Attenuation Effect of Dust Storm on Port Sudan Microwave Signal Level In Comparison With Some Models

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Abstract—Dust storms are significant meteorological phenomena which occur for a percentage of time in arid and semi-arid areas especially at African and Middle East, and this phenomena affect signal attenuation signal level especially at Ku band and higher frequency with direct impact on telecommunications system performance. A study on dust storm effect on Microwave links in arid area covering a wide range of radiofrequency especially in 18GHZwas running in Khartoum, Sudan. The study used Management system (computerized system) for monitoring transmitted and received signal levels of one microwave links operating at (18GHz) as well as an automatic weather station. This paper presents a description of measurement results and reports for dust storms as they affect the radio wave propagation especially at frequencies above 10GHz, for Port Sudan –Dar Elnaeem link in Port Sudan city. The effect of dust storms on propagation is studied by measuring the storm parameters, visibility and attenuation due to these storms. The measurement results have been compared with the attenuation prediction models like Elshaikh and Goldhirsh Model. Few prediction models have been developed to determine the attenuation due to dust storm in dB/km. All prediction models have assumed that the intensity of dust storm is uniformly distributed around the area covered by the dust storm. However, real dust storm is a complex phenomenon which is difficult to be described by theoretical physical or mathematical models. In this work, we compare between the existing attenuation prediction models based on measured dust storm and measured attenuation in Sudan. The empirical relation found that the measured attenuation is higher than the predicted by the models studied.

Keywords—Dust Storm, Microwave, Frequency, attenuation, Visibility

I. INTRODUCTION

The propagation of microwave signals in dust storms have found considerable interest recently, due to the increasing number of satellite and terrestrial links as well as many radar applications which operate at frequencies above 10GHz. When microwaves pass through a medium containing precipitations like rain, snow or dust particles, the microwave Signals get attenuated through two phenomena:

1) Absorption of energy by these particles.

2) Scattering of energy out of the beam by these particles.

Microwaves suffer absorption and scattering by the atmosphere especially at higher frequencies Where the scattering effects become more severe. Sensitivity to weather condition like rain, fog, cloud, snow, dust storm and other phenomena can effect quality of telecommunication system especially in 10 GHz frequency bands and higher due to attenuation signal. Microwave Attenuation signal due to Dust storm one of these potential technical challenges need to be investigate in order to provide reliable wireless communication system with good performance. Dust storm occur in many
parts of the world, especially in the Middle east, arid parts of Asia, south west of USA in dry states like Texas and Arizona. Dust storms are becoming more frequent in some parts of the world; there is significant correlation between the increased occurrences of dust storm and the climate change phenomenon.

The goal of a short-term measurement is to compare the measurements with the result of indirect methods. Experiments conducted in different environments such as, Sudan, Saudi Arabia and Iraq using different link length and frequencies.

S. I. Ghobrial [1,2,3 & 4] reported that the attenuations is less than 0.5 dB at 2 GHz link during a dust storm in Khartoum with visibility less than 150 meters. The link is Khartoum North Wadi Saidnaa has a path of 18 km flat terrain. Another microwave link that runs from Halfayat El Muluk to the Post Office Head Quarters in Khartoum has been studied. The radio path length was around 20 km. The frequency at which the study was made was 7.5 GHz. The Minimum visibility recorded was 0.15 km on 26th August 1985 at 0700. The attenuation caused by the storm is less than 0.5 dB [5, 6, and 7]. On the other hand, Ghobrial and Jervase measured in Khartoum a peak attenuation of 6.4 dB observed on a 25-km Link at 10.5 GHz affected by dust storm produced a visibility is less than 100 m. The wind speed was recorded as 30 knot and vertically polarized signals were transmitted at a height of 30 m and the receive antenna was at a height of 27 m [8, 9]. Elfatih A. A. Elsheikh, reported the attenuation in two microwave links in Khartoum during a sever dust storm on 21 September 2008[10, 11] where visibility was reduced to 50 meters. Attenuation was recorded by Marconi microwave system. The measured total attenuation for SOBA_MUD link was equal to 32 dB at 13GHz and 15.2 km link. Whereas, the measured total attenuation for SOBA_JERRAIF link equal to 36 dB at13GHz and 13km link length. On 6 June 2014 Md. Rafiqul Islam [12] reported attenuation during a sever dust storm where visibility was 150 meter the recorded attenuation was 13.3 dB for MABLOOLJREEF SHAREG link 6.2 km operating at 22.4 GHz.

