Clear Sky Noise on Satellite DTV Reception at Ku Band in Southeast Asia Region

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1. Introduction

Laos is located in Southeast Asia at tropical region and near the equator. The temperature and humidity are always high throughout the year. The yearly variation of the meteorological environment is not so much different. The monthly averages a year are ranges from 23°C to 29°C in temperature and 67% to 85% in humidity [1]. Currently, using of small aperture antenna with very low noise figure is constantly increasing in Southeast Asia countries to receive satellite digital television broadcasting in Ku band at homes. The noise figure (NF) is currently in the value of as low as 0.45dB. When receiving satellite signals by these antennas, atmospheric noises are easily received. Radio wave propagation with frequencies above 10 GHz is significantly affected not only by rain, but also by water vapor in atmosphere. Therefore the effects of the atmospheric noise in frequencies above 10 GHz could not be neglected especially in regions where humidity and temperature are constantly high.

2. Atmospheric Noise on Satellite Broadcasting

There are two kinds of noise in satellite communication system such as atmospheric noise and man-made noise. The atmospheric noise is a noise collected by the antenna which can be received from any sources that enters through the receiving antenna, including noise due to absorption and radiation of energy by water and oxygen molecules in atmosphere and the man-made noise is noise due to arising of temperature of components inside the both receiver and transmitter.

Radio wave absorption due to constituents of atmosphere in the satellite propagation path includes rain attenuation and attenuation due to atmospheric gases, acts as causes for increasing antenna noises of receiver. Its value changes accordance with atmospheric condition. Equations (1) and (2) are widely used as the mathematical relationship between antenna noise temperature (T_n), and the total atmospheric attenuation A(dB) existing on propagation path.

$$T_n = T_o (1 - 10^{-[A(dB)/10]}) \quad (K) \qquad (1)$$

where T_o is earth surface temperature, in K.

Relation obtained by equation (1) is shown by solid line in Fig. 1. Due to the noise is dependent on the mean path temperature (T_m), and the temperature is not uniform on the propagation path, Altshuler et al [2] developed an expression for estimating the mean path antenna noise temperature from the surface temperature, which is defined as:

$$T_n = T_m (1 - 10^{-[A(dB)/10]}) \quad (K) \qquad (2)$$

where T_m is expressed as follows:

$$T_m = 1.12T_o - 50$$

Relation obtained by equation (2) is shown by dotted line in Fig. 1. As compared two curves, antenna noise temperature is considerably coincident at atmospheric gas attenuation less than 2 dB. Therefore, from practical viewpoints, either equation (1) or (2) may be used for determining clear sky attenuation.
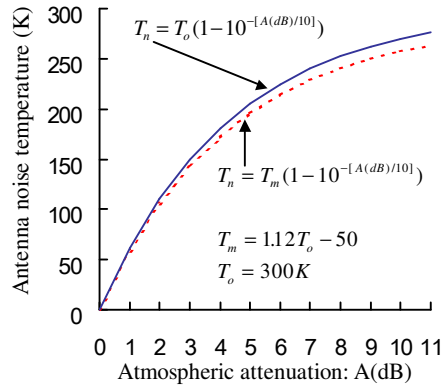

Graph axes: Antenna noise temperature (K), vertical axis from 0 to 300. Horizontal axis: Atmospheric attenuation: A(dB), from 0 to 11.

$$T_n = T_o(1 - 10^{-[A(dB)/10]})$$

$$T_n = T_m(1 - 10^{-[A(dB)/10]})$$

$$T_m = 1.12T_o - 50$$

$$T_o = 300K$$

Fig. 1 Antenna noise temperature as a function of atmospheric attenuation on a slant path.

3. Clear Sky Noise Characteristics in Vientiane

3.1 Measurement

The clear sky noise attenuation has been measured since early 2003 at Department of Electronics Engineering, Faculty of Engineering (FE), National University of Laos (NUOL) in Vientiane, Laos, at (Lat $17^o 58'$ N, Long $102^o 36'$ E), 175m above mean sea level (msl). There are three-store building and tropical trees in this area. In order to reduce effects of thermal noises from these surrounded environments, an antenna is mounted on the top of 11 m height tower. An offset parabolic antenna 45 cm in diameter with noise figure of 0.6 dB was set to have elevation angle of 59 degrees. The direction of antenna is identical with that of the stationary satellite located in southeast direction, and its bearing was shifted by 5 degrees in east direction to avoid incidence of satellite signals.

