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Analysis Of Rain Attenuation Reduction In Sudan for Ku-Band Satellite Communication Link

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Abstract:

Rain attenuation prediction is one of the vital steps to be considered when analyzing a satellite communication links.The parameters presented in this paper are specific attenuation and total path attenuation due to rain at horizontal, circular, and vertical polarizations in Ku band. The data rates are collected from the metrological authority, ministry of environment, forestry and physical development. A horizontally polarized signal encounters more rain attenuation than that of vertically and circularly polarized signal.In this paperthe annual rain rate and monthly variation of rate are predicted for five cities of Sudan, namely Khartoum, Halfa, Nyala, Kosti,and ED-Dmazeen.

Introduction:

Satellites are specifically made for telecommunication purposes. They are used for mobile applications such as communication to ships, vehicles, planes, hand-held terminals and for TV and radio broadcasting. They are responsible for providing these services to an assigned region (area) on the earth. The power and bandwidth of these satellites depend upon the preferred size of the footprint, complexity of the traffic control protocol schemes and the cost of ground stations. A satellite works most efficiently when the transmissions are focused with a desired area. When the area is focused, then the emissions don't, go outside that designated area and thus minimizing the interference to the other systems. This leads more efficient spectrum usage. [1]
The interest of many telecommunication companies to provide high speed wireless internet access, broadcast multimedia information, multimedia file transfer, remote access to a local network, inter-active video conference and Voice-Over-IP has forced migration from lower frequency bands which are already congested to higher frequency bands such as microwave and millimeter bands. The choice of these bands became the key solution to today's request because of large bandwidth availability, small device size and wide range of spectrum availability. Although with all the inherent advantages, rain is the major offender to optimum performance and usage of these bands. Rain attenuation results in outages that compromise the quality of signal and link availability making it a prime factor to be considered in designing both terrestrial and satellite links. This means that the design of any communication device in this spectrum range requires knowledge of rain fade in order to provide optimum link availability and robust and reliable link to any telecommunication systems that offer aforementioned benefits [2].

The performance metric considered mostly in link analysis is the system availability. That is, the time percentage the link is providing service either at or below the specified given bit error rate.It was confirmed that at frequencies just above 5 GHz, the rain fade depth becomes noticeable and severe at a frequency above 10 GHz [3].

Atmospheric effects play a major role in the design of satellite-to-earth links operating at frequencies above 10 GHz. Raindrops absorb and scatter radio waves, leading to signal attenuation and reduction of the system availability and reliability. The severity of rain impairment increases with frequency and varies with regional locations [4]. Hence the incidence of rainfall on radio links becomes even more important for frequencies as low as about 7 GHz particularly in the tropical and equatorial climates, where intense rainfall events are common [5]. It is therefore very important when planning both microwave and terrestrial line-of-sight system links; to make an accurate prediction of rain induced attenuation on propagation paths [6]. Initially, attenuation prediction attempts involved extrapolation of measurements to other locations, frequencies, and elevation angles; however, the complex nature and regional variability of rain make this approach highly inaccurate [7].

Ku band:

The Ku-band frequency range is allocated to be exclusively used by satellite communication systems, thereby eliminating the problem of interference with microwave systems. Due to higher power levels at new satellites Ku-band allows for significantly smaller earth station antennas and RF units to be installed at the VSAT location. KU Band is a part of the electromagnetic spectrum in the microwave range of frequencies ranging from 12 to 18 GHz. The Ku band (Kurtz-under band) is primarily used for satellite communications, particularly for editing and broadcasting satellite television. This band is split into multiple segments broken down into geographical regions, as the ITU (International Telecommunication Union) determines.The Ku band is a portion of the electromagnetic spectrum in the microwave range of frequencies ranging from 11.7 to 12.7GHz (Downlink frequencies) and from 14 to 14.5GHz (Uplink frequencies). The most common Ku band digital reception format is DVB (main profile video format) .Advantages of Ku band is no interference from microwave links and other technologies operates with a smaller satellite dish (diameters from 0.9m) it is cheaper and easier installation,needs less power and cheaper RF unit. The disadvantages it is more expensive capacity and sensitive to heavy rain fade (significant attenuation of the signal) / possibly can be managed by appropriate dish size or transmitter power.

