CN RATIO CHARACTERISTICS OF KU-BAND ANTENNA

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ABSTRACT

For individual reception of the satellite broadcasting in Ku-band, small aperture antenna having about 50cm in diameter are used. As the radiation patterns are wide in small aperture antenna, those are to be affected by ambient noise sources, and the noise temperature of antennas tends to rise. This effect is larger when the noise factor of receivers is lower. When a receiver with lower noise figure is used, amount of CN ratio fluctuation of the atmospheric noises is excessive even on a fine day and noise level is high in Southeast Asia. When scintillation phenomena occurred during high atmospheric noise, the CN ratio fell more.

1. INTRODUCTION

Digital satellite broadcasting is used in many countries. For house-to-house reception of the digital satellite broadcasting in Ku-band, small-aperture antennas having about 50 cm diameter are used. In Laos and Thailand, mosaic patterns appear on the screen for receiving digital satellite broadcasting. Receiving troubles have been reported in visual images transmission by digital satellite broadcasting [1]. The latest antenna investigated influence with the atmospheric noise given to the CN ratio.

When receiving satellite signals by a small-aperture antenna, atmospheric noises are easily received since its directivity covers a broad range. In the meantime, the noise figure (NF) of receivers has been decreasing year by year and it is currently in the range of as low as 0.4 ~ 0.6 dB for small-aperture antennas. The CN ratio was examined from the characteristics of a noise figure and atmospheric noise. In the tropical zone, air temperature and humidity are high throughout the year and the amount of water vapour contained in the atmosphere is higher all the time than that in the temperate zone.

In conclusion, the noise figure is low and the large antenna of the CN ratio is always affected by the influence of atmospheric noise.

2. EFFECT OF ATMOSPHERIC NOISE

Radio wave absorption due to atmospheric gas in Ku-band is caused by oxygen, water vapour molecules, and clouds. Absorbed substances generate thermal noises and are therefore added to the signal as antenna noise. As a result, rainfall attenuation, clouds, and atmospheric gas absorption act as causes for increasing antenna noises of the receiver. Equations (1) and (2) are used widely as the mathematical relation between antenna noise temperature and attenuation (L) existing on the propagation path.

$$T_n = T_o(1 - L) \qquad (1)$$

where Tn denotes antenna noise temperature (K) and To denotes earth surface temperature (K). Relations obtained by Equation (1) are shown by solid lines in Fig. 1. Since temperatures are not uniform on the propagation path, the following equation proposed by Altshuler et al. [2] is also used where To is replaced by Tm.

$$T_n = T_m(1 - L) \qquad (2)$$

Tm is expressed as follows:

$$T_m = 1.12T_o - 50 \qquad (3)$$

Relations obtained by Equation (2) are shown by dotted lines in Fig.1

Amount (L) of atmospheric gas attenuation is considerably smaller than rain fall attenuation. Therefore, from practical viewpoints, either Equation (1) or (2) may be used. In this paper was used Equation (1). Kinpara introduced an equation for obtaining values close to the observation [3]. This equation is best suited for obtaining rain fall attenuation, but Equation (1) can be used for the case where attenuation of gas existing in the atmosphere is small. Otsu checked how Tm was changed depending on earth surface temperature and humidity [4]. This study showed that there is a difference in Tm depending on earth surface temperature. This should be taken into considerations for rain fall resulting in much attenuation.

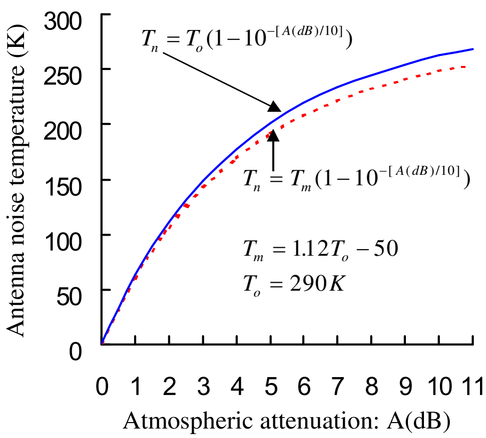

Figure 1. *Relationship between sky noise temperature and atmospheric attenuation*

Attenuation by oxygen in Ku-band is kept sufficiently away from the absorption around 60 GHz and can be neglected. Attenuation of oxygen for 11 GHz in Japan is calculated to be approximately 0.04 dB in zenith angle [5]. It is considered in this paper that atmospheric attenuation always includes attenuation by oxygen.

