THE STUDY OF SCINTILLATION ON C-BAND LOW ELEVATION ANGLE AT SRI-RACHA SATELLITE EARTH STATION

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Abstract : Tropospheric and ionospheric scintillation may impact on C-band satellite communication systems, particularly at low-margin systems and low elevation angles. This paper presents the characteristics of C-Band scintillation at low elevation angle received and recorded the satellite signal from INTELSAT above the Pacific Ocean Region (POR) from January 2002 to December 2002 in the period of solar maximum. We received 3.9525 GHz beacon signal at Sri-Racha satellite earth station by the 32 meters in diameter antenna with 8 degrees of elevation. The analysis was found that the values of amplitude fluctuation is mostly about 0.5-0.6 dB peak to peak and S_4 = 0.03-0.04. The maximum amplitude fluctuation is about 9 dB peak to peak occurring in April. The occurrence numbers of scintillation is most frequently in April and minimum in November. The occurrence numbers of tropospheric scintillation are most frequently in April and October, and minimum in November. It relates to temperature and water vapor pressure variation in N_{wet}. The occurrence numbers of ionospheric scintillation are most frequently in April and September, and minimum in November. It varies corresponding to both equinoctial periods (vernal and autumnal equinox in March and September) and solstice periods (June and December) respectively.
Keywords : Tropospheric scintillation, ionosphric scintillation, satellite communication, amplitude fluctuation

1. INTRODUCTION

More than two decades, satellite communication technology has become the important way to link the worldwide communication system. However the signal could degrade by many natural phenomena such as scintillation fading, rain attenuation, sun noise interference and etc. These phenomena impact on the signal in the random of amplitude and phase changing and result in worsening of accurate data as approached in Fig.1.

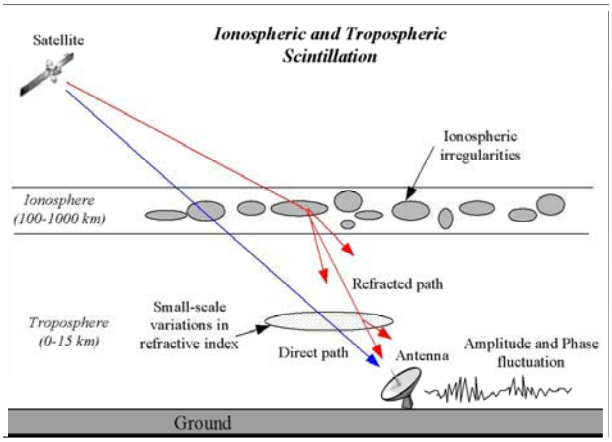

Fig.1 Multipath propagation affected by ionospheric and tropospheric scintillation

Many researchers try to decrease these natural variation problems which have the specific characteristic for each local area that can not predict [1-3]. Consequently, the study on the statistics of satellite signal under the natural condition is significant and necessary for the system designing or system planning and managing based on the statistics of satellite signal of their area to improve the quality of signal. Due to the fact that when the signal propagates through the irregularity of the atmosphere, especially troposphere and ionosphere, the effect on the signal caused by troposphere leads to the changing in refractive index, absorption and scattering of the signal resulting in frequency higher than C-band (4-6 GHz). While the effect on the signal caused by ionosphere leads to Faraday rotation and time delay resulting in frequency lower than C-band.

2. SCINTILLATION PHENOMENA AND SCINTILLATION INDEX

2.1 Scintillation phenomena

Scintillation is a rapidly amplitude and phase signal fluctuations. In C-band scintillation compose of two scintillation types according to their cause. One called tropospheric scintillation is affected by atmospheric turbulence in temperature, humidity and pressure which translate into small-scale variations in refractive index N [4] given by the relation [3].

$$N = 77.6\frac{P}{T} + 3.73\times10^5\,\frac{e}{T^2} \qquad (1)$$

where P is the pressure in the unit of millibars (mbar), T is the absolute temperature in the unit of Kelvins and e is the vapor pressure in the unit of millibars. The first term of equation (1) is the dry term (N_{dry}) and the second term is the wet term (N_{wet}). Tropospheric scintillation intensity is increased with high carrier frequency, low elevation angle, and small receiving antenna and usually occurs in summer around noon. It can adversely affect uplink power control systems if the response time of the system is too slow. The changing rate of amplitude caused by tropospheric scintillation actually decreases as lower elevation angle. Meanwhile, another one called ionospheric scintillation occurred due to electron density irregularities in F layer and E_S layer. The irregularities producing scintillations are predominantly in the F layer at altitudes ranging from 200 to 1000 kilometers. A new patch of irregularities forms after sunset by expanding westward and drifts eastward with velocities ranging from 100 to 200 m/s. After local midnight, these irregularities movement will be halt and reverse the direction and decay for one-hour period [4]. Ionospheric scintillation has been expected that it is caused by relatively stationary irregularities which move perpendicularly to the radio wave path. The amount of ionospheric scintillation observed is a function of the irregularity size, the distance between the irregularities and the receiver, and the Fresnel zone size [3].