Rain attenuation:

Rain attenuation is the dominant factor in path loss variation above 10GHz, and can have an effect below that frequency at low elevations.

Rain affects the transmission signal by:

1. Change polarization
2. Increases the system noise temperature
3. Attenuates the signal

All the above mechanisms cause degradation in the received signal quality and become increasingly significant as carrier frequency increases.Rain fade is an interruption of wireless communication signals as a result of rain or snow droplets whose separation approximates the signal wavelengths. The phenomenon can affect satellite Internet connections as well as satellite television and other systems. Most satellite communication takes place in the microwave portion of the electromagnetic radiation spectrum. Signals at these wavelengths, typically on the order of a few inches, are affected by heavy concentrations of water droplets or ice crystals in the atmosphere. When the mean distance between water droplets or crystals is comparable to the wavelength of the electromagnetic signals, severe attenuation can occur. The observed effect is a degradation or loss of communications during heavy downpours, snow squalls, and blizzards.Rain fade usually does not last long. Once a heavy shower or squall has passed, normal communications returns. However, during tropical storms or severe winter storms at northern latitudes, fadeouts can persist for hours at a time. The phenomenon occurs with all types of satellite systems, including geostationary (GEO), low-earth-orbit (LEO), and medium-earth-orbit (MEO). It can also affect the Global Positioning System (GPS).[8]

Calculation of rain attenuation:

The rate at which the rain water would get accumulated in a rain gauge in the area of interest is called rain rate. Rain attenuation is a function of rain rate. It is calculated in percentage time. A percentage time is generally of a year.
Percentage time is denoted as p and rain rate as $\boldsymbol{Rp}$. Specific attenuation α is given by:

$$\alpha = aRp^{b} dB/km$$

Bothaand b depend upon frequency and polarization. Table (1) shows the values of those constant.For circular polarization a and b calculates by below equations:

$$ac = \frac{ah + av}{2}$$

$$bc = \frac{(ah * bh) + (av * bv)}{2 * ac}$$

Total attenuation, denoted by A is given by:

$$A = \alpha L dB$$

Because the rain density is unlikely to be uniform over the actual path length, an effective path length must be used rather than the actual (geometric) length
Where: $\boldsymbol{L}$ is the effective path length of the signal through rain.
$\boldsymbol{LG}$is Horizontal projection of Ls Thus effective path length L is given by:

$$L = Ls * rp$$

$\boldsymbol{Ls}$: the slant Height and it depends upon the antenna angle of elevation $\boldsymbol{El}$ and rain height.
Where $\boldsymbol{rp}$ is the reduction factor of percentage time p and LG that is:

$$LG = Ls \cos El$$

Therefore rain attenuation is:

$$Ap = aRp^{b} LsdB$$

Rain attenuation effects are negligible at the range of 2GHz, they are prevalent at higher frequencies especially above 20GHz. Rain attenuates the signal by scattering or absorbing radiation.
The slant-path length, $\boldsymbol{L_s}$, below the freezing rain height is obtained:

$$Ls = \frac{hR - h0}{\sin(El)}$$

Where $\boldsymbol{El}$ the elevation angle and $\boldsymbol{ho}$is the station height in km,$\boldsymbol{hR}$ is Rain Height at which freezing occurs.

Table 1: specific attenuation coefficients

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Frequency GHz	a_H	a_V	a_C	b_H	b_V	b_C
10	0.0101	0.00887	0.0549	1.276	1.264	0.1387
12	0.188	0.0168	0.1024	1.217	1.200	1.215
15	0.0367	0.0335	0.0351	1.154	1.128	1.1415
20	0.0751	0.0691	0.0721	1.099	1.065	1.0827