![Figure 1: Frequency of Dust storm occurrence in Khartoum, Madni, Port Sudan (2016) visibility <1km](image)

Dust Storms affect the Microwave Attenuation Signal and its high affected in high frequency, and he degrade the performance of Microwave links especially in arid area limited research was carried out in the dust storm attenuation area and the scarcity of measured data forces made researchers work on
predictive models of dust storms. Few theoretical models have been developed based on single scattered, multiple scattering or mutual interaction phenomena [13, 14, 15].

II. MATERIALS AND METHODS

18 GHz Microwave Links have been installed in different lengths and different location, tow links in Khartoum, one link in Madani and last one in Port Sudan as shown in fig.2 and Table 1. All links have been monitored by Management system (U2000) and were collected for all the transmitted and received signal levels were recorded. Also we collect visibility data from Meteorological department.

Figure 2: Geographical details of the Microwave links for Port Sudan Area

Figure 3: Geographical details of the Microwave links in Khartoum area
Four Microwave links at 18GHz in different lengths were under study in Khartoum, Madani and Port Sudan and we will used Port Sudan link in this study, as shown in Table I. The links have been monitored the Transmitted and Received Signal Levels (TRSL) have been recorded for one year from 1Jan 2016 to 31 Dec 2016. A study one attack Storm in this paper in Port Sudan Area. The system comprises the four microwave links data acquisition and processing system. An Automatic Weather Station (AWS) operating at Khartoum International Airport. Visibility reduction is measured using the near infrared link.

### III. EXPERIMENTAL SETUP

Table 1: Details of the four terrestrial links that are used for the study.

<table>
<thead>
<tr>
<th>#</th>
<th>Link</th>
<th>Location</th>
<th>Frequency MHZ</th>
<th>Length KM</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hantoop</td>
<td>14.430381°, 33.531254°</td>
<td>18,981.00</td>
<td>4.36</td>
<td>Madani</td>
</tr>
<tr>
<td></td>
<td>Alingaz</td>
<td>14.449780°, 33.566480°</td>
<td>17,971.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Port Sudan-center</td>
<td>19.617635°, 37.221069°</td>
<td>18,910.00</td>
<td>4.84</td>
<td>Port Sudan</td>
</tr>
<tr>
<td></td>
<td>Port Sudan</td>
<td>19.585830°, 37.189500°</td>
<td>17,900.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Umdawban</td>
<td>15.426000°, 32.838800°</td>
<td>18,640.00</td>
<td>6.96</td>
<td>Khartoum</td>
</tr>
<tr>
<td></td>
<td>Alaasilat-01</td>
<td>15.369670°, 32.867630°</td>
<td>17,630.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Eldoroshab</td>
<td>15.727900°, 32.581900°</td>
<td>18,810.00</td>
<td>8.06</td>
<td>Khartoum</td>
</tr>
<tr>
<td></td>
<td>Alsamra</td>
<td>15.764940°, 32.645740°</td>
<td>17,800.00</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The visibility data were collected from Automatic Weather Station, operating at Khartoum International Airport, and Transmitted and Received Signal Levels (TRSL) were collected from Management system (computerized system)include the measured and calculated attenuation due to dust storms at 18GHz in 29 March 2018 in Port Sudan Links Table I and Figure 1.

### IV. DATA COLLECTION

Different approaches have been adopted to evaluate microwave signal attenuation due to dust storm in terms of its characteristics such as the number of dust particles per cubic meter, the mass of dust per cubic meter or visibility. Therefore, various investigations showed that the scattering of electromagnetic waves propagating in dust storms is influenced by various factors including incident wave frequency, permittivity, density, and geometric scale, distribution of grains, moisture and chemical behavior of dust particles [16]. Two recent attenuation prediction models have been investigated. These models have been based on certain assumptions but rely on some empirical inputs such as particle shape, chemical composition, size and dielectric constant.

