# On Application Of Adaptive IIR Digital Filter For Extracting Scintillation And Rain Attenuation

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**Abstract**

Characteristic of two combination phenomena in Ku-band satellite down link, troposphere amplitude scintillation concurrent with rain attenuation are examined, and extracted individually from raw data with the aid of a filtering technique. Based on application of adaptive IIR digital filter, Fast algorithm of variable step-size QLMP (VSQLMP) are available. The procedure of application can be concluded and successful, the spectra of two-combination effect are extracted individually, the harmonic of noise is reduced for all weather condition and system characteristic by variable step-size adaptive algorithm.

## 1. Introduction

This work have so far been the investigation of short-term and long-time statistics of scintillation and rain attenuation phenomena in Ku-band satellite down link. This measurement focus on near equator region in Thailand, where large scintillation and heavy rainfall occur frequently. In particular, both phenomena can concurrently. Base on data analysis, the effect of two combination are described. By utilizing the difference in amplitude variation rate for rain attenuation and scintillation fading, the effect of two phenomena are extracted with the aid of a filtering technique [1][2]. In the past, the extraction of scintillation from attenuation has been carried out by Butterworth digital low-pass filter and Butterworth digital high-pass filter [1][2][3] , however, it is not possible to establish a unique filter cutoff frequency for all weather condition and system characteristics . Therefore, be expected to be applied to wide regions and different climates. This work separate two combination phenomena by technique of adaptive IIR digital filter which are very useful in various signal processing applications , such as the variation of satellite signal with unknown frequencies from observation time series. By this technique, the cutoff frequency of variable signal are adapting by adjust parameters in the algorithm. In reference [4] two combination effect are extracted by Quantized Gradient-based algorithm (QLMP) when the step-size is constant parameters. This paper separate the two effect and reduce noise by fast algorithm of the variable step-size QLMP algorithm (VSQLMP). This method shows a difference approach to control step-size used with adaptive IIR filter for frequency estimation.

## 2. Measurement and Data Analysis

Scintillation and rain attenuation measurements were carried out in Bangkok, Thailand. The configuration of earth station is presented in table1.

Table 1
Principal System Parameters

| Satellite | Thaicom2 |
|---|---|
| Location of ground station | 13° 45′ 36″ N<br>108° 48′ 17″ E |
| Antenna Diameter | 30 cm offset |
| Receiving frequency | 12.260 GHz |
| Elevation angle | 59.9° |
| Data sampling rate | 100 ms |

The results are presented here correspond to selected data acquired from January 2001 until December 2001. All data were recorded on digital recorder with the sampling interval of 125 mSec (8 sampling point per second). From the measurement, Figure1 shows the probability density of occurring number of two combination phenomena measured in monthly. Two combination phenomena (scintillation concurrent with rain attenuation) shows a marked seasonal of rainy dependence, reaching a maximum number of occurring in August and minimum number of occurring in May.

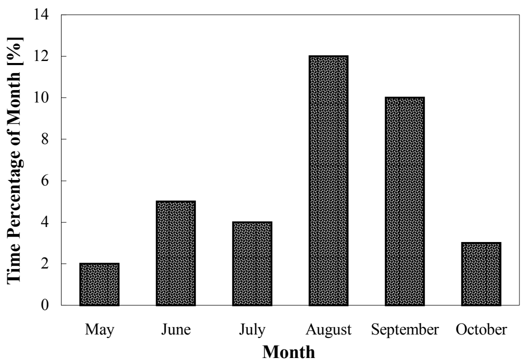


Figure 1. Diurnal variation of rain attenuation

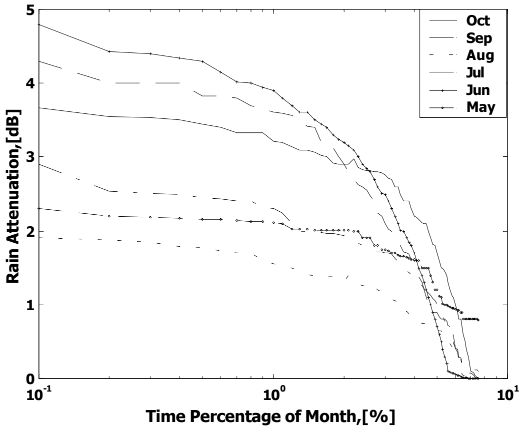


Figure 2. Cumulative probability of rain attenuation

Figure 2. shows cumulative probability of rain attenuation cconcurrent with scintillation, reaching a maximum total fade in June and minimum total fade in August. Therefore, the data in June is most effective to analyze. There are two type of data analysis, time domain and frequency domain. As for the frequency domain, the power spectrum was derived by Fast Fourier Transform (FFT), the data length size is set to 20,000 point. The mean power spectrum can be displayed by two asymptotic with value close to slop of Kolmogorov spectrum.

