A New Prediction Method for Scintillation Expression

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Abstract: This paper presents the analysis of satellite received signal by focus on the new prediction method for amplitude scintillation expression. A predict method based in the relationship of standard deviation values and the peak to peak values of amplitude scintillation in various of time period and various of sampling rate of signal variation. The principal techniques finding, the proper sampling rate and time interval, for the best expression method. The experiment has been performed in Bangkok of Thailand, at King Mongkut's Institute of Technology, Ladkrabang, data collected in C-Band and Ku-Band on high elevation angles. The result of analysis shows the relationship between two methods is given by $\sigma_x = \alpha(P-P)+\beta$. The value of α depends on sampling rate by closely with three-minute maximum time interval.

Keywords: Satellite communication, radio-wave propagation, scintillation

1. INTRODUCTION

Scintillation describes the condition of rapid fluctuations of the signal parameters of a radiowave caused by time dependent irregularities in the transmission path. Signal parameters affected include amplitude, phase, angle of arrival, and polarization. [1]

Scintillation phenomena can be produced in both of ionospheric and tropospheric, observed during the period April 1999 to December 2002 which received from THAICOM2 satellite (in both C-Band and Ku-Band) link to Thailand at Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang (KMITL).

Karasawa et-al [2] presented a prediction method for the calculation of standard deviation value (σ_x) of signal variation. This method has come to be extensively used in the recent. Meanwhile, the technique of deriving a peak-to-peak value [P-P] has even longer history of use. One advantage of this latter approach is that it permits measurements to be made very simply without requiring any special measurement requirement. However, no examination of the relation between two scintillation expression methods. Thus we investigated the relationship between two approaches that are dependent on the sampling rate and the time interval, and it was confirmed the excellent correlation.

2. OVERVIEW OF COLLECTED DATA

2.1 Measurement setup

The experimental data were collected from THAICOM2 satellite in C-Band and Ku-Band on high elevation angles at King Mongkut's Institute of Technology, Ladkrabang, Bangkok, Thailand during the period of April 1999 to December 2002. All data were recorded on digital recorder with the sampling interval of 125 mSec (8 sampling point per second). The principal system parameters of the experiment are summarized in Table 1.

2.2 Measurement and Analysis

Data consist of scintillation occurring on clear sky, ionospheric scintillation in the 3.916 GHz and tropospheric scintillation in the 12.260 GHz.

Fig. 1 shows the example of the record signal in presence of severe of troposphere occurring in daytime. Tropospheric scintillations are rapid fluctuations of signal amplitude and phase, due to any atmosphere process, including attenuation in heavy clouds or rain, or diffraction from index of refraction irregularities produces by turbulence [3-5].

Table 1. Principal System Parameters

Satellite	THAICOM2
Location of ground station	13° 38′ 17″ N 100.8° 38′ 17″ E
Location of satellite	78.5° E
Antenna diameter	2.50 m (C-Band) 30 cm (Ku-Band)
Receiving frequency	3.916 GHz (C-Band) 12.260 GHz (Ku-Band)
Elevation angle	59.9°
Data sampling rate	125 mSec

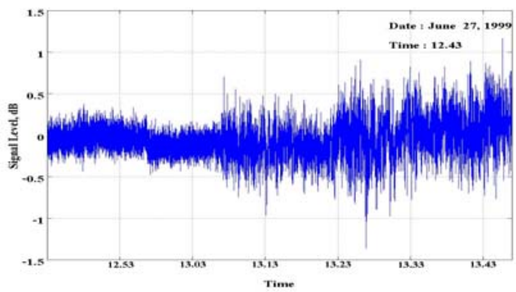

Fig. 1 An example of Tropospheric scintillation event measured at 12.260 GHz, *June 27, 1999;*

