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Temperature and Water Vapor Density Effects On Weather Satellite

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Abstract

There are different factors that affect the strength and reception of a satellite signal. Errors might be made by the satellite or anyone working on it. This can cause a variable level of interference to the signal. There are also circumstances, such as weather which may be impossible to alter, that effect the satellite's signal. All these things can cause interference and make proper operation of the satellite very difficult. In this paper, Temperature and water vapor density effects on weather satellite .
Keywords:Satellite, weather, attenuation, water vapor density, Temperature.

1. Introduction

A communications satellite is an orbiting artificial earth satellite that receives a communications signal from a transmitting ground station, amplifies and possibly processes it, then transmits it back to the earth for reception by one or more receiving ground stations.The most common factor which greatly affects the satellite signals is the weather. Extreme weathers like typhoon, heavy rains, strong winds, thick snow, heavy fogs, thunder, lightning and other related weather conditions will hamper or delay the pick-up or receipt of signals. Hence, this will affect the quality of signals being transmitted.

2. Rain Attenuation

Above about 10GHz, rain attenuation becomes dominant impairment to wave propagation through the troposphere. Extensive efforts have been undertaken to measure and model long-term rain attenuation statistics to aid communication system design. Measured data is necessarily restricted to specific locations and link parameters. For this reason, models are most often used to predict the rain attenuation expected for a given system specification,[4].

3. Noise temperature of an earth station antenna

The noise captured by the antenna consists of noise from the sky and noise due to radiation from the earthFigure(1),[2,3].

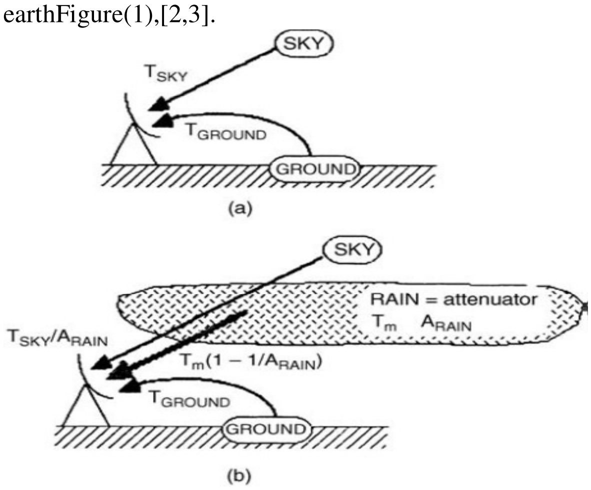

Fig.1.Contributions to the noise temperature of an earth station: (a) clear sky conditions and (b)conditions of rain

3.1 Clear skyconditions

At frequencies greater than 2GHz, the greatest contribution is that of the non-ionized region of the atmosphere which, being an absorbent medium, is a noise source. In the absence of meteorological formations (conditions described as 'clear sky'), the antenna noise temperature contains contributions due to the sky and the surrounding ground (Figure 1a).The antenna noise temperature is thus given by:

$T_A = T_{sky} + T_{GROUND}$(K°) (1)

Where

- T_{GROUND}=290 k° for lateral lobes whose elevation angle E is less than -10°.
- T_{GROUND} = 150 k° for -10° < E < 0°.

- T_{GROUND} = 50 k° for 0° < E < 10°.
- T_{GROUND} = 10 k° for 10° < E < 90

3.2 Conditions of rain

The antenna noise temperature increases during the presence of meteorological formations, such as clouds and rain (Figure 1b), which constitute an absorbent, and consequently emissive, medium. Using equation (2), the antenna noise temperature becomes:

$$T_A = \frac{T_{sky}}{A_{Rain}} + T_m \left(1 - \frac{1}{A_{Rin}}\right) + T_{GROUND} \quad K° \qquad (2)$$

Where A_{Rain} is the attenuation and T_m the mean thermodynamic temperature of the formations in question. For T_m , a value of 275K° can be assumed .

3.3 Calculation of sky noise temperature as a function of attenuation.

The effective sky noise due to the troposphere is primarily dependent on the attenuation at the frequency of observation

$$T_{sky} = T_m(1 - 10^{\frac{-A}{10}}) \quad K° \qquad (3)$$

where T_{sky} is the sky noise and T_m is the mean absorption temperature of the attenuating medium (e.g., gaseous, clouds, rainfall) and A is the specific attenuation,[1].

4.Conversion of relative humidity to water vapor density.