The next, selected data of combination phenomena are passing through Fast algorithm of the variable step-size VSQLM*p* digital high-pass filter first order. To estimate the effect on scintillation phenomena of cutoff frequency used for data filtering. The filter coefficient will be estimated by adaptive algorithm, described in the next section.

## 3. The Variable Step-Size QLMP Algorithm.

In this section, we describe the variable step-size QLM*p* algorithm that was proposed in ref [5]. To simplify, assuming that the input signal to the adaptive digital filter ($x(n)$) is satellite signal variations measured during 60 minute and 8 sampling of the scintillation concurrent with rain attenuation. The filter is analyzed at various parameters from the derivation of the transfer function High Pass Filter (HPF) and Low Pass Filter (LPF).

The transfer function of the HPF can be expressed as follows:

$$H(z) = -\frac{z^{-1} + a(n)}{1 + \rho a(n) z^{-1}} \tag{1}$$

where $a(n)$ is the filter coefficient will be estimated by an adaptive algorithm, ρ is the pole construction factor should be close and less than unity to ensure the stability of the filter. The steepest decent algorithm used to update the HPF filter coefficient is:

$$a(n+1) = a(n) - \mu \frac{\partial y(n)^p}{\partial a} \tag{2}$$

because

$$|y(n)|^p = \begin{cases} (y(n))^p & ; p : even \\ \operatorname{sgn}(y(n)) \cdot (y(n))^p & ; p : odd \end{cases} \tag{3}$$

thus Eq. (2) becomes

$$a(n+1) = a(n) - \mu \cdot \mathrm{p} \cdot (y(n))^{p-1} \frac{\partial y(n)}{\partial a} \;; \tag{4}$$

$\mathrm{p} = odd$

$$a(n+1) = a(n) - \mu \cdot \mathrm{p} \cdot sgn(y(n)) \cdot (y(n))^{\mathrm{p}-1} \frac{\partial y(n)}{\partial a};$$

$\mathrm{p} = even$

The output signal of the first-order adaptive HPF is as follows:

$$y(n) = x(n-1) - a(n)x(n) + \rho a(n) y(n-1) \tag{5}$$

and the differential of the filter output with respect to $a(n)$ is given by:

$$\frac{\partial y(n)}{\partial a} = -x(n) + \rho y(n-1) \tag{6}$$

Next, the used of the *Quantizing Gradient* algorithm which does not require any matrix inversion or division and it can reduce an amount of multiplication computational equal to the length of input data, the updated formula of Eq. (4) becomes:

$$a(n+1) = a(n) - \mu \cdot sgn\left\{ p \cdot (y(n))^{p-1} \frac{\partial y(n)}{\partial a} \right\}; \tag{7}$$

$p = odd$

$$a(n+1) = a(n) - \mu \cdot sgn\left\{ p \cdot sgn(y(n)) \cdot (y(n))^{p-1} \frac{\partial y(n)}{\partial a} \right\};$$

$p = even$

where $\operatorname{sgn}(x) = x/|x|$ , μ is step size parameter.

In the next section, we analyzed adaptive IIR Low Pass Filter present in Figure 3. and then the variable step-size QLM*p* algorithm. From the block diagram, $x(n)$ is the satellite signal which scintillation and rain attenuation concurrently , $y(n)$ is the output signal which scintillation are extracted from input signal by adaptive IIR HPF , $z(n)$ is the output signal which attenuation are extracted from input signal by adaptive IIR LPF described by:

$$z(n) = x(n) - y(n) \tag{8}$$

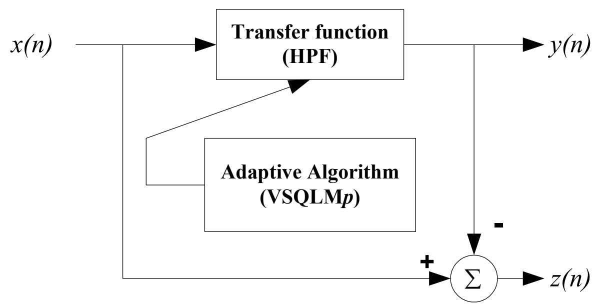


Figure 3. Block diagram of Adaptive IIR Digital Filter

The objective of the variable step-size QLMP algorithm is to ensure large $\mu(n)$ when the algorithm is for from the optimum and the $\mu(n)$ decreasing as we approach the optimum. The adaptive algorithm used to update recursion is given by:

$$a(n+1) = a(n) - \mu(n) \cdot \operatorname{sgn}\left[\operatorname{sgn}(y(n)) \cdot \frac{\partial y(n)}{\partial a}\right] \tag{9}$$

where

$$\mu(n+1) = \kappa\mu(n) + \beta\varphi^2(n) \tag{10}$$

and

$$\varphi(n) = \alpha\varphi(n-1) + (1-\alpha)y^2(n) \tag{11}$$

the parameters $0<\kappa<1$, $\beta>0$ and $\mu(n+1)$ are set to $\mu_{min}$ or $\mu_{max}$, the positive constant $\alpha$ $(0<\alpha<1)$ is an exponential weighting parameter that governs the averaging time constant, i.e., the quality of the estimation.

## 4. The Results

Figure 4. (a) shows the example of input satellite signal variation during rain observed in June 11, 2001. As can be seen two kinds of phenomena persist, attenuation phenomena caused by bulk rain and scintillation phenomena arising from scattering at atmospheric reflective index. Two combination phenomena are concurrently. The periodic of occurring about 1 hour. Figure 4.(b) shows scintillation extracting from raw data by using the variable step-size QLMP algorithm (VSQLMP) for a 1st order adaptive high pass filter. Figure 4. (c) shows rain attenuation extracting form raw data by using the variable step-size QLMP algorithm (VSQLMP) for a 1st order adaptive low pass filter. In this case, the step-size parameter value $\alpha$=0.989, $\kappa$=0.955, $\beta$=0.0001 and the pole radius $\rho$ of the 1st order IIR high pass filter and low pass filter is 0.955.

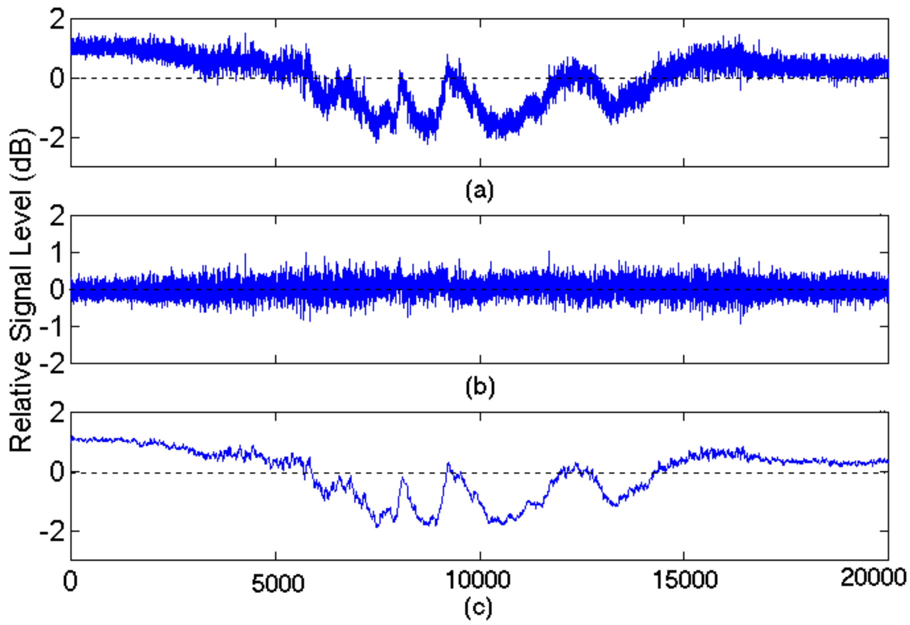


Figure 4. (a) Example of scintillation concurrent with rain
(b) Scintillation extracting from raw data by using VSQLMP algorithm (HPF)
(c) Rain attenuation extracting from raw data by using VSQLMP algorithm (LPF)