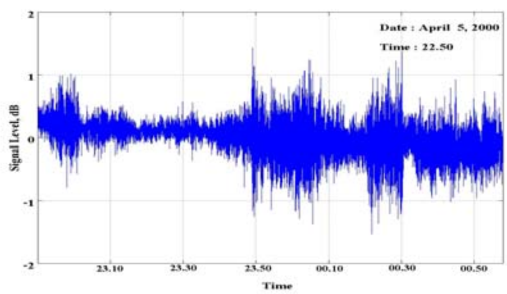

Fig. 2 An example of Ionospheric scintillation event measured at 3.916 GHz, *April 5, 2000;*

Fig. 2. shows the example of the record signal in presence of severe of Ionospheric occurring in nighttime. Ionospheric scintillation results when ion density irregularities in the ionosphere interfere with radio waves traveling through the ionosphere. These signals are subject to variations in both amplitude and phase [2].

From experiment data, measurements with mean fades more than 0.5 dB, referred to scintillation data. To assess thirty minute for one event of scintillation. This paper reporting the analysis of event by focus on the relationship of standard deviation and peak-to-peak value in different sampling rate and different time interval as follow in section 4.1 and 4.2.

3. SCINTILLATION EXPRESSION METHODS

Scintillations are manifested by the range of received signal variations. There are a number of methods for representing these level variations, as well as various methods for utilizing the in formation involved. Since it is not possible to precisely determine the time-variable intensities of electric field at any given moment in advance, statistical methods are necessary in order to depict received signal fluctuation due to scintillation, are employed by using average values, standard deviation, and so on to represent the fluctuation.

3.1 Peak-to-peak values $(P-P)$

One approach to determine the scintillation fluctuation range is simply to read the maximum value and the minimum value of the receiving levels in any desired time. This method are easy to calculate and grasp, it can be applied to all types of scintillation. However, this approach is not well applied to the analysis of long period.

3.2 Standard deviation values (σ_x)

The other is to express the scintillation fluctuation range is to derive the standard deviation of the received signal level at an arbitrary time. This method is widely used to represent the scintillation.

This paper, we used the statistical methods to determine of the standard deviation value. It can be represented by: [5]

$$\sigma_x = \left(\frac{x_1^2 + x_2^2 + \dots\dots\dots\dots\dots\dots + x_n^2}{n-1} \right)^{\frac{1}{2}} \tag{1}$$

where x_i is the difference between the random values

$\bar{x}$ is the mean value

n is the whole number of data

3.3 Relationship between peak-to-peak value and standard deviation value

The correlation coefficients between peak-to-peak values and standard deviation values were investigated, and it has been compute of a 40-minute stationary scintillation event. It was confirmed that excellent correlation. The correlation coefficient γ ranging from 0.850 to 0.999. As the results, the relationship in peak-to-peak values and standard deviation values is given by [6] [7]:

$$\sigma_x = \alpha(P-P) + \beta \tag{2}$$

where

$$\alpha = \frac{n\sum_{i=1}^{n}(P-P)_i \cdot (\sigma_x)_i - \sum_{i=1}^{n}(P-P)_i \cdot \sum_{i=1}^{n}(\sigma_x)_i}{n\sum_{i=1}^{n}(P-P)_i^2 - \left(\sum_{i=1}^{n}(\sigma_x)_i\right)} \tag{3}$$

$$\beta = \overline{\sigma_x} - \alpha\overline{(P-P)} \tag{4}$$

4. EXPERIMENTAL AND RESULTS

4.1 Sampling rate analysis

All data were recorded on digital recorder with the sampling interval of 125 mSec (8 sampling point per second) to ensure that the system could follow even the very fast fluctuation level waveforms. In this paper, the scintillation fluctuation range were examined the sampling rate before embarking to analysis the relationship between peak-to-peak values and standard deviation values, and it was confirmed that excellent correlation. Table. 2 shows the various condition of sampling rate for the experimental.

One-minute maximum-minimum (peak-to-peak) values and standard deviation values of amplitude scintillation were derived for both data sets.

