Applications of Propagation Models to Design Geostationary Satellite Links Operating in Ka Band over Indian Rain zones

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ABSTRACT:

The lower frequency regions below 15 GHz is in extensive use in communications through satellite and terrestrial links. The 20-30GHz radio-frequency regions offer three major advantages for satellite communications over the lower frequencies. These advantages are spectrum availability, reduced interference potential and reduced equipment size. At Ka band, propagation impairments strongly limit the quality and availability of satellite communications. Attenuation due to rain plays a significant role in tropical regions especially countries like India, where great diversity of climatic conditions exist.

KEY WORDS: satellite communications, attenuation, Indian region

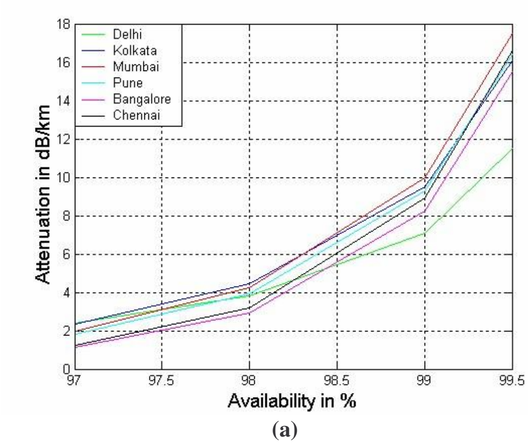
INTRODUCTION:

Currently in Indian region C and Ku-band frequencies are being used for commercial satellite communications. In future Ka-band will be used for wideband applications. Propagation studies are essential for estimation of attenuation so that Ka-band satellite links operating in different parts of Indian region can be registered appropriately.

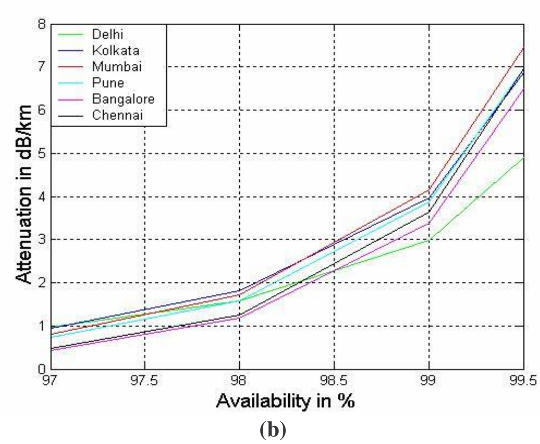
In this work, rain data over 1.5*1.5 degrees grid have been calculated over Indian region, which is long-term data measured by European Centre for Medium Range Weather Forecasts (ECMWF) U.K for more than 20 years. The surface water vapour densities and integrated liquid water contents (ILWC) have been calculated using data from National Centre for Environmental Prediction (NCEP), NOAA. By analyzing this data, rain zones have been modified, and links at different regions have been designed. In this work attenuation due to rain, gaseous and cloud over Indian region are calculated.

RAIN ATTENUATION:

Attenuation due to rain is a dominant factor for determining link availability at frequencies above 10 GHz. It depends on temperature, drop size distribution, terminal velocity and the shape of the raindrops [1]. Calculations have been done from point rainfall rate by using ITU-DAH model for different availabilities [2]. Figure 1 shows specific attenuation due to rain rate at different locations and for satellite location 83 ^{0}E



(a)



(b)

Fig. 1 Specific attenuation for different availabilities at different locations at (a) 30 GHz (b) 20GHz

Figure 2 shows annual average availability at frequencies 30 and 20GHz (horizontal polarization) for satellite location of 83^0 E for annual average availability of 99.5%, which corresponds to worst month availability of 98.44%.

