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The Impact of Water Vapor in Atmosphere on Ku Band Satellite DTV Reception in a Sub-Tropical Region

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Abstract: Southeast Asia, which is located near the equatorial region. The temperature and humidity are always high throughout the year. The atmospheric noise in clear sky (clear sky noise) is high. There are frequently the mosaic patterns in a Ku band Satellite DTV screen in the fine weather.

In this paper, clear sky attenuation on a satellite-earth path at frequency Ku band in a sub-tropical region is described. The measurement results show that diurnal clear sky noise vary with respect to the water content concentration characteristics, which has the significant value in early morning and low at daytime. During high clear sky noise when the scintillation is appeared, the mosaic patterns are observed in the DTV.

1. Introduction

Lao P.D.R and Thailand are located in sub-tropical region and near the equator. The temperature and humidity are always high throughout the year, which has a maximum mean humidity at about 90%, as well as high temperatures exceeding 30 degrees during the rainy season [4], [5].

At the present, the satellite DTV broadcast in Ku band can be directly received by using a small aperture antenna in homes. Use of this type of antenna is constantly increasing in this region. Scintillation is most severe in the equatorial region, within 20^o of the magnetic equator, north and south, and in high latitudes [7]. Scintillation phenomena generally increase in proportion to reductions on the antenna aperture [9]. There are frequently the mosaic pattern occur in a Ku band Satellite DTV screen in the fine weather. In order to provide good quality reception, the effect of these environmental factors needs to be observed. To respond to theses needs, this paper discussed the phenomena associated with signal attenuation due to the water content in atmosphere and to quantify the impact of these environmental factors on signal propagation.

2. Noise temperature

The overall noise temperature of a receiving system is determined by: antenna noise temperature, feed line loss and converter noise temperature. Recently, in the Ku band satellite received antenna using small aperture, the converter noise figure lowered at 0.6-0.7 dB. Noise figure of the converter is related to the equivalent noise temperature T_e as shown [8]:

$$T_e = (F-1)\, T_o \quad (K) \tag{1}$$

where F is the noise figure, which is usually expressed in dB, and T_o is ordinary temperature 290K

For the small aperture satellite received antenna, the waveguide is very short length, feed line losses is negligible. The system noise temperature T_s of the receiver becomes

$$T_s = T_a + T_e \quad (K) \tag{2}$$

where T_a is antenna noise temperature.
Antenna noise temperature can be calculated by [8]:

$$T_a = T_m\,(1 - \frac{1}{L}) \quad (K) \tag{3}$$

where L is the loss factor due to the absorbing medium. Its value is proportional to the atmospheric attenuation. T_m is a mean path temperature. If L is expressed in dB, then

$$T_a = T_m\,(1 - 10^{\{-A(dB)/10\}}) \quad (K) \tag{4}$$

where A is the atmospheric attenuation which is expressed in decibels.

From the equations as mentioned above yields the relationship between the antenna noise temperature, atmospheric attenuation and equivalent noise figure as shown in Fig.1.

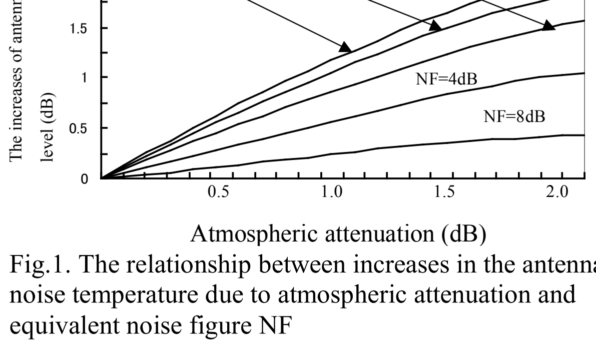

Fig.1. The relationship between increases in the antenna noise temperature due to atmospheric attenuation and equivalent noise figure NF

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Fig.1 shows that when low noise figure converter is used. As atmospheric attenuation increased, the antenna noise level increased sharply. However, a receiver having a large noise figure did not show a large increase in the antenna noise level with an increase in atmospheric attenuation.