Table. 2 The condition of sampling rate.

Sampling rate	Frequency	Time
1 min / 480 point	8 Hz	125 mSec
1 min / 240 point	4 Hz	250 mSec
1 min / 120 point	2 Hz	500 mSec
1 min / 60 point	1 Hz	1 sec
1 min / 30 point	0.5 Hz	2 sec
1 min / 15 point	0.25 Hz	4 sec

Fig. 3 shows the percentage of cumulative occurrence of correlation coefficients in each of sampling rate of ionospheric scintillation are occurring in C-Band. It can be seen that the sampling interval of 125 mSec, 250 mSec, 500 mSec, 1 sec, 2 sec, and 4 sec has been the excellent correlation between peak-to-peak values and standard deviation values.

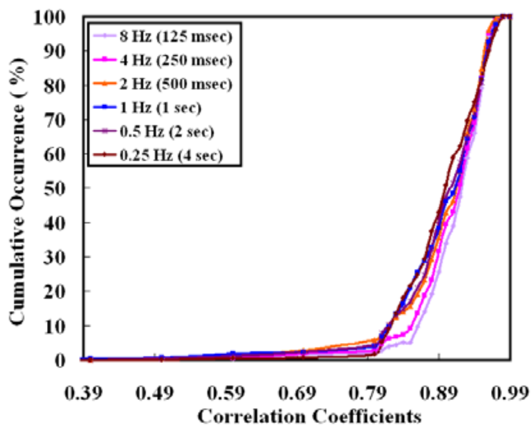

Fig. 3 The percentage of cumulative occurrence of correlation coefficients in each of sampling rate of ionospheric scintillation in the 3.916 GHz

2 min, and 3 min are excellent correlation, so it can be use for 3 min. maximum.

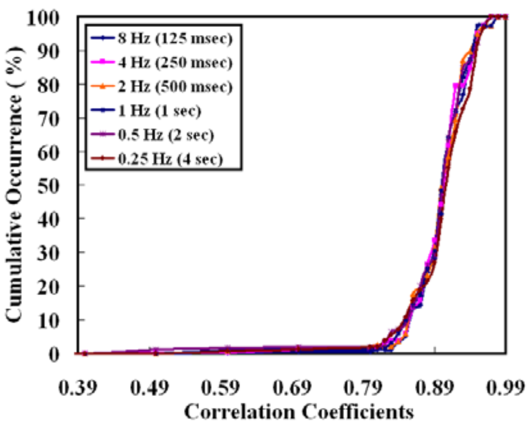

Fig. 4 The percentage of cumulative occurrence of correlation coefficients in each of sampling rate of tropospheric scintillation in the 12.260 GHz,

Fig. 4 shows the percentage of cumulative occurrence of correlation coefficients in each of sampling rate of tropospheric scintillation in Ku-Band. It can be seen that the sampling interval of 125 mSec, 250 mSec, 500 mSec, 1 sec, 2 sec, and 4 sec has been the excellent correlation between peak-to-peak values and standard deviation values same as Fig. 3.

As the result, the sampling interval of 125 mSec, 250 mSec, 500 mSec, 1 sec, 2 sec, and 4 sec has been the excellent correlation, ranging from 0.850 to 0.999 in both C-Band and Ku-Band. Next, the condition of sampling rate (Table. 2) was used to analysis the relationship between peak-to-peak values and standard deviation values.

4.2 Time interval analysis

In the section 4.1, one-minute maximum-minimum (peak-to-peak) values and standard deviation values of amplitude scintillation were derived for both data sets. This section, we were examined the time interval of 1 min, 2 min, 3 min, 4 min, 5 min, 8 min, and 10 min every group of sampling rate, and it was confirmed that excellent correlation.