The surface water vapor density p_o (g/m³) at a given surface temperature (T_O) may be calculated from the ideal gas law:

$$P_O = \frac{(RH)es}{0.461(273+T_0)} \qquad (4)$$

where RH is the relative humidity, and e_s (N / m²) is the saturated partial pressure of water vapor that corresponds to the surface temperature T_0 (°C) .
See Figure 2. The relative humidity corresponding to 7.5 (g/m³) at 20°C (86°F) is RH = 0.42 Or 42%,[1]

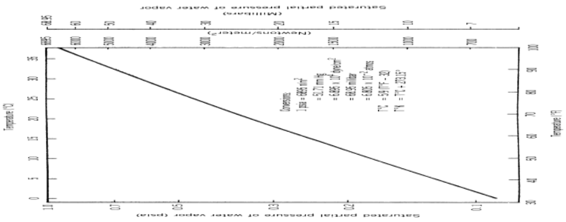

Fig.2 The saturated partial pressure of water vapor versus temperature

5. Excess attenuation due to atmospheric gases on satellite links.(clear air attenuation).

The zenith one-way attenuations for a moderately humid atmosphere (e.g., 7.5 g/m³ surface water vapor density) at various starting heights above sea level are given in Figure 3 and in table (1) .

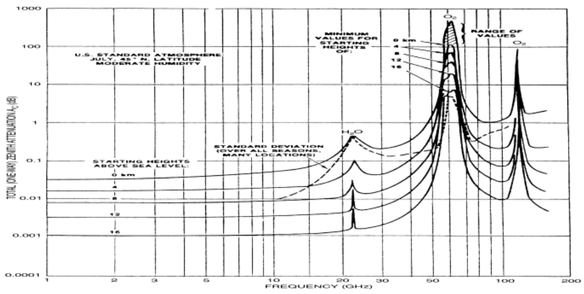

Fig.3 Total zenith attenuation versus frequency

Table (1) Typical one – way clear air total Zenith attenuation values (7.5 g/m³ H_2O,July , 45°N latitude,21°C)

Frequency (GHz)	Altitude				
	0 km	0.5 km	1.0 km	2.0 km	4.0 km
10	0.055	0.05	0.043	0.035	0.02
15	0.08	0.07	0.063	0.045	0.023
20	0.30	0.25	0.19	0.12	0.05
30	0.22	0.18	0.16	0.10	0.045
40	0.40	0.37	0.31	0.25	0.135
80	1.1	0.90	0.77	0.55	0.30
90	1.1	0.92	0.75	0.50	0.22
100	1.55	1.25	0.95	0.62	0.25

The water vapor content is the most variable component of the atmosphere. Corrections should be made to the values derived from Figure(3) and Table (1) in regions that notably vary from the 7.5 g/m³

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value given Such regions would be arid or humid, jungle or desert. This correlation to the total zenith attenuation is a function of the water vapor density at the surface *p*0 as follows:

ΔA_{c1} $= b_p$ (p_o - 7.5 g/m³) (5)

Where ΔA_{c1} is the additive correction to the zenith clear air attenuation that accounts for the difference between the actual surface water vapor density and 7.5 g/m³. The coefficient b_p is frequency dependent and is given in Figure 4. To convert from the more familiar relative humidity or partial pressure of water vapor. The surface temperature *T*0 also affects the total attenuation because it affects the density of both the wet and dry components of the gaseous attenuation,[1,3]

ΔA_{c2} $= c_T$ (21° - T_0) (6)

Where ΔA_{c2} is an additive correction to the zenith clear air attenuation. Figure 4 gives the frequency-dependent values for c_T . The satellite earth terminal elevation angle has a major impact on thegaseous attenuation value for a link. For elevation angles greater than about 5°, the zenith clear air attenuation value *Ac* is multiplied by the cosecant of the elevation angle θ . The total attenuation for an elevation angle θ is given by:

$A_c = A'_c \csc\theta$ (7)

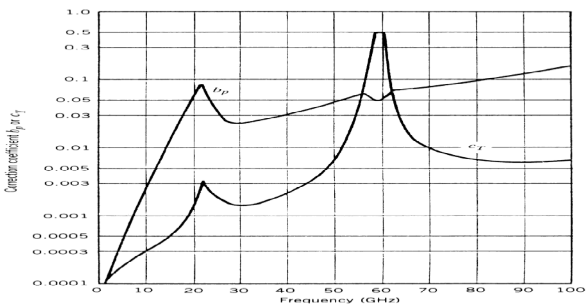

Fig.4 water vapor density and temperature correction coefficients

6. Results and Discussions

To compute the attenuation effects on satellite, noise temperature of an earth station (Conditions of rain), water vapor density and calculation of clear air attenuation a Matlab program has been written and obtained results as given below:

6.1 Computed factors

The computed result of the Matlab program are follows:

θ: the elevation angle to the satellite, in degrees =25

h_s: the altitude of the ground station above sea level, in km = 0.25

Φ: the latitude of the ground station, in degrees N or S = 25

h_R: rain height at the ground station of interest = 4.5348

L_s : the slant-path length = 10.1388 Km

L_G : the horizontal projection = 9.1888 Km

rp : the reduction factor = 0.7100

R_p : the rain rate distribution = 22

k : dependent variables, each of which are functions of frequency, elevation angle, and polarization tilt angle = 0.00887

α : dependent variables, each of which are functions of frequency, elevation angle, and polarization tilt angle = 1.264

β_R : the specific attenuation = 0.4413

$A_{0.01}$: the predicted attenuation exceeded for 0.01% of an average year = 3.1769

p : , exceeded for other percentages = 0. 1

A_p : the attenuation, Ap, exceeded for other percentages, p = 1.2360

Tm: absorption temperature of the attenuating medium = 275 db

T_{sky} : the sky noise = 68.1117 K°

T_{GROUND} = 10 K°

TA : the antenna noise temperature = 117.6104 K°

RH: the relative humidity = 0.5

e_s: the saturated partial pressure of water vapor =2300 N / m²

To: the surface temperature = 20°C

p_o: The surface water vapor density = 8.5139 (g/m³)

total zenith attenuation from table (1) = 0.24db

bp: The coefficient b_p is frequency dependent and is given in Figure 4 = 0.05

ΔA_{c1} is the additive correction to the zenith clear air attenuation that accounts for the difference between the actual surface water vapor density and 7.5 g/m³ = 0.0507 db

cT: the frequency-dependent values for c_T is given in figure 4 = 0.0015

ΔA_{c2} is an additive correction to the zenith clear air attenuation = 0.0015 db

clear air zenith attenuation A'_c = 0.2922 db

The total attenuation for an elevation angle θ = 0.6914 db.

6.2 Discussion

It is clear that the relationship between time accumulation of rain (percentage) is nearly inversely proportional and less attenuation values are obtained as rain duration get longer, fig(5).

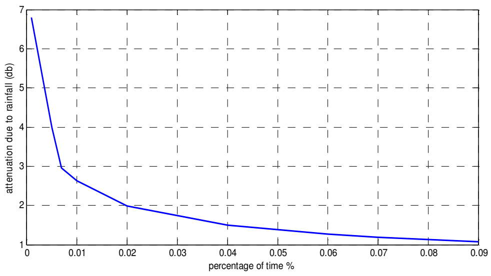

Fig.5percentage of time and attenuation due to rainfall

When attenuation due to rain increase the sky noise temperature and antenna noise temperature increase and this is obvious in fig(6).Also the increase of sky noise temperature is proportional to antenna noise temperature as shown in fig(7).

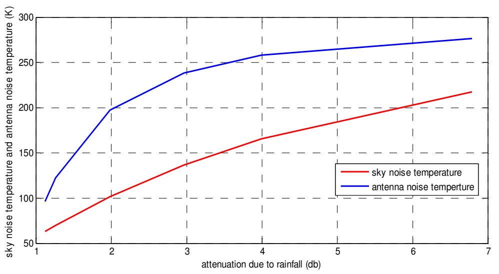

Fig.6 condition of rain.

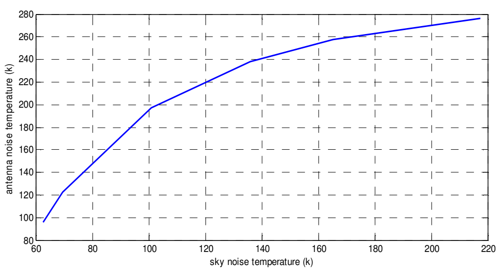

Fig.7 sky noise temperature and antenna noise temperature

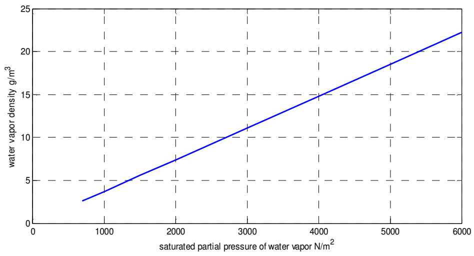

Fig.8saturated partial pressure of water vapor and water vapor density

For saturated partial pressure of water vapor situation the relationship is approximately linear with proportionality as in fig(8).

7. Conclusion

This paper discusses effects of temperature and vapor on the received satellite signal. It has been found that the attenuation is reduced by longer rain time. On the other hand attenuation show proportional with curvature behavior when related to antenna noise temperature while linearly proportional relationship is observed between attenuation and sky noise temperature.
Water vapor density and saturated partial pressure of water vapor are in linear relationship whereas sky noise temperature and antenna noise temperature show curvature relationship with proportional tendency.
In conclusion, longer rainfall duration will deteriorate the signal continuity and temperature effect is manageable.

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