3. Weather parameters and clear sky noise in Laos

3.1 Temperature and humidity

The radiometers were installed at the Electronic Dept, Faculty of Engineering, National University of Laos in Vientiane, Laos, at (Lat 17° 58 ′ N, Long 102 ° 36 ′ E), 175m above mean sea level (msl). The signal and clear sky noise levels have been obtained by using offset parabolic antenna with diameter 45 [cm]. The noise figure of receiver is 0.6 dB and standard reference temperature 290K, which is carried out from early 2003 to the present. The radiometers were pointed in the direction of the THAICOM satellite, whose operation frequency Ku band with elevation angle 57 degrees. Clear sky noise temperatures were sampled in every minute and stored in laptop computer in term of voltages and these raw data have been sent to Tokai University, Japan for analysing. In addition to the rain rate, sunshine, ambient temperature as well as relative humidity has been measured at this location. The information from rain gauge has been utilised to identify the period that there is no rain along the propagation path. The measurement results of data obtained are shown in Fig. 2 and Fig.3

Fig.2 shows the diurnal variations in temperature and humidity of the days, which were no rain (monthly mean curves for August 2003) at Vientiane, Laos. The temperature values are usually low at midnight, decreasing in the early hours of the morning, and then increasing rapidly until just after midday. It then decreases during the night. As the temperature increases the relative humidity usually decreases or vice versa. The daily average maximum temperature is about 32.7°C and minimum 25.5°C followed by the maximum humidity 90% and minimum 60%.

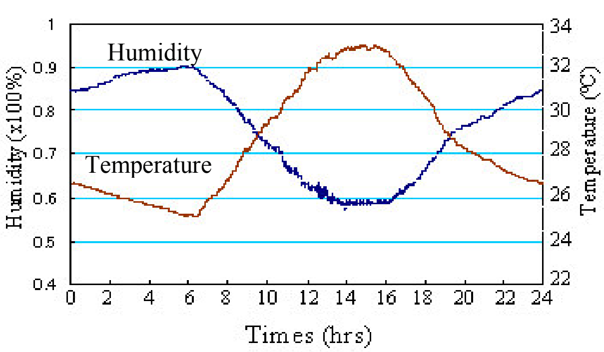

Fig.2. Typical diurnal variation in temperature and relative humidity during August, 2003. (The days there were no rain) Vientiane, Laos.

3.2 Atmospheric noise in clear sky

Clear sky attenuation is mainly due to absorption caused by water vapour and oxygen molecules. It increases with the relative humidity as well as the temperature. The water vapour concentration is strong function of temperature and humidity. From the relative humidity and ambient temperature the absolute water vapour concentration ρ_w expressed in g/m^3 at ground level can be calculated by the following equation [3]:

$$\rho_w = 216.7\, (E)/(T_K) \qquad (g/m^3) \qquad (5)$$

where T_K is the absolute temperature (°K), E is the water vapour pressure (hPa). The relative between water vapour pressure E and relative humidity is given by [1]

$$E = (U\, E_S)/(100) \qquad (hPa) \qquad (6)$$

where U is the relative humidity (percent), E_S is the saturated vapour pressure (hPa) which can be approximated as a function of temperature t is given by [2]:

$$E_S = 6.11 exp[\,(19.7t)/(t+273)] \qquad (hPa) \qquad (7)$$

Eq.5 is used for approximation ρ_w as results are shown in Fig.3, which corresponded to 20-24.3 g/m^3 of water vapour concentration in the clear sky.

Fig. 3 shows the measurement results of clear sky noise and calculated results of water vapour concentration in clear sky for one month August 2003, which is selection of the day there were no rain (15 days). The results show that the peak value of diurnal variation of clear sky attenuation is in early morning, which is low in daytime, but the night-time it increases again. The characteristics are similar behaviour to each other. Clear sky noise with low value at about 3:00pm and peaks at about 6:00 am when relatively higher levels of absolute humidity are observed. The variation of clear sky noise in every month is the same characteristic and also the difference between dry and wet season was not found. The atmospheric noise characteristic that we measured at KMITL in Bangkok Thailand, its characteristic is mostly same as Vientiane, but only in afternoon time fluctuations were slow. It is because of antenna elevation was lower was 32 degrees.

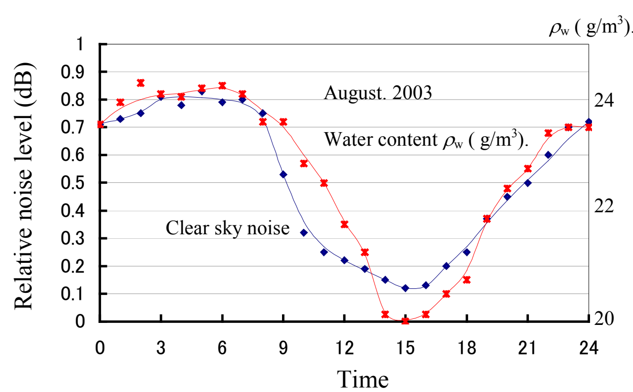

Fig.3. The diurnal variation in clear sky noise and water vapour concentration during August, 2003 at Vientiane, Laos.