### Elshaikh Model (2008)

Elshaikh. [3] Has proposed a prediction model based on Mie scattering which can calculate the specific attenuation in microwave wave band with high reliability. The model has related attenuation coefficient to the visibility, particle size distribution. Elshaikh. [3] Has proposed a prediction model based on Mie scattering which can calculate the specific attenuation in microwave wave band with high reliability. The model has related attenuation coefficient to the visibility, particle size distribution according to the relation.
Goldhirsh derived an attenuation prediction model for dust storms expressed by

\[ A = \frac{r_{ef}}{V} \left( x + yr_{e}^{2}f^{2} + zr_{e}^{3}f^{3} \right) \text{[dB/km]} \]

Where:
\[ r_{e} = \] Equivalent particle radius in meter. 
\[ V = \] Visibility in kilometer. 
\[ f = \] Frequency in GHz. 
\[ x = \frac{1886\times e''}{(e''+2)^{2}+e''^{2}} \]
\[ y = 137 \times 10^{3} \times e'' \left\{ \frac{6(7e''^{2}+7e''^{2}+4e''-20)}{5[(e''+2)^{2}+e''^{2}]^{2}} + \frac{1}{15} + \frac{5}{3(2e''+3)^{2}+4e''^{2}} \right\} \]
\[ z = 379 \times 10^{4} \left\{ \frac{(e'-1)^{2}(e'+2) + 2(e'-1)(e'+2)-9}{[(e'+2)^{2}+e''^{2}]^{2}} \right\} \]

A= Attenuation coefficient 
\[ e' = \] Real dielectric constant 
\[ e'' = \] Imaginary dielectric constant

**Goldhirsh Model**

Goldhirsh derived an attenuation prediction model for dust storms expressed by

\[ A = \frac{2.317 \times 10^{-3} \cdot e''}{((e'+2)^{2} + e''^{2}) \cdot \lambda} \cdot \frac{1}{V^{\gamma}} \text{[dB/km]} \]

Where:
\[ A= \] Attenuation coefficient 
\[ V =\] visibility in kilometers 
\[ \gamma = \] a constant value equal to 1.07 
\[ \lambda = \] wavelength in meters 
\[ e' = \] Real dielectric constant 
\[ e'' = \] Imaginary dielectric constant

VI. RESULTS AND DISCUSSION

Microwave signal attenuation due to the dust Storm was monitored on 29 March 2018 in part of north Sudan and Port Sudan area by Microwave management system and this management can monitor measurement and record Transmit and received signal level during providing cell phone service in Sudan.

Figure 4 shows a record of microwave signal level during the storm; on the other hand, Sudan meteorological Authority recorded a visibility less than 100m during the storm.
Table 2: Antenna parameters at Port Sudan - Dar Elnaeeem Link

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Portsudan Center</th>
<th>Dar Elnaeeem</th>
</tr>
</thead>
<tbody>
<tr>
<td>RX Freq</td>
<td>18910</td>
<td>17900</td>
</tr>
<tr>
<td>Polarization</td>
<td>Vertical</td>
<td>Vertical</td>
</tr>
<tr>
<td>Antenna diameter</td>
<td>0.3 m</td>
<td>0.3 m</td>
</tr>
<tr>
<td>Antenna gain</td>
<td>32 dBi</td>
<td>32 dBi</td>
</tr>
<tr>
<td>Antenna height</td>
<td>30 m</td>
<td>25 m</td>
</tr>
<tr>
<td>TX Power</td>
<td>21 dBi</td>
<td>21 dBi</td>
</tr>
</tbody>
</table>