The clear sky noise was measured with frequency of 12.01 GHz. Clear sky noise temperatures were sampled every minute and stored in a laptop computer in terms of voltages. In addition, the rain rate, sunshine, ambient temperature, and relative humidity are also measured. The information from the rain gauges has been utilized to identify periods with no rain along the propagation path. The period of one hour before and after rainfall were excluded from this analyzing.

As for noise level, 1 GHz output frequency of the LNB was carried to inside a building, using coaxial cables and connected to the spectrum analyzer or broadband analyzer. Data were obtained with settings of the spectrum analyzer; central frequency was set to 1320 MHz, frequency span to 50 MHz, resolution bandwidth to 300 KHz, video bandwidth to 100 Hz, and sweep time to 5 sec. Broadband receiver (DX Antenna, DSA-464EII) with bandwidth 30 MHz was used, and noise generator (Tamagawa Electronics, TSG-106) was used for level calibration. To ensure stability of the receiver with regard to the outside air temperature, a directional coupler (directivity coupling factor for 12 GHz is 8.8 dB) was connected to the LNB, and measurements were taken for two days every two months using the noise diode (E.T.N. Advanced Electronics, P/N 7626) as the reference level (15.19 dBK for 12 GHz). The stability obtained by this configuration was within 0.1 dB. In the outside area at Vientiane, air temperature varies little throughout the year.

3.2 Clear Sky Noise Attenuation

Clear sky noise attenuation is mainly due to absorption caused by water vapor and oxygen molecules. It increases with the relative humidity as well as with temperature. The water vapor content in air is a strong function of temperature and humidity [3]. From the relative humidity and ambient temperature the absolute water vapor content ρ_w expressed in g/m^3 at ground level can be calculated by the following equation [4]

$$\rho_w = 216.7E/T_k \ (\text{g/m}^3) \qquad (3)$$

where T_K is the absolute temperature (K) and E is the water vapor pressure (hPa). The relation between water vapor pressure E and relative humidity is given by E=(UE$_S$)/(100), where U is the relative humidity (%) and E_S is the saturated water vapor pressure (hPa) which can be approximated as a function of temperature t, and is given by $E_S = 6.11\exp[(19.7t)/(T_K)]$.
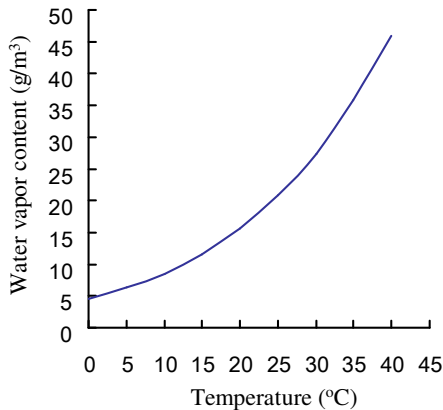
Fig. 2 Dependence of water content in the atmosphere on surface temperature.
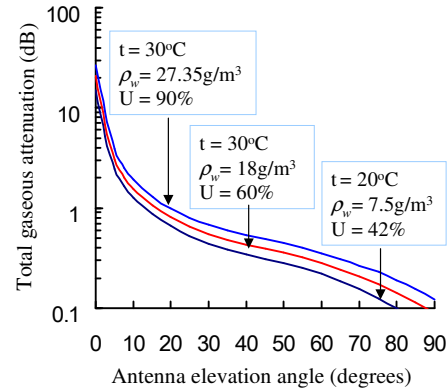
Fig. 3 Total gaseous attenuation in the atmosphere

Fig. 2 shows water vapor in the atmosphere with surface temperature between 0 and 45 degrees. Relative humidity is considered to be 90%. When the temperature is near and above 30 degrees, the water vapor content fairly quickly increases. Fig. 3 shows cumulative distribution of total gaseous attenuation to the antenna elevation angles, in case of temperature (t), water vapor content (ρ_w) and relative humidity (U) which are assumed to be the fixed parameters. Gaseous attenuation gradually increases when elevation angle decreases. It suddenly increases at antenna elevation angles below 10 degrees.