A comparison of the diurnal pattern of humidity and water vapour concentration with the daily variation of the clear sky attenuation shows that the clear sky attenuation pattern is similar to the water vapour concentration pattern. Therefore, the clear sky attenuation along slant path may be estimated from ground-based humidity measurements [3]

As shown in Fig.3, the peak value of diurnal variation of clear sky attenuation is in early morning. As compared to rain attenuation is relatively small, but cannot be neglected for frequency above 10GHz in particular, where the location which has high humidity and temperature.

Vientiane, Laos, the region, where the temperature is always high throughout the year. During March to December, the maximum temperature ranged from 30-38^{o}C and minimum 20-25^{o}C. The yearly variation of the meteorological environment is not so much different, except for January and February and temperature is fairly low. The maximum is 32^{o}C and minimum 15^{o}C [4]. The relative humidity is very high over whole year, with average daily values from 60% to 95% [4], corresponding to 20-35 g/m^3 of water vapour content in the clear sky.

Absorption due to due to water vapour varies slowly with time in response to variations in the water vapour content in the atmosphere. As such, the gaseous absorption increases with the relative humidity as well as the temperature. Consequently, the total clear sky noise varies with respect to water vapour concentration ρ_w (g/m^3).

Fig.4 shows an atmospheric noise levels of the last six days year 2003, the date 26 to 31 December, which is dry season with lower temperature in one year period at Vientiane, Laos. The mean average humidity of this month in Vientiane is about 70% and 74% in Bangkok, Thailand [4], [5].

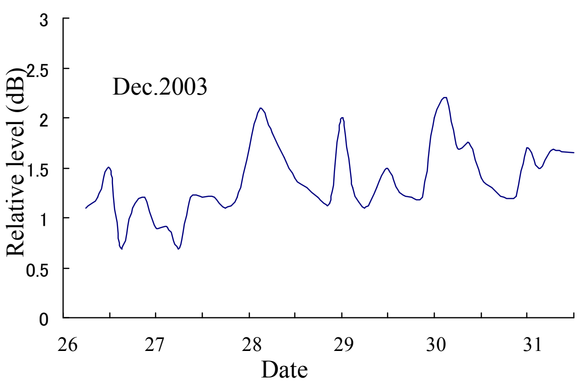

Fig.4. The atmospheric noise levels of the last six days of year 2003 at Vientiane, Laos.

4. Antenna elevation angle and clear sky noise attenuation

Fig.5 shows the measurement results of atmospheric noise of different type of antenna. We used two kinds of antenna offset parabolic and centre feed antenna with the same aperture size of 45 cm in diameter. The measurements were carried out in Vientiane Laos for a short time in December 22, 2003 at 14:00 for offset parabolic, and December 20, 2003 at 11:20 for centre feed antenna. During the two times of measurement, the weather was the same condition, mainly dry with daytime temperature the 22-26^{o}C range and humidity was 45% - 65%. The objective of the measurement was to compare antenna noise characteristics of two type antennas when change of elevation angle.

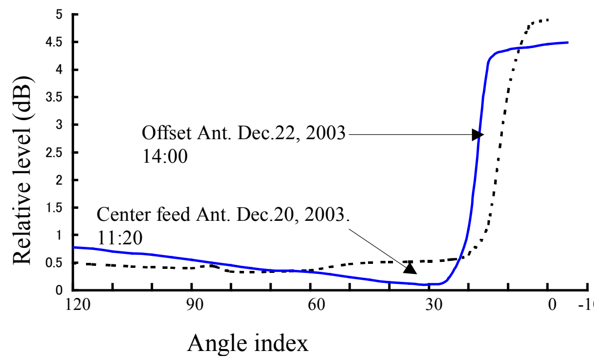

Fig.5. Comparison of antenna noise characteristics between offset parabolic and centre feed antenna

The measurement results indicate that atmospheric noise of offset parabolic antenna gradually decreases, reaches the minimum value when the elevation angle is between 30-40 degrees. Then drastically increases when elevation angle was about 25 degrees, reaching to maximum value when elevation angle was less then 20 degrees as shown in solid line Fig.5. The dotted line is the centre feed antenna atmospheric noise, which indicated that the value is almost constant and suddenly increases when the elevation angle is lower than 15 degrees.