There is substantially no long-term observation data for atmospheric noises in Ku-band. The following experimental data are derived from the results of measurement of 11 GHz taken in Japan using an antenna having 1.5 m diameter.

$$Lm11(dB) = 0.0066\rho s+0.0425 \qquad (4)$$

where ρs denotes water vapour content on the surface ρw (g/m^3). ρw is expressed as follows:

$$\rho w = 2.17(U \cdot E)/T \qquad (5)$$

where U denotes relative humidity (%), E denotes saturated vapour pressure (mb), and T denotes temperature (K) in the absolute temperature. Fig.2 shows water vapour content in the atmosphere with temperature between 20 and 30 degrees. Relative humidity is considered to be 42% to 90%.

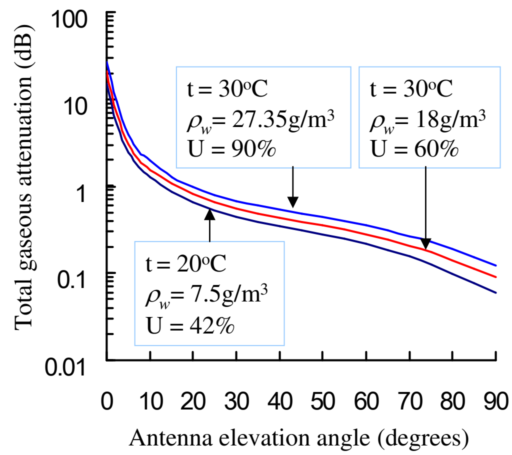

Figure 2. *Attenuation due to water vapor content in the atmosphere*

When the temperature near 30 degrees, water vapour content increases suddenly. Maximum average monthly relative humidity in Vientiane, capital of Laos is more than 85% throughout the year, and maximum average temperature is 29.1 degrees (April) [6]. In Bangkok, Thailand, maximum average yearly humidity is 89% and maximum average temperature is 30. 5 degrees (April) [7]. Water vapour content in the atmosphere is substantially high throughout the year since both are located in high-temperature and high-humidity regions. In Tokyo, annual mean temperature is 5.8 degrees and average humidity is 50% in January and the same is 27.1 degrees and 72%, respectively in August [7]. Based on maximum average relative humidity 90% and temperature 30 degrees which are close to the meteorological data obtained in Vientiane and Bangkok, the atmospheric noise is calculated by experimental Equation (4) for atmospheric noise at the zenith angle measured in Tokyo to be 0.101 dB. The atmospheric attenuation in tropical zone thus calculated is about twice the average of Tokyo (0.223 dB).

In the countries close to the equator, effects of the atmosphere in Ku-band can not be ignored. Current receivers have lower noise figures. Therefore, attenuation due to atmospheric noise results in constant reduction in CN ratio.

3. MEASUREMENTOF TMOSPHERIC NOISES

The atmospheric noises are received by a receiver with lower NF (majority of receivers available on the market has NF of about 0.4 ~0.6dB), noise level increases exceeding that of receivers with higher NF. Noise temperature of the offset parabolic antenna on fine days is approximately 40 (K). When atmospheric noise is input in the form of resistance loss (R), antenna noise temperature (Ta) is expressed as follows:

$$Ta = TaoR+(1 - R)To \qquad (6)$$

where Tao denotes antenna noise temperature on fine days and To denotes thermal noise from the environment (290 K). The overall noise detected by the receiver is the sum of antenna noise and noise generated by the receiver both are converted into the input. Noise temperature (Ts) of the receiving system is expressed by the following equation in which (F) denotes noise figure of the receiver.

$$Ts = Ta+Te = TaoR+(1 - R)To+(F-1)To \qquad (7)$$

From the ratio between noise temperature (Tso) of the receiving system on fine days and noise temperature of the receiving system involving attenuation media such as atmospheric noise, the equation for checking noise level (Tn) (decibel level) is introduced as follows:

$$Tn = 10\log(Tso/Ts) \qquad (8)$$

where Tso is Tao + Ts. Deterioration of receiving signals due to atmospheric noise loss(0~1dB) obtained by Equation (8) is shown in Fig.3 .