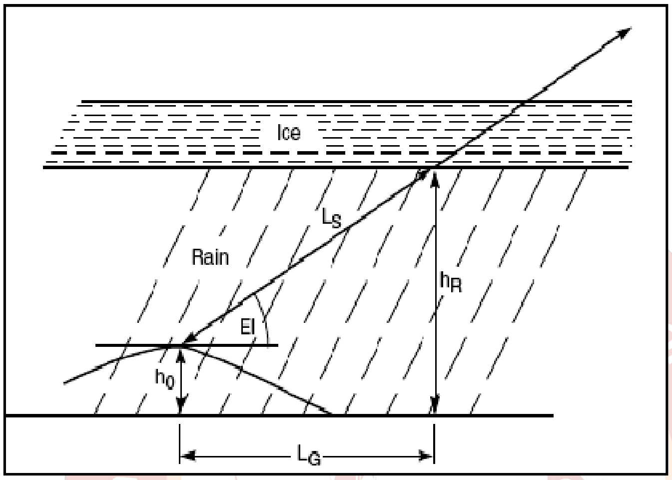

Figure (1) link under rain

Results:

Table 2: *Rp*for five Sudanese different cities in august 2013 and 2014:

City	*Rp* (mm/h) 2013	*Rp* (mm/h) 2014
Khartoum	0.0927	0.0703
ED-Dmazeen	0.373	0.4614
Wadi-Halfa	0.0067	0
Nyala	0.187	0.157
Kosti	0.316	0.233

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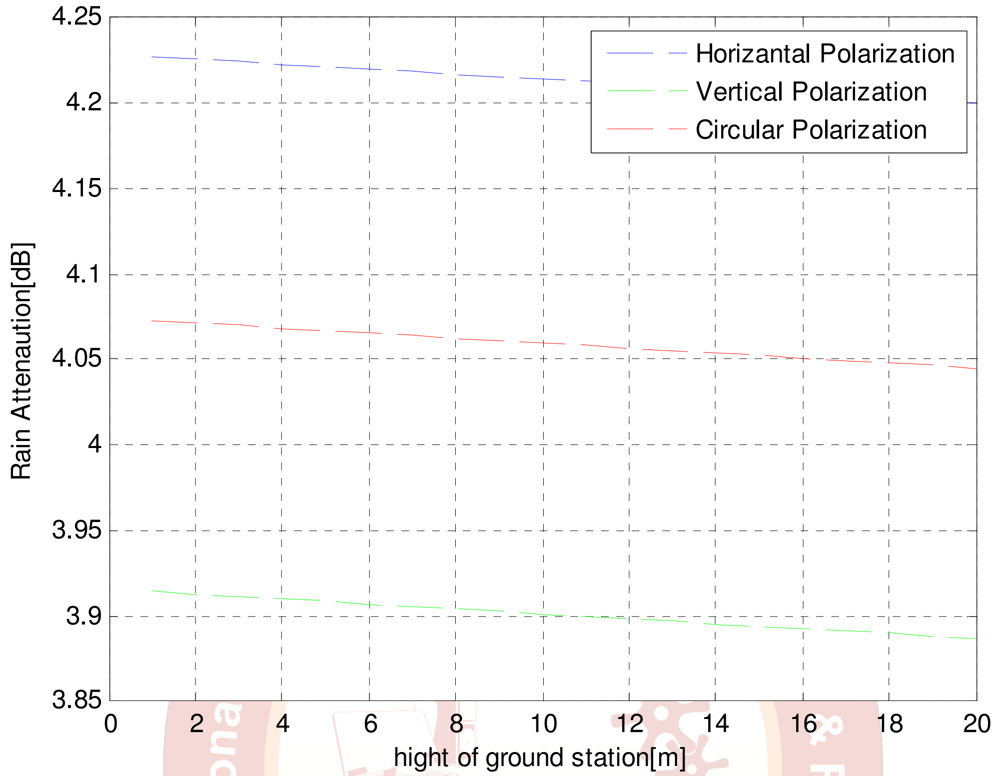