Table 3: RSL and TSL Power reading each 15 minutes

<table>
<thead>
<tr>
<th>Monitored Object</th>
<th>Performance Event</th>
<th>End Time</th>
<th>Min power</th>
<th>Max power</th>
</tr>
</thead>
<tbody>
<tr>
<td>EST-Dar Elnaeeem -RTN RSL (dbm)</td>
<td>03/29/2018 12:30:00</td>
<td>-41.60</td>
<td>-42.30</td>
<td></td>
</tr>
<tr>
<td>EST-Dar Elnaeeem -RTN RSL (dbm)</td>
<td>03/29/2018 12:30:00</td>
<td>14.00</td>
<td>14.00</td>
<td></td>
</tr>
<tr>
<td>EST-Dar Elnaeeem -RTN RSL (dbm)</td>
<td>03/29/2018 12:45:00</td>
<td>-40.80</td>
<td>-42.30</td>
<td></td>
</tr>
<tr>
<td>EST-Dar Elnaeeem -RTN TSL (dbm)</td>
<td>03/29/2018 12:30:00</td>
<td>14.00</td>
<td>14.00</td>
<td></td>
</tr>
<tr>
<td>EST-Dar Elnaeeem -RTN RSL (dbm)</td>
<td>03/29/2018 13:00:00</td>
<td>-40.80</td>
<td>-42.30</td>
<td></td>
</tr>
<tr>
<td>EST-Dar Elnaeeem -RTN TSL (dbm)</td>
<td>03/29/2018 13:15:00</td>
<td>14.00</td>
<td>14.00</td>
<td></td>
</tr>
<tr>
<td>EST-Dar Elnaeeem -RTN RSL (dbm)</td>
<td>03/29/2018 13:30:00</td>
<td>-40.80</td>
<td>-42.20</td>
<td></td>
</tr>
<tr>
<td>EST-Dar Elnaeeem -RTN RSL (dbm)</td>
<td>03/29/2018 13:45:00</td>
<td>-57.60</td>
<td>-58.20</td>
<td></td>
</tr>
<tr>
<td>EST-Dar Elnaeeem -RTN TSL (dbm)</td>
<td>03/29/2018 12:30:00</td>
<td>23.00</td>
<td>23.00</td>
<td></td>
</tr>
<tr>
<td>EST-Dar Elnaeeem -RTN RSL (dbm)</td>
<td>03/29/2018 13:00:00</td>
<td>-57.60</td>
<td>-58.20</td>
<td></td>
</tr>
<tr>
<td>EST-Dar Elnaeeem -RTN TSL (dbm)</td>
<td>03/29/2018 13:15:00</td>
<td>23.00</td>
<td>23.00</td>
<td></td>
</tr>
<tr>
<td>EST-Dar Elnaeeem -RTN RSL (dbm)</td>
<td>03/29/2018 13:30:00</td>
<td>-57.60</td>
<td>-58.20</td>
<td></td>
</tr>
</tbody>
</table>

RSL: Received signal level (power)
TSL: Transmitted signal level (power)
Figure 4: Measured signal level (power) for Port Sudan –Dar Elnaeem link on 29st March 2018 as a function of time. It shows that measured total attenuation for Port Sudan –Dar Elnaeem link was equal to 16 dB at 18GHz and 4.84 km link length.

Measured and Expect Attenuation

Dust storm attenuation was predicted using models proposed by Goldhirsh and Elshaikh with the Parameters = $28\mu m, \varepsilon'=4.2$, $\varepsilon''=1.56$, $V$ = less than 100m and $f$=18GHz. Equations (1) to (5) were used to estimate the attenuations and presented in Table 4.

<table>
<thead>
<tr>
<th>Goldhirsh. Model(AG)</th>
<th>Elshaikh Model(AE)</th>
<th>Length Km</th>
<th>Goldhirsh. Total(TAG)</th>
<th>Elshaikh Total(TAE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.13</td>
<td>1.13</td>
<td>4.84</td>
<td>0.629</td>
<td>5.46</td>
</tr>
</tbody>
</table>

Table 4: Length of link between Port Sudan and Dar Elnaeem

Attenuation per KM (Goldhirsh model) = $AG/Km$
Attenuation per KM (Elshaikh model) = $AE/Km$
Total attenuation for the Goldhirsh model = $AGT$
Total attenuation for the Elshaikh model = $AET$
Figure 5: Comparison between calculated values of the attenuation using Elshaikh, Goldhirsh Model and measured values at 18GHz.

Measured and expected attenuation are compared in Table 3, it’s clear that the measured attenuation are 11dB higher than the expected by both model for Port Sudan- Dar El naeem link.

<table>
<thead>
<tr>
<th>Link</th>
<th>Goldhirsh Model (TAG)</th>
<th>Elshaikh Model (TAE)</th>
<th>Measured (TAM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port Sudan- Dar El naeem</td>
<td>0.629 dB/km</td>
<td>5.46dB/km</td>
<td>16 dB/km</td>
</tr>
</tbody>
</table>

Table 5: Comparison between measured and expected attenuation for all link

TAM: Total measures attenuation coefficient
TAG: Total attenuation by Goldhirsh model
TAE: Total attenuation by Elshaikh model

VII. CONCLUSION

A field study aimed at studying the effect of Microwave signal in arid land has been done in Port Sudan. One Microwave link operating at 18 GHz in Sudan – Port Sudan region were monitored during Dust Storm and one found more than 16 dB attenuation for 4.86 Km length. One used two Models proposed by Goldhirsh and Elshaikh to expect attenuation for both models it was found that the both models are under estimate comparing with measured results. On the other hands the measured attenuation coefficient over visibility distance is less than that predicted by both models in most cases.

Dust storms can cause serious attenuation in signal level especially at Ku band and higher Frequencies with direct impact on telecommunications system performance.

REFERENCES