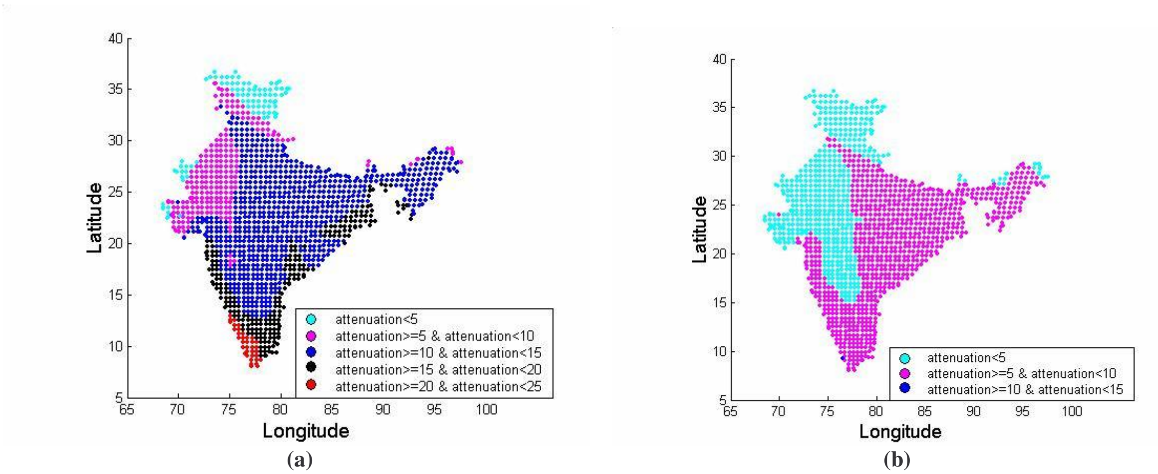
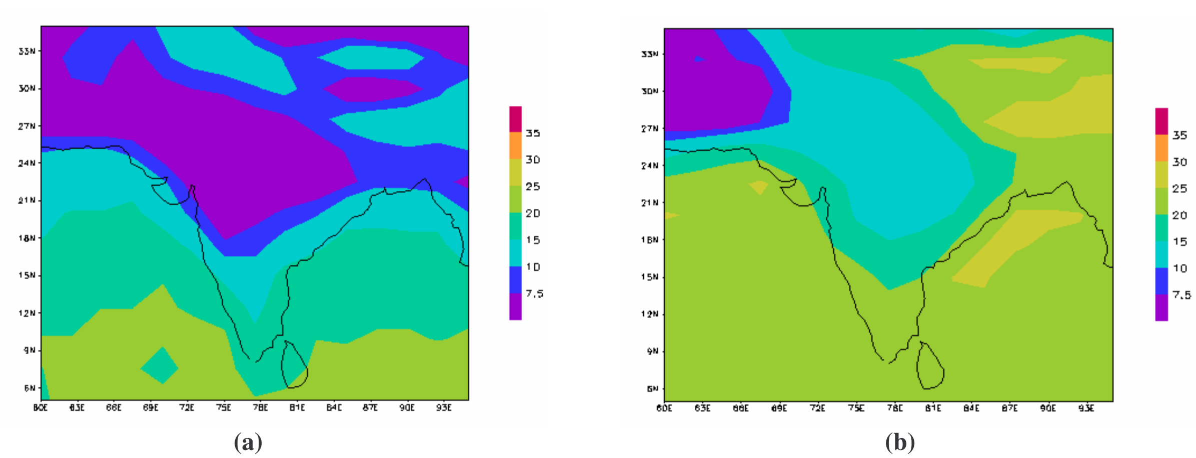


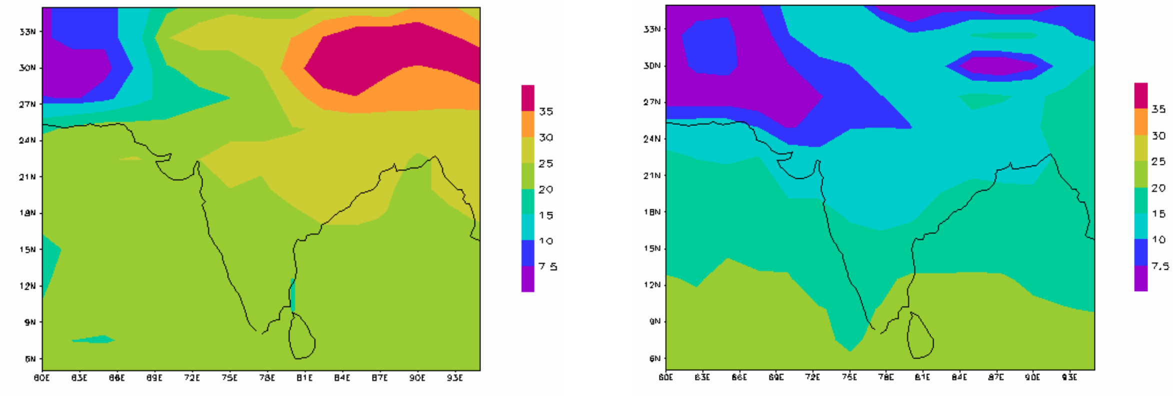
Fig. 2 Specific attenuation (dB/km) for annual average availability of 99.5% at (a) 30 GHz (b) 20GHz