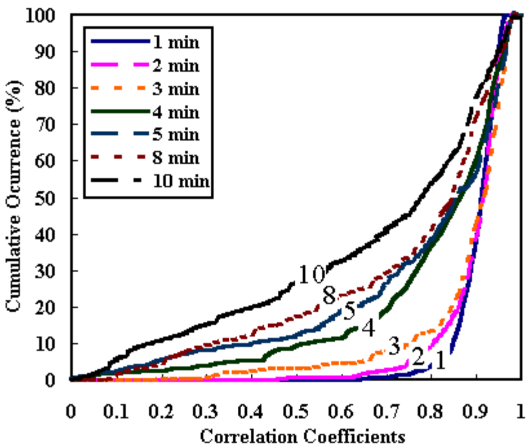

Fig. 5 The percentage of cumulative occurrence of correlation coefficients in each the time interval of ionospheric scintillation in the 3.916 GHz.

Fig. 5 shows the percentage of cumulative occurrence of correlation coefficients in each time interval of ionospheric scintillation in the 3.916 GHz, which was examined over a comparatively short period of time from April 1999 to December 2002. It can be seen that the time interval of 1 min, 2 min, and 3 min are excellent correlation, so it can be use for 3 min. maximum.

Fig. 6 shows the percentage of cumulative occurrence of correlation coefficients in each time interval of tropospheric scintillation in the 12.260 GHz. It can be seen that the time interval of 1 min, 2 min, and 3 min has been the excellent correlation same Fig. 5.

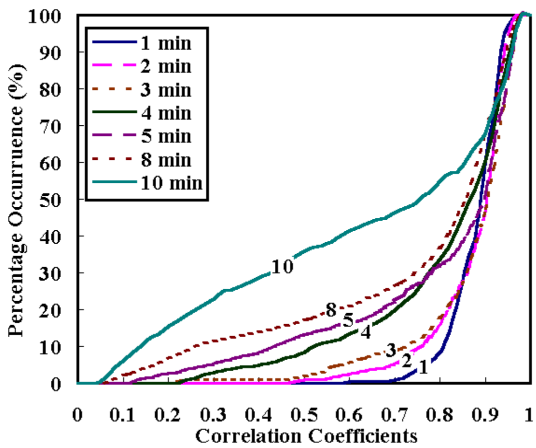

Fig. 6 The percentage of cumulative occurrence of correlation coefficients in each the time interval of tropospheric scintillation in the 12.260 GHz.

In this paper, we used the time interval of 1min because it has been the excellent correlation better than several the time intervals in both C-Band and Ku-Band. Next, the time interval of 1 min was used to analysis the relationship between peak-to-peak values and standard deviation values.

4.3 New prediction for scintillation expression

This section, we examined the relationship between peak-to-peak values $(P-P)$ and standard deviation values (σ_x) which was confirmed the excellent correlation, and used the condition of sampling rate of 125 mSec, 250 mSec, 500 mSec, 1 sec, 2 sec, and 4 sec and the time interval of 1 min.

Fig. 7 shows one example of the relationship between $(P-P)$ and (σ_x) in each the condition of sampling rate and the time interval of 1 min observed in Sep 4, 2000, obtains from 186 example ionosphere scintillation (C-Band) which measured during April 1999 to December 2002. The relationship are given by:

$$\sigma_x = 0.16(P-P)+\beta \text{ ; Sampling rate 125 mSec}$$

$$\sigma_x = 0.17(P-P)+\beta \text{ ; Sampling rate 250 mSec}$$

$$\sigma_x = 0.18(P-P)+\beta \text{ ; Sampling rate 500 mSec}$$

$$\sigma_x = 0.20(P-P)+\beta \text{ ; Sampling rate 1 sec}$$

$$\sigma_x = 0.23(P-P)+\beta \text{ ; Sampling rate 2 sec}$$

$$\sigma_x = 0.27(P-P)+\beta \text{ ; Sampling rate 4 sec}$$

Fig. 8 shows the same as Fig. 7, but observed in Aug 4, 2001, obtains from 134-example troposphere scintillation (Ku-Band) which measured during April 1999 to December 2002. The relationship shows the same as Fig. 7.

