(K)	108.27	108.27
Receiver sensitivity(dBm)	-102	-102

Results and Discussions

Based on a satellite longitude of and the earth station longitudes, the free space path loss at X and Ku bands is summarized in **Table 4**. The results showed that The FSL and atmospheric attenuations is higher at Ku band. Due to the large area of Libya, the distances are different so the losses are different. The results showed that the free space loss in the south of Libyan is the lowest and that is because the signal passes less distance. The gaseous attenuation and scintillation fade dept are listed in **Table 5** and **Table 6** respectively. The gaseous attenuation proportionally increase once there is an increase in the humidity, temperature and pressure. It is also observed that gaseous attenuation also increases with decreasing the elevation angle. When the results of gaseous attenuation for the six regions are compared, it appears that gaseous attenuation is higher in the west of Libya for all the investigated frequencies and the maximum value of the attenuation is in Tripoli followed by Misrata, while the lowest attenuation is in El-Kufra. The results show that scintillation fade depth is most severe in west regions and the highest value is in Tripoli due to the high humidity and lowest value is in El Kufra for illustration purposes. The results show that the dust storm attenuation increases with frequency and decreasing the visibility. The highest values of the attenuation for sand and dust storms are in Sebha and El-Kufra and this is because the sand storms is most severe in both cities, heavy dust storms reduce the visibility during the storms to few meters that reached (4 m). Dust and storms are not encountered frequently in the west and east regions. The lowest values for attenuation are in Tubruk and Misrata, and this is due to the high visibility (10 km) as shown in. Sand and dust storms attenuations do not depends on the transmutations parameters such as elevation angle. Therefore, the maximum attenuation value is 6.7452(dB/km) in Sebha and El-Kufra occur at Ku band. The values determine the availability of the received signal as well as its quality. The positive value of link margin is an indication of a superior system performance, it means that the system will meet the desired minimum performance.

Table 4 Elevation angles , distance to satellite and FSL

Location	Elevation Angle	Distance	FSL X band	FSL Ku band
Tripoli	50.281	37105.61	204.96	205.94
Sebha	56.338	36737.49	204.87	205.85
Tubruk	52.608	36924.24	204.91	205.89
El-Kufra	61.617	36449.09	204.80	205.78
Benghazi	52.215	36955.55	204.92	205.90
Misrata	51.157	37039.93	204.94	205.92

Table5 Sand and dust storms, gases attenuation and scintillation fade depth

Site \ Frequency (GHz)	Sand and dust storm attenuation dB/km	
	X band	Ku band
Tripoli	0.000832	0.00299
Sebha	1.8724	6.7452
Tubruk	0.000748	0.00269
El-Kufra	1.8724	6.7452
Benghazi	0.000832	0.00299
Misrata	0.000748	0.00269

Table 6 Scintillation fade depth and Gaseous attenuation

Site \ Frequency (GHz)	Scintillation fade depth dB		Gaseous attenuation dB	
	X band	Ku band	X band	Ku band
Tripoli	0.8241	Tripoli	0.16369	0.2064
Sebha	0.6174	Sebha	0.1135	0.1538
Tubruk	0.6143	Tubruk	0.11379	0.1395
El-Kufra	0.4479	El-Kufra	0.09067	0.1109
Benghazi	0.6503	Benghazi	0.12152	0.1499
Misrata	0.6883	Misrata	0.11815	0.1454

All the link margins which are predicted here are based on dust and sand storm attenuation, free space loss, gaseous and scintillation attenuation leads to a total degradation in link performance as listed in **Table 7**, it appears that as dust and sand attenuation increases, both signal strength and link margin decrease. The link margin depends on many factors, including the transmitted power, the antenna gain and losses. The dust and sand storms has a serious impact on the link margin as the visibility decrease, there was a significant decrease in the link margin, Sebha and El-Kufra has the lowest visibility therefore the link margin is the lowest. The attenuation is low in the west and east of Libya which is observed by link margin, C/N and E_s/N_o are high.