GASEOUS ATTENUATION:

Attenuation by atmospheric gases depends on frequency, elevation angle, and altitude above sea level and water vapour density. It is relatively small compared to rain attenuation. Frequency below 10GHz it may normally be neglected, however it is significant above 10GHz, especially for low elevation angles. Water vapor is the main contributor to gaseous attenuation in the frequency range below 30GHz with a maximum occurring at 22.5GHz. The attenuation due to oxygen absorption exhibits an almost constant behavior for different climatic conditions, whereas the attenuation due to water vapor varies with temperature and absolute humidity.

Figure 2 show surface water vapour densities (gm/m^3) at 1000 hpa, during different months over Indian region in the year 2004. (Courtesy: National Centre for Environmental Prediction (NCEP), NOAA.) . The amount of water vapour densities over Indian region is extremely variable and depends strongly on temperature. The average data of one year is used for calculation of specific attenuation over Indian region using ITU-R model (3).

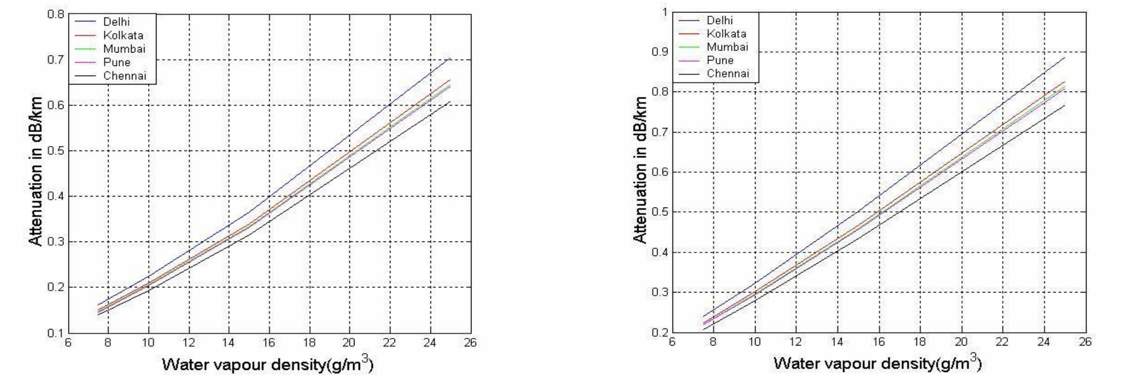




(c) (d)

Fig. 2 Surface water vapour densities (gm/m^3) at 1000 hpa during (a) January to March 2004 (b) April to June 2004 (c) July to September 2004 (d) October to December 2004

Figure 3 shows specific attenuation due to water vapour densities at different locations and for satellite location 83 ^{0}E.