3.3 Measurement results

Clear sky noise level in Vientiane was checked every month throughout a year. The data for months that are considered to be noteworthy are shown in Fig. 4 and Fig. 5. The variable characteristic is nearly same trend in every month reaches the maximum in early morning and minimum in the daytime during midday to 15:00. In Fig. 6 diurnal relative humidity at Vientiane in 2004, which shows that diurnal variation characteristic in each months is similar. High humidity is in July (rainy season) and low in March (dry season). Diurnal variations of clear sky noises are compared to the diurnal variations of humidity and water vapor in [3]. The results show that their characteristics are similar behaviour. Also, the relationship between diurnal variation of clear sky noise and water vapor in atmosphere is given in Fig. 7 which indicates that a high correlation occurs during midnight to early morning where clear sky noise is high and with low correlation is during 9:00 to noon where the density of water vapor and humidity are low. The total correlation coefficient is about 0.93.
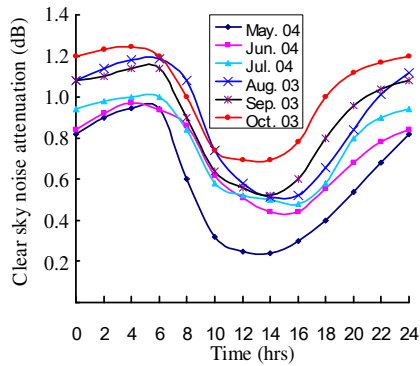
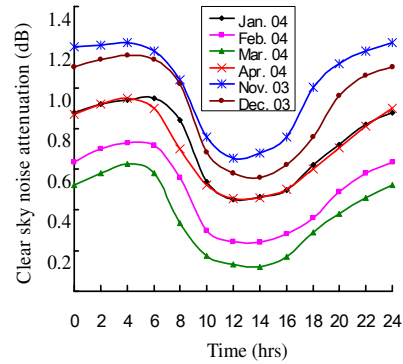**Fig. 4** Diurnal variation in relative value of clear sky noise in wet season at Vientiane, Laos.

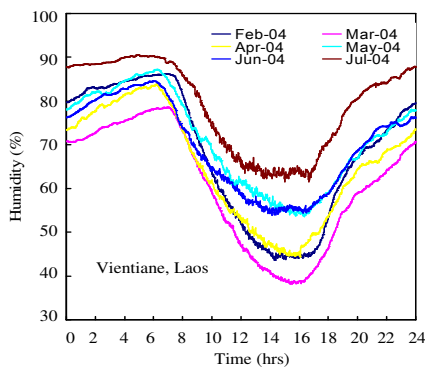**Fig. 5** Diurnal variation in relative value of clear sky noise in dry season at Vientiane, Laos.

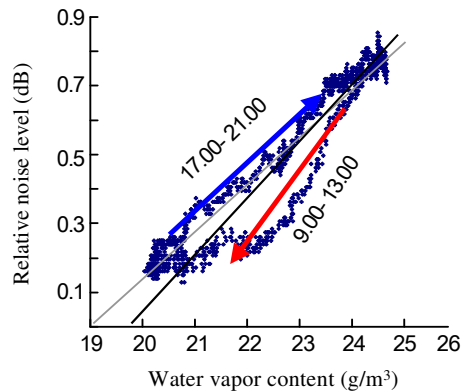**Fig. 6** Diurnal variation of relative humidity at Vientiane, Laos.

Fig. 7 Relationship between diurnal variation in clear sky noise and water vapor at Vientiane

4. Conclusions

At present, noise figure of the receiver for digital satellite television is being reduced, and NF of 0.45 dB has been realized in the Ku band broadcasting. When antenna with lower noise figure is used, amount of level fluctuation of the atmospheric noises is high even on fine day. The clear sky noise level is high in Southeast Asia where temperature and humidity are high and the atmosphere eventually contains much amount of water vapor. The clear sky noise characteristics are similar behaviour with humidity and water vapor with correlation coefficient is more than 0.9. The difference of mean diurnal variation of clear sky noise is about 0.7 dB. And in very near future, the Ka band will be used for new satellite broadcasting band. Therefore the compensation of clear sky noise attenuation should be needed to clarity.

References

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