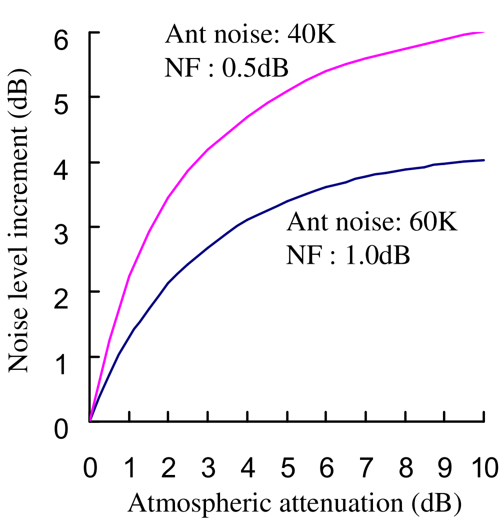

Figure 3. *Deterioration of receiving signals as a function of atmospheric noise*

4. ATMOSPHERIC NOISE CHARACTERISTICS IN VIENTIANE

Atmospheric noises measured in the past were used for assumption of rain fall attenuation in the satellite propagation path. The noise figure of receivers used so far was in the range of 6 ~ 10 dB. For this reason, radiometer was used for measurements of atmospheric noises. Current receivers have improved noise figure and therefore, atmospheric noise can be detected with ease. In other words, receivers are always subjected to deterioration of CN ratio due to atmospheric noise.

The atmospheric noises measurement has been carried out at the Electronic Dept, Faculty of Engineering (FE), National University of Laos (NUOL) in Vientiane, Laos, at (Lat 17° 58 ′ N, Long 102 ° 36 ′ E), 175m above mean sea level (msl).Due to there are three-story building and tropical trees in this area. In order to reduce effects of thermal noises from the surrounded environments, an antenna was mounted on the top of 11 m height tower. An offset parabolic antenna 45 cm in diameter with low noise figure 0.45 dB was set to have elevation angle of 57 degrees. The antenna noise was measured with frequency of 12.01 GHz. and water content , air temperature , and humidity of the atmosphere obtained from the surface meteorological data. The atmospheric noise of simple average taken at the same time in one month was obtained while data at rain fall were excluded. At 6:00 AM, the humidity starts to decrease in inverse proportion to increase in the air temperature. Block diagram of the experimental arrangement for measuring antenna noise is shown in Fig.4.

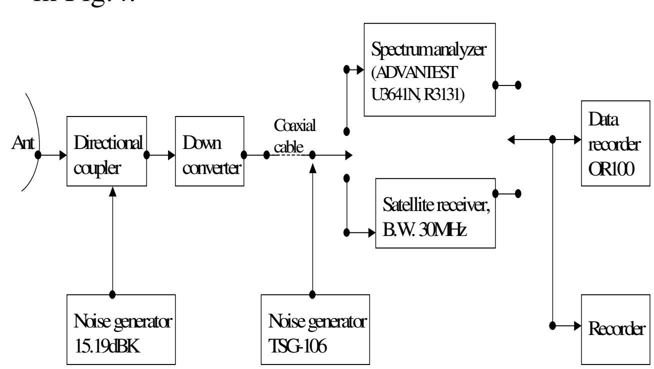

Figure 4. *Block diagram of the antenna noise receiving system*

Atmospheric noises decrease with a similar manner as observed for the humidity. A correlation is recognized between atmospheric noise, and water vapour content and humidity. At 15:00, the noise level reaches the minimum. Meanwhile, atmospheric noise level in Vientiane was checked every month throughout the year. Same trend of changes is noticed every month. As for diurnal variation characteristics in the atmospheric noise in each month, the noise reaches the minimum in the daytime and attains the maximum early in the morning. Changes in fluctuation of the maximum and the minimum were not associated with average relative humidity in each month.