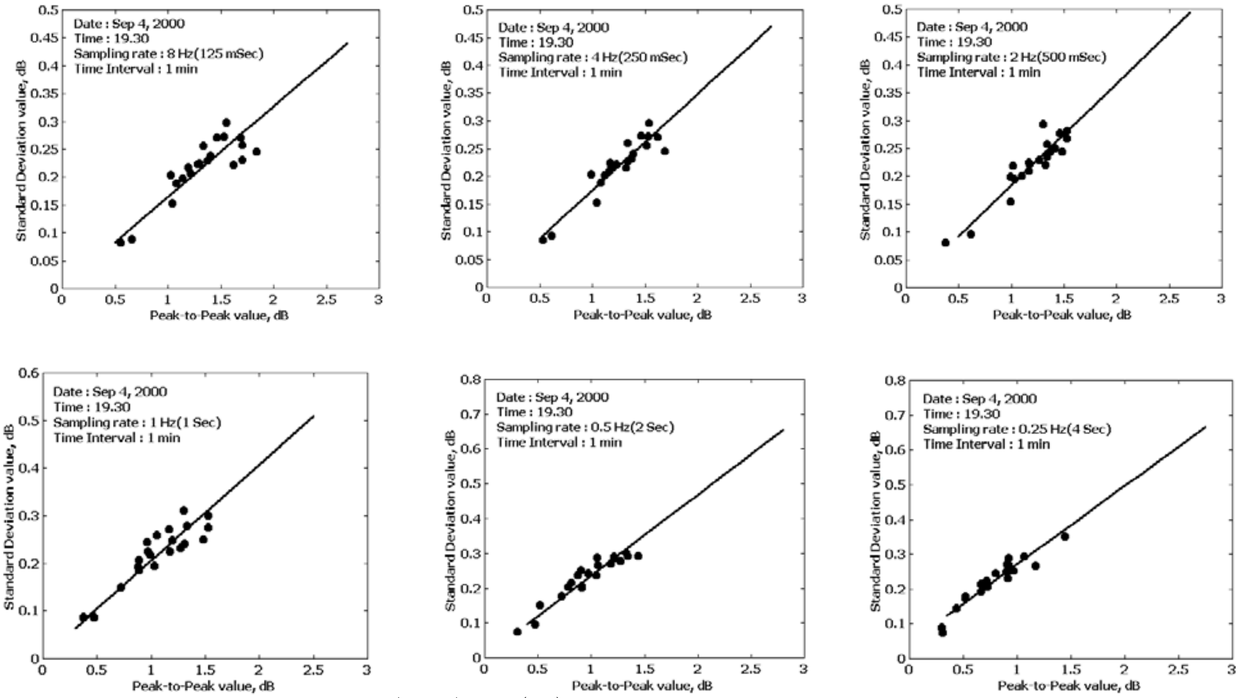

Fig. 7 The relationship between $(P-P)$ and (σ_x) of ionospheric scintillation in the 3.916 GHz, *September 4, 2000;*