Table 7 Link margin calculations

	P_r (dBm)		Sensitivity (dBm)	C/N (dB)		E_s/N_o (dB)		Link Margin	
	Ku band	X band	X, Ku band	Ku band	X band	Ku band	X band	Ku band	X band
Tripoli	-90.5	-90.4		14.98	15.08	9.04	9.14	11.5	11.55
Sebha	-98.8	-93.9		6.6	11.61	0.7	5.67	3.1	8.09
Tubruk	-92.2	-92.1	-102	13.31	13.38	7.37	7.4412	9.79	9.86
El-Kufra	-100.5	-95.8		4.9	9.884	-1.01	3.942	1.4	6.719
Benghazi	-92.2	-92.2		13.26	13.32	7.31	7.3839	9.735	9.8
Misrata	-91.32	-91.24		14.20	14.27	8.26	8.3364	10.68	10.76

Conclusion

The knowledge of various propagation losses as dust and sand storm, gaseous and tropospheric scintillation and their combined effects is of ultimate importance for satellite communication service at higher frequencies for planning, budgeting and predicting link margin, the transmission and receiving of radio waves signals on path between satellite and earth stations. The predicted attenuations showed the caused effects the propagation of radiowave signals depends on local weather conditions for major cities in Libya. An analysis of the impact of the dust storm on the margin of the satellite link was presented. The dust storm properties are seen in terms of visibility and particle size. The results showed that the attenuation increases with frequency and decreased visibility. The results concluded that the impact of sand and dust storm was sever in the south and it caused decrease in the link margin and the received signal quality as implied by lower values of C/N and Es/No. X-band communication requires less link margin compare to Ku-band because atmospheric losses increases with frequency.

References

[1]- Aderemi, M. Luka, and A. Alatishe, "Satellite link design: A tutorial," Internationla Journal of Electrical and Computer Sciences IJECS-IJENS, vol. 11, no. 4, 2011.

[2]- L. J. Ippolito, and L. J. Ippolito Jr, Satellite communications systems engineering: atmospheric effects, satellite link design and system performance: John Wiley & Sons, 2017.

[3]- Abuhdima, E. M, Saleh, I. M.,2010. Effect of sand and dust storms on microwave propagation signals in southern Libya. IEEE, 695–698.

[4]- S. Fadil, and N. Abuhamoud, "Prediction of Microwave Signal Attenuation due to Dust and Sand Storms at (4-18 GHz): Case of study (south of Libya)," Journal of Pure and Applied Sciences, vol. 17, no. 4, 2018.

[5]- World Temperatures — Weather Around The World. 2019; Available from: https://www.timeanddate.com/weather/.

[6]- M. O. Kolawole, Satellite communication engineering: CRC Press, 2002.

[7]- K. Singh, A. Nirmal, and S. Sharma, "LINK MARGIN FOR WIRELESS RADIO COMMUNICATION LINK," ICTACT Journal on Communication Technology, vol. 8, no. 3, 2017.

[8]- A. Al-Qaisi, and A. A. Sharadqeh, "Signal-To-Noise-Ratio of Signal Acquisition In Global Navigation Satellite System Receiver," Signal, vol. 3, no. 8, 2012.

[9]- A. M. Al-Saegh, A. Sali, J. Mandeep, A. Ismail, A. H. Al-Jumaily, and C. Gomes, "Atmospheric propagation model for satellite communications," MATLAB Applications for the Practical Engineer: IntechOpen, 2014.

[10]- J. S. Seybold, Introduction to RF propagation: John Wiley & Sons, 2005.

[11]- S. Fadil, and N. Abuhamoud, "(Link Budget of GEO Satellite (Nile Sat) at Ku-band Frequency) Case of study Tripoli and Sebha," Journal of Pure and Applied Sciences, vol. 18, no. 4, 2019.

[12]- I. Recommendation, "676-9," Tropospheric attenuation by atmospheric gases, 2012.

[13]- R.Prabhakar1, T.V. Ramana, "Effect of Scintillations on Ka-band Frequency Satellite signals," International Journal Of Advancement In Engineering Technology, Management and Applied Science (IJAETMAS), vol. 04 ,pp. 136-141, March,2017.

[14]- Elabdin,Z., Islam, M. R., Khalifa, O., A Raouf,H.E., . Salamial,M.,2008. Development of mathematical model for the prediction of microwave signal attenuation due to dust storm. IEEE, 1156–1161.

[15]- Islam, M. R., ELABDIN,Z., Elshaikh,O., Khalifa,O., ALAM,A.Z., KHAN,S., NAJI,A.W.,2010. Prediction of signal attenuation due to duststorms using Mie scattering. IIUM Engineering Journal, 11(1), 71–87.

[16]- K. Harb, B. Omair, S. Abdul-Jauwad, A. Al-Yami, and A. Al-Yami, "A proposed method for dust and sand storms effect on satellite communication networks," Innovations on communication theory INCT,(Istanbul, Turkey), pp. 33-37, 2012.