It is considered that fluctuation of the average of monthly atmospheric noises is attributable to effects of clouds existing in the atmosphere.

Attenuation of the clouds in the zenith angle direction for the frequency of 10 GHz obtained by Slobin [8] is in the range of 0.052 ~ 0.073 dB for thin clouds to light clouds, 0.084 ~ 0.216 dB for medium clouds to heavy clouds, and 0.326 ~ 0.457 dB for very heavy clouds. Thus noise level varies depending on status of the clouds in the upper air. In Laos, clear blue sky is seen rarely and the sky is always covered by thin clouds on fine days.

In May, atmospheric noises increase suddenly in the night after sunset and there is a big difference between noises in the daytime and in the nighttime. In Laos, rainy season starts in May and the amount of rain fall increases rapidly. Both temperature and the humidity are high and fluctuation of water vapour content is excessive. In one observation, apparent atmospheric attenuation as much as approximately 0.7 dB was measured in four hours from 6:00 to 10:00 AM alone.

5. ANTENNA NOISE CHARACTERISTICS WITH DIFFERENT NOISE FIGURE AND ELEVATION ANGLES

Since the noise figure of the satellite receiving set declining, CN ratio increased. It will compare 3 or 4 year before, the noise figure fell by about 0.2dB with products on the market. The characteristic of the conventional products and a new product was compared. The result of having measured the new and old antenna elevation characteristic is shown in Fig. 5. Noise level of about 0.5dB has been improved. Naturally CN ratio has also been improved. When antenna noise level is low, good CN ratio characteristic is acquired.

It could be confirmed that antenna noises vary depending on meteorological conditions of the environments. Changes in antenna noises in the direction of zenith angle are not in perfect agreement with those in horizontal direction.

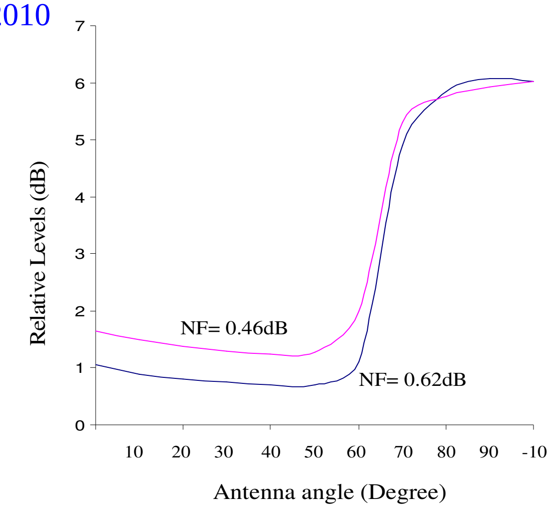

Figure 5. *Antenna noise characteristics of two different NF antenna with different elevation angles*

However, analysis of observations on the ground surface and at high altitude taken at various locations in the world reveals that even if air temperature and dew point temperature exhibit linear changes, relative humidity varies, especially at the altitude more than 850 mbar [9]. For this reason, water vapour content in the atmosphere shows complicated characteristics. Changes in relative humidity at various locations in Laos and Thailand are little throughout the year. However, antenna noises vary greatly due to changes in water vapour content in the atmosphere.

6. CONCLUSIONS

At present, system noise of the receiver is being reduced. It is understood that antenna noise are easily introduced. When a receiver with lower noise factor is used, amount of level fluctuation of the atmospheric noises is excessive even on a fine day and noise level is high in Southeast Asia where temperature and humidity are high and the atmosphere eventually contains much water vapor. At the instant when the scintillation phenomenon is caused under these conditions and resulted in level reduction, troubles such as mosaic noise occur.

ACKNOWLEDGEMENT

Khamphoui Southisombath would like to express his gratitude to Dr. Yoshiaki Moriya for their comments to this paper.

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