The severity of intensity scintillation can be illustrated in Fig.2. The characteristics of scintillation vary widely with frequency, geomagnetic, latitude position and solar activity. Both ionospheric and tropospheric scintillations have diurnal and seasonal variations.

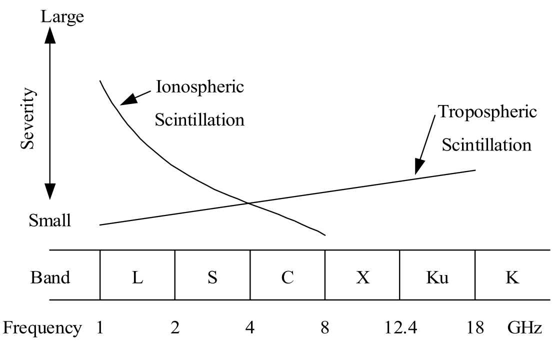

Fig.2 Degree of severity intensity scintillation

Fig.3 shows a sample signal of scintillation observed in daytime due to troposphere and Fig.4 shows a sample signal of scintillation observed in nighttime due to ionosphere. The signal fluctuation of ionospheric scintillation change more rapidly.

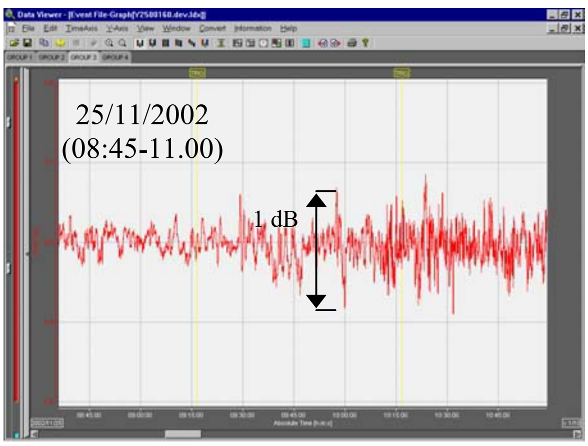

Fig. 3 Typical pattern of tropospheric scintillation

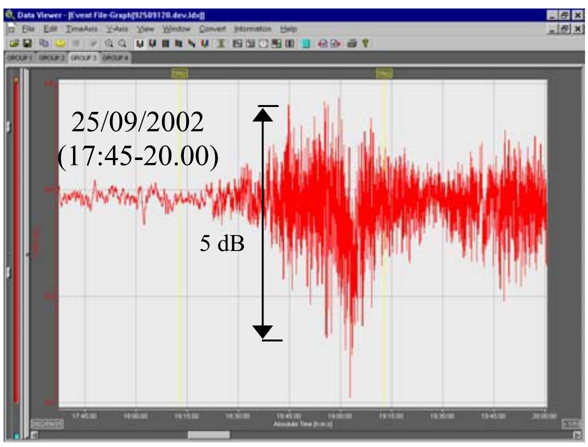

Fig. 4 Typical pattern of ionospheric scintillation

2.2 Scintillation index

The strength of the scintillation can be determined variously measurement. The most normal one is to read the maximum and minimum of receiving levels in any desired time, called peak to peak method, but scintillation is variation and random phenomenon. According to this reason that can overcome this apparent randomness in the fine detail of amplitude fluctuations, called scintillation index S_4 expressing the normalized variance by using the standard deviation. Scintillation index S_4 can be presented by the following formula:

$$S_4 = \frac{\sigma_x}{m_x} \tag{2}$$

where σ_x is the standard deviation of received signal power in watts and m_x is the mean value. In general, an S_4 value of 0.5 is taken as the boundary between weak and strong scintillation [3].

3. EXPERIMENTAL SYSTEM

This experiment received C-band beacon signals from the INTELSAT 802 satellite above the Pacific Ocean Region from January, 2002 to December, 2002 at Si-Racha satellite earth station of Thailand. It is about 100 kilometers southeast of Bangkok. All data were recorded on digital data recorder at a sampling interval of 1 sec. Table 1 gives the specification employed in the measuring.