The atmospheric noise measurements with different elevation angles, zenith direction (90^{o}), horizontal direction (0^{o}) and ground direction (-10^{o}) using a centre feed antenna 45cm in diameter, were performed at faculty of Engineering, National University of Laos, located in the southeast of the capital about 3.5 km.

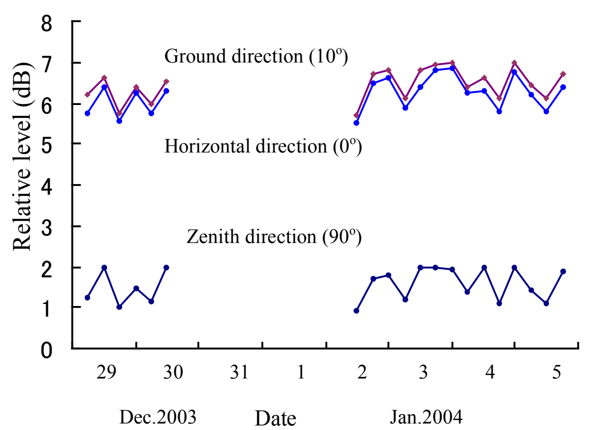

Fig.6. The diurnal variation of atmospheric noise with different elevation angle during last days of 2003 and early days of 2004 at Vientiane, Laos.

The measurement is conducted four times per day, at 6:00am, noon, 6:00pm and midnight in clear weather condition, which carried out two times in short period was one and half day, dated 29 and 30 December 2003 and three and half days on January 2004 were date 2, 3, 4 and 5. The measurement results indicate in Fig.6 that show the interval of diurnal variation of atmospheric noise is about 1dB, and their characteristics are similar each other. The characteristic variations correspond to the change of the weather condition of circumference.

5. Appearance of mosaic patterns in DTV screen

According to the POST-PARTNERS project between communications research laboratory (CRL), Japan and KMITL, Thailand. We designed a test plan and set up measurement system to conduct the field test. The main purpose was to measure the performance of the Ku band Satellite DTV reception in Thailand and Japan. The measurement system is equivalent condition and the same weather condition (fine weather).

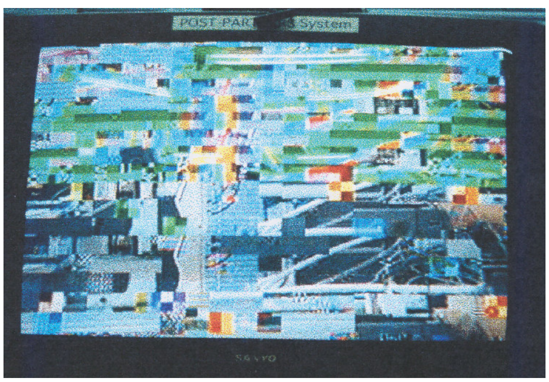

Fig. 7. The mosaic patterns appear in a satellite DTV in Thailand

The test results can be found that satellite DTV signal with good reception quality in Japan, but in Thailand there were mosaic appearances in DTV

The mosaics occurred on satellite DTV in Thailand as an atmospheric noise level was about 2dB and scintillation level changed around 3dB. Both phenomena occur at the same time. The clear sky attenuation, which has level about 2 dB is observed in Vientiane Laos. The scintillation phenomena of Ku band is measured by using small aperture antenna offset parabolic 50 cm in diameter with high elevation angle of satellite THAICOM-2 at KMITL, Bangkok Thailand. The product of fluctuation of the scintillation values is about 4.5dBp-p. Scintillation phenomena generally increase in proportion to reductions on the antenna aperture [9]. The occurrence numbers of scintillation widely vary depending on months. In addition, the occurrence number in the daytime is largely different from that in the night-time. The scintillation level fluctuation has a certain relation with the temperature [9]. The mosaic patterns are observed in the DTV as shown in Fig. 7

6. Summary and conclusions

In Laos and Thailand, water vapour content in the atmosphere is high due to high temperature and humidity. Which in turn causes the higher clear sky noise temperature. The measurement results show that the clear sky noise and humidity characteristics have similar behaviour to that of the calculated results of water vapour concentration. The diurnal clear sky attenuation increases at the night time to early morning and lower at daytime. The different mean value of variation is about 0.7 dB.

The Ku band satellite DTV signals are received from THAICOM satellite by using small aperture antennas. When the scintillation is appeared in addition to the high clear sky noise temperature in early morning. The mosaic patterns are observed in the DTV.

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