Figure (2) the maximum rain attenuation in Khartoum 2013 for Ku-band

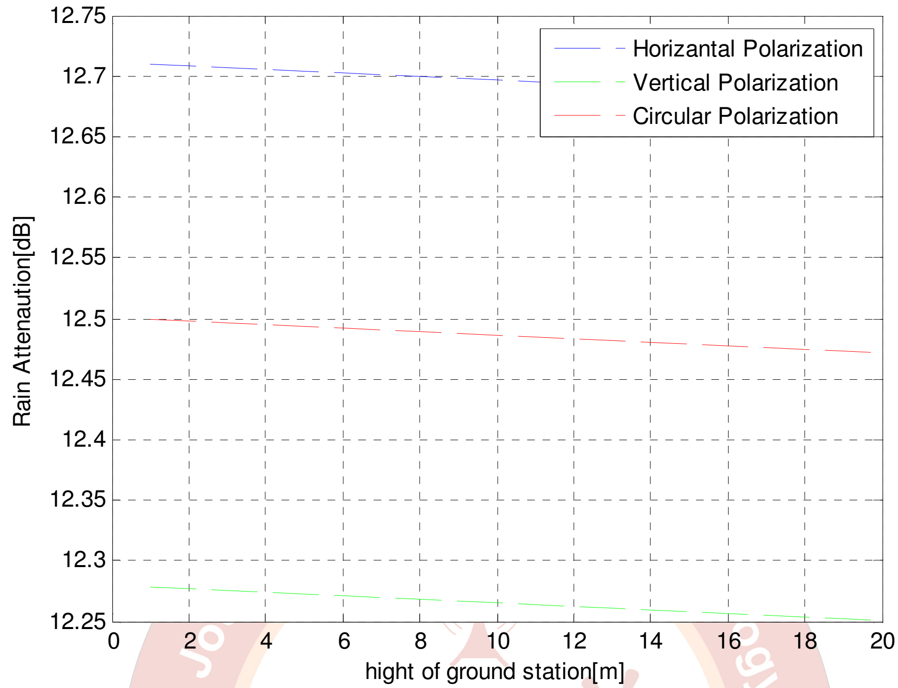

Figure (3) the maximum rain attenuation in ED-Damazine 2014 for Ku-band

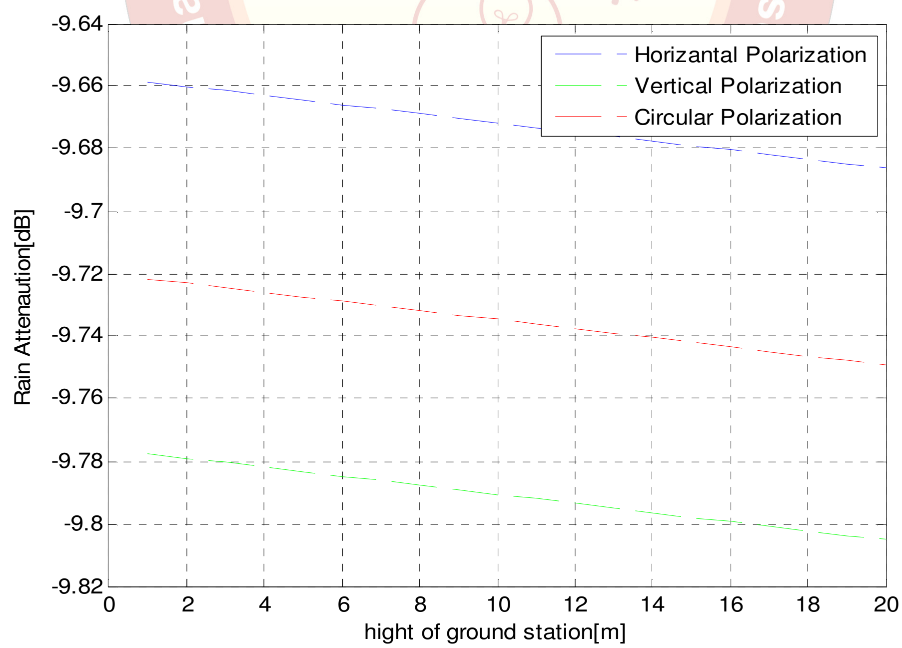

Figure (4) The maximum rain attenuation in Wadi-Halfa 2013 for Ku-band

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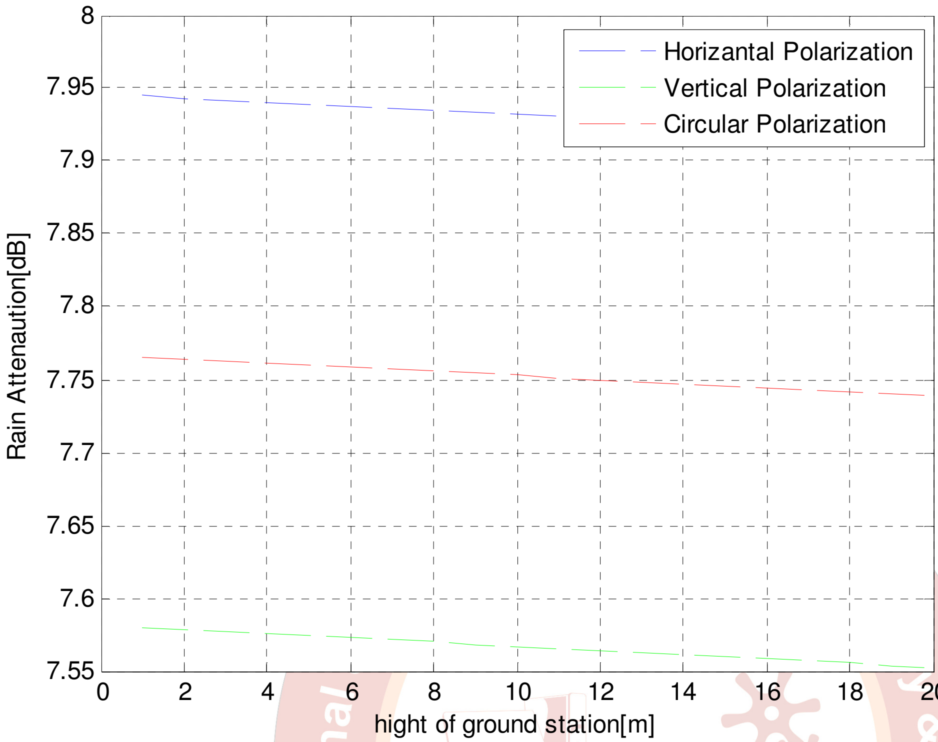

Figure (5) the maximum rain attenuation in Nyala 2013 for Ku-band

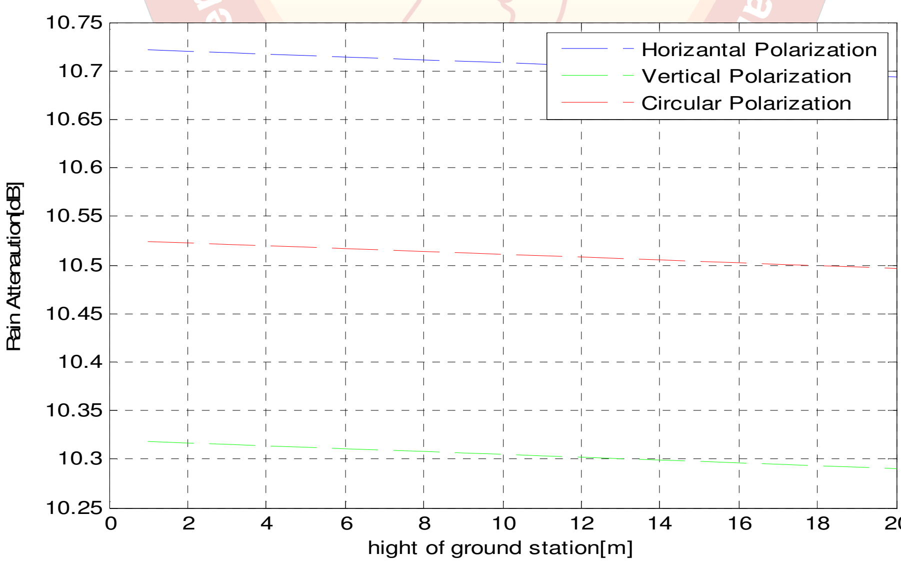

Figure (6) the maximum rain attenuation in Kosti 2013 for Ku-band

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Conclusion:

This paper presents the rain attenuation for ku band VSAT link for the selected cities in Sudan. The rain rate is max at ED-Dmazeen among the concerned cities, which is followed by Kosti, Nyala, Khartoum, and wadi-Halfa, respectively. The specific attenuation of the mentioned cities has the maximum value of 12.71and the minimum value of -9.87, followed by significant difference for various height of antenna. It is also found that the horizontally polarized signal is more attenuated by the rain than the circularly and vertically polarized signal. Thus, using vertical polarization in highly rain_ area like ED-Dmazeen is more economical.

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