Table 1 Specification for measurement

Satellite	INTELSAT 802 (174^{o}E)
Receiving Position	Si-Racha earth station
Latitude	13^o 06' N
Longitude	100^o 56' E
Elevation angle	8^o
Azimuth angle	93.96^o
Receiving frequency	3.9525 GHz (beacon)
Antenna aperture	32 m∅
Antenna gain	65 dB (4 GHz)

4. SCINTILLATION OBSERVATION AND ITS RESULTS

We examined the level fluctuation of scintillation that occurred in the observation period from January, 2002 to December, 2002 in term of peak to peak values and S_4 index by dividing scintillation event into one minute. In this case, one scintillation occurrence is counted every one minute period of scintillation event. Histogram of the level fluctuation and the S_4 index during our observation has shown in the Fig.5 and 6 respectively. From the figures, the value of fluctuation was mostly about 0.5-0.6 dB peak to peak and S_4 = 0.03-0.04. From the S_4 index, we can demonstrate that the scintillation phenomena at Sri-Racha are the weak scintillation.

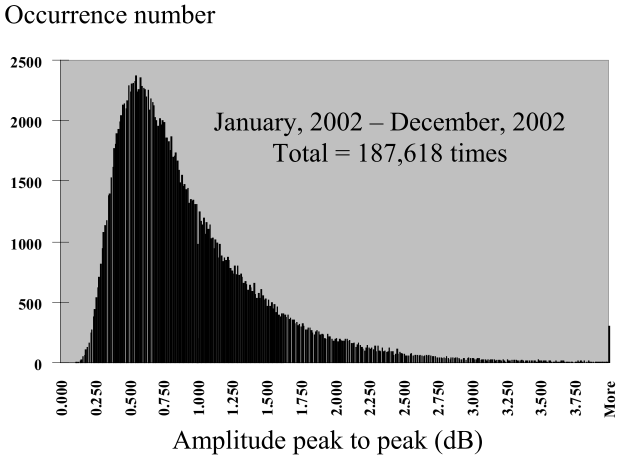

Fig.5 Histogram of the signal level fluctuation

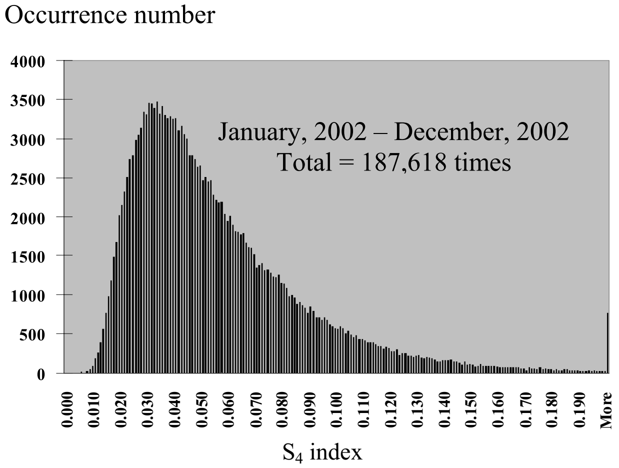

Fig.6 Histogram of the S_4 index

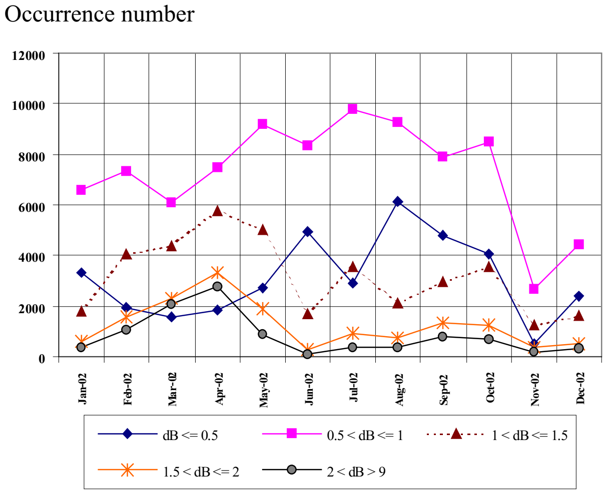

Fig.7 Classification of amplitude level scintillation in each month

Fig.7 shows the classification of scintillation intensity in each month. The high amplitude fluctuation levels can be clearly observed in April 2002. When considering seasonal variation, total occurrence numbers of scintillation in each month as shown in Fig.8. The occurrence numbers of scintillation were most frequently in April corresponding to the seasonal variation of equinoctial periods (around March to early April and last August to October), and minimum in November and December corresponding to the seasonal variation of solstice periods (around June and December) [6-7].