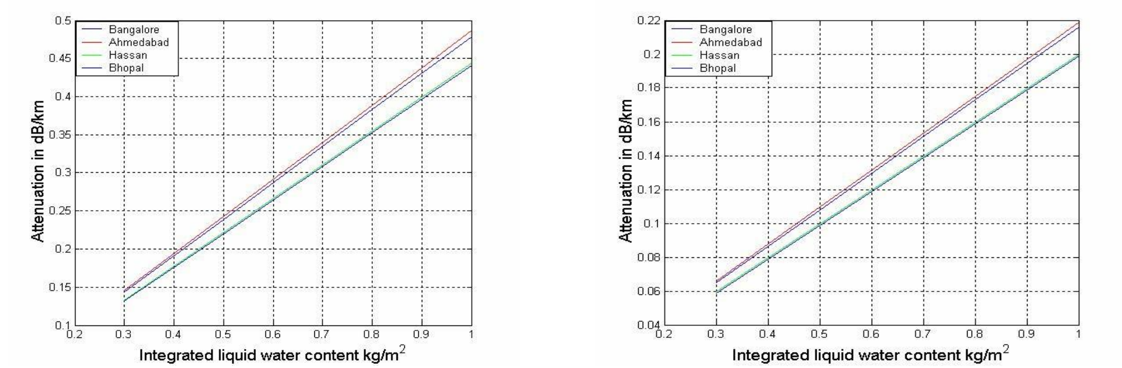


(a) (b)

Fig. 3 Specific attenuation due to water vapour densities at (a) 30GHz(b) 20GHz

CLOUD ATTENUATION:

Cloud attenuation depends liquid water content (LWC) and on the temperature because of its effects on the dielectric properties of water [4]. The attenuation due to ice-clouds can be neglected in the microwave range, although ice clouds should be taken into account for signal depolarization. The content of integrated water vapour varies with geographic locations. Figure 4 shows specific attenuation due to Integrated water vapour content (ILWC), kg/m^2 at different locations for satellite location of 83 ^{0} E.



(a) (b)

Fig. 4 Specific attenuation due to ILWC at (a) 30GHz (b) 20GHz

LINK CALCULATIONS:

Table1 shows a forward link for particular locations of the earth station and terminal for satellite location of 83 ^{0}E:

Table1.Forward link:

Uplink (30GHz)Bangalore (Elevation: 73.83)	Downlink (20GHz) Ahmedabad (Elevation: 60.51)
Antenna diameter (Hub): 6m	Antenna diameter (VSAT): 0.6m
Rain attenuation (dB): 15.5, availability: 99.5%	Rain attenuation (dB): 4.18,availability: 99.5%
Clear sky attenuation(Gaseous & Clouds):0.82	Clear sky attenuation(Gaseous & Clouds):0.74
Carrier data rate: 24.576Mbps	Carrier data rate: 2.048Mbps
E.I.R.P. earth station (dBW): 76.25	E.I.R.P.satellite (dBW): 47.7
G/T satellite (dB/k): 15	G/T earth station (dB/k): 14.42
Eb/No (dB): 16.52	Eb/No (dB): 9.98
Eb/No (dB)(Total): 9.11	

Table 2 shows a return link for the same locations of the terminal, earth station and the satellite

Table2.Return link:

Uplink (30GHz)Ahmedabad (Elevation: 60.51)	Downlink (20GHz) Bangalore (Elevation:73.83)
Antenna diameter (VSAT): 0.6m	Antenna diameter (HUB): 6m
Rain attenuation (dB): 9.8, availability: 99.5%	Rain attenuation (dB): 6.5,availability: 99.5%
Clear sky attenuation(Gaseous & Clouds):0.97	Clear sky attenuation(Gaseous & Clouds):0.61
Carrier data rate: 512 kbps	Carrier data rate: 512 kbps
E.I.R.P.earth station (dBW): 46.26	E.I.R.P.satellite (dBW): 28
G/T satellite (dB/k): 15	G/T earth station (dB/k):33.93
Eb/No (dB): 8.76	Eb/No (dB): 13.74
Eb/No (dB): (Total): 7.56	

For requirement of higher data rate and higher link availability, attenuation due to rain creates major problem .In above example, forward link shows rain attenuation 15.5 dB and return link shows rain attenuation 9.8 dB. It can be compensated by increasing uplink power of earth station (Hub) up to certain limit. However for the return link, VSAT is power-limited. To compensate the attenuation it is necessary to use adaptive fade mitigation techniques such as adaptive coding and modulation.

CONCLUSION:

In tropical regions many factors affect earth-space link. Attenuation due to rain plays a significant role in the design of earth-space links. The values of rain fall rate, water vapour densities and integrated liquid water vapour content (ILWC) strongly varies in tropical regions. For accurate prediction of attenuation it is necessary to perform long-term data measurements of above factors over Indian tropical region.

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