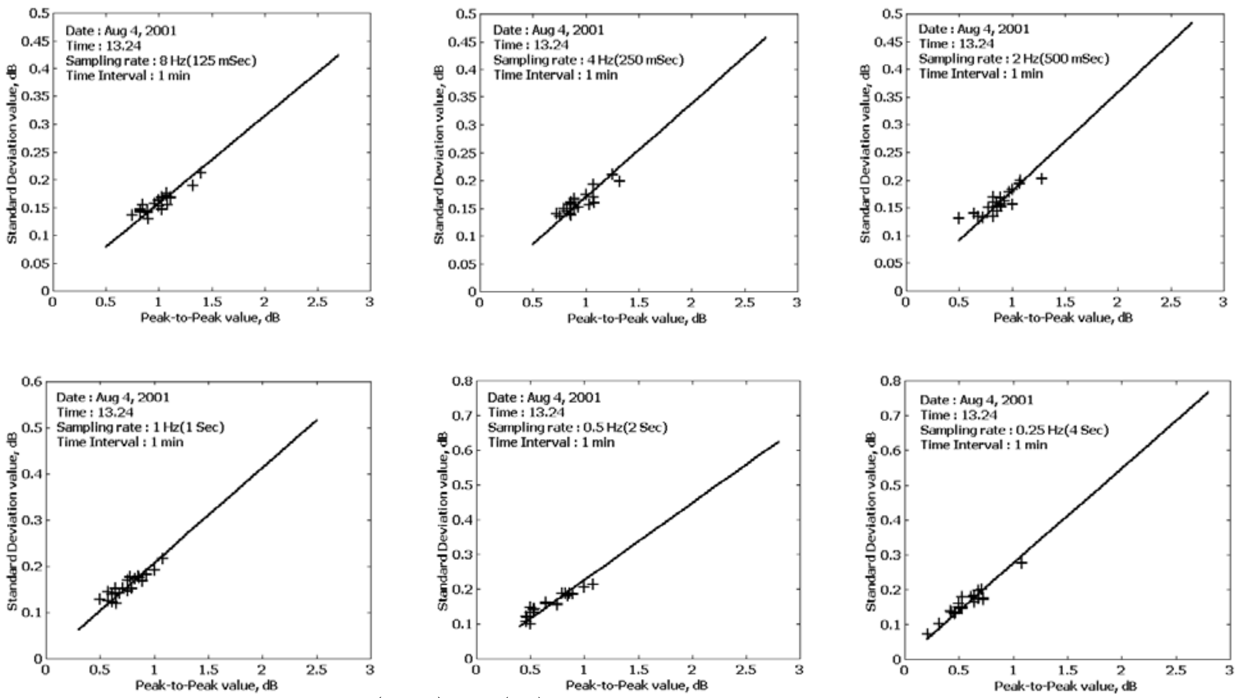

Fig. 8 The relationship between $(P-P)$ and (σ_x) of tropospheric scintillation in the 12.260 GHz, *August 4, 2001;*

5. CONCLUSION

From the examination is finding the relationship between peak-to-peak values and standard deviation values, also consider the condition of sampling rate and the time interval. The relationship is given by $\sigma_x = \alpha(P-P)+\beta$, base on the excellent correlation coefficients were obtained ranging from 0.85-0.999. The principal findings are summarized as follow:

1. The sampling rate of 125 mSec, 250 mSec, 500 mSec, 1 sec, 2 sec, and 4 sec has been the excellent correlation in both C-Band and Ku-Band.
2. The time interval of 1 min has been the excellent correlation better than several the time intervals in both C-Band and Ku-Band.
3. The relationship between peak-to-peak values and standard deviation values are dependent on the sampling rate and the time interval. As the results the relationship are given by:

$\sigma_x = 0.16(P-P)+\beta$; Sampling rate 125 mSec

$\sigma_x = 0.17(P-P)+\beta$; Sampling rate 250 mSec

$\sigma_x = 0.18(P-P)+\beta$; Sampling rate 500 mSec

$\sigma_x = 0.20(P-P)+\beta$; Sampling rate 1 sec

$\sigma_x = 0.23(P-P)+\beta$; Sampling rate 2 sec

$\sigma_x = 0.27(P-P)+\beta$; Sampling rate 4 sec

where the value of α is the number 0.16, 0.17, 0.18, 0.20, 0.23 and 0.27 are depend on sampling rate and β is value ranging from 0.001-0.1.

4. The relationship between peak-to-peak values and standard deviation values in condition of ionospheric scintillation in C-Band (3.916 GHz) is nearly same as in condition of tropospheric scintillation in Ku-Band (12.260 GHz).

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