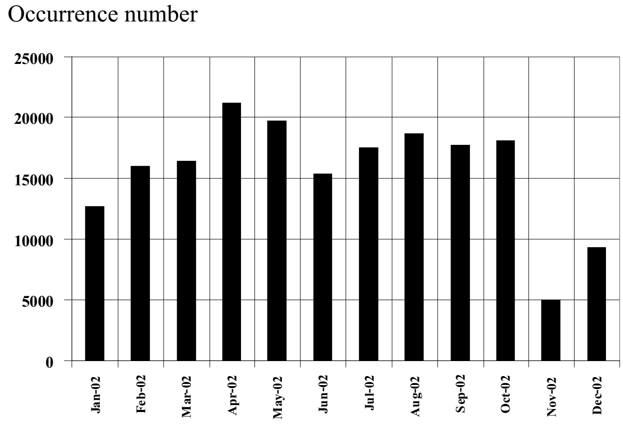

Fig.8 Total occurrence numbers of scintillation by monthly

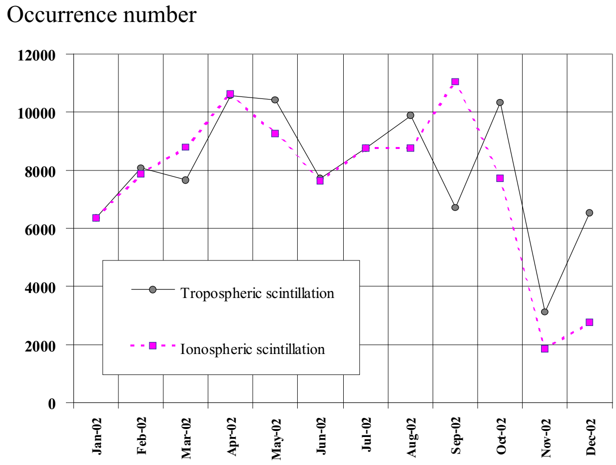

Fig.9 Total occurrence numbers of tropospheric and ionospheric scintillation by monthly

Fig.9 shows total occurrence numbers of monthly tropospheric and ionospheric scintillation. The occurrence numbers of tropospheric scintillation were most frequently in April and October, and minimum in November. The occurrence numbers of ionospheric scintillation were most frequently in April and September, and minimum in November. Diurnal variation of the occurrence of scintillation, from the experiment results, the ionospheric scintillation mostly occurred between 18:00-01:00 LT due to the appearing of F layer in ionosphere [7], and the tropospheric scintillation mostly occurred between 10:00-16:00 LT.

The good corresponding between scintillation occurrences and monthly mean values of N can approach as Fig.10. The values of refractive index N at Si-Racha satellite earth station were calculated from (1) by using the temperature, pressure and water vapour pressure observed five times a day (07:00, 10:00, 13:00, 16:00 and 19:00) at a nearby meteorological station (Lam- Chabang station).

Occurrence number

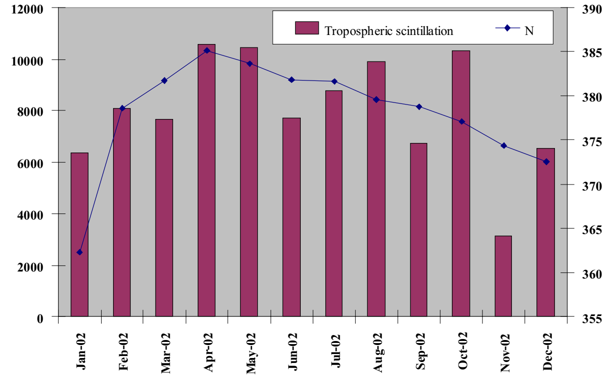

Fig.10 Monthly comparison of scintillation occurrences and refractive index *N*

5. CONCLUSIONS

This paper analyzed and studied the long-term characteristics of C band satellite signal at low elevation angel in 2002. It was found that the values of amplitude fluctuation and S_4 index were mostly about 0.5-0.6 dB peak to peak and S_4 = 0.03-0.04. From the S_4 index, we can demonstrate that the scintillation phenomena at Sri-Racha are the weak scintillation. The maximum amplitude fluctuation was about 8-9 dB peak to peak, which occurred in April and May. The occurrence numbers of scintillation were most frequently in April, and minimum in November and December.

The occurrence numbers of tropospheric scintillation were most frequently in April and October, and minimum in November. It related according to temperature and water vapour pressure variation in N_{wet}. The occurrence numbers of ionospheric scintillation were most frequently in April and September, and minimum in November and December. It varies corresponding to both equinoctial periods (vernal and autumnal equinox in March and September) and solstice periods (June and December) respectively.

6. ACKNOWLEDGMENT

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