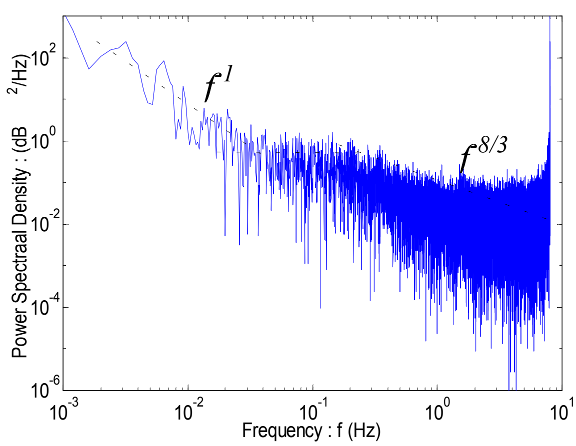


Figure 5. The frequency spectral of signal level variation during rain showed in figure 4.(a)

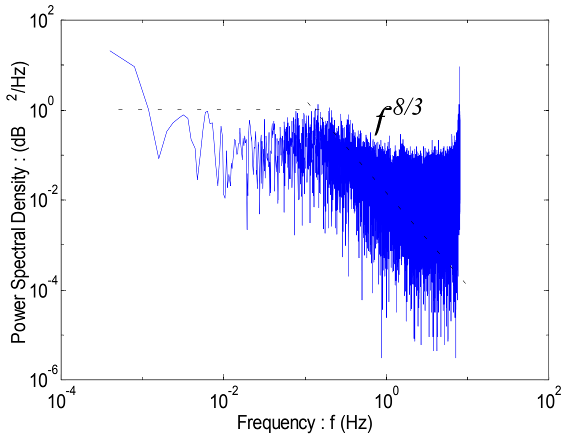


Figure6. The frequency spectral of scintillation showed in figure 4. (b)

Figure 5. shows the power spectrum of signal variation present in figure 4.(a) The spectrum was derived by Fast Fourier Transform(FFT). As can be seen that the shape of signal fluctuations due to scintillation superimposed on rain attenuation. It could be seen that the –20dB/dec slope occurs between 0.04 Hz until 0.04 Hz, while a flat portion appears between 0.04 Hz and 0.3 Hz.

Figure 6. shows the power spectral of scintillation after extracting present in figure 4.(b). The shape of spectral are quite close to the theoretical for Kolmogorov spectrum as derived and published by Takarskii [6].

Figure 7. shows the power spectral of rain attenuation after extracting present in figure 4.(c). The shape of spectral occurs -20dB/dec as the slope theoretically predicted for rain effect Matricciari [3].

## 5.Conclusion

In the past, the extraction of scintillation from the underlying dominant attenuation has been carried out by Butterworth high-pass filtering. However, it is not possible

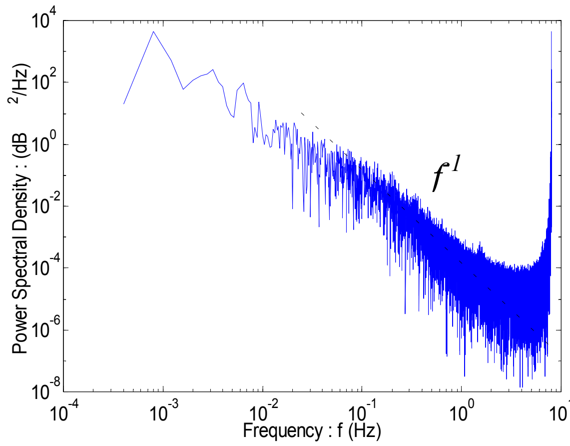


Figure 7. The frequency spectral of attenuation showed in figure 4.(c)

to establish a unique filter cutoff frequency for all weather VSQLMP application have been encountering in satellite signal. This algorithm used the output signal energy of QLMP to control step-size update with the gradient noise reduced and high convergence speed than QLMP. In application of real-time experiment an initial value of step-size is an important condition because its performance depend on the presence of noise. If high presence of noise, minimum point of error surface then providing inaccuracies of estimated frequency.

## References

[1] W. J. Vogel, G. W. Torrence,and J. E. Allnutt, “Scintillation fading on a low elevation angle satellite path: Assessing the Austin experiment at 11.2 GHz ,” *in Proc. Eight Int. Conf. Antennas Propagat*., Heriot-Watt Univ., UK, March 30 April 2, 1993, IEE Conf. Publ. Nr. 370, pt. 1, pp. 48-51.

[2] Y. Karasawa and T. Matsudo, “Characteristics of fading on low-elevation angle earth-space paths with concurrent rain attenuation and scintillation,” *IEEE Trans. Antennas Propagat*., vol. 39, no. 5, pp. 657-661, May 1991

[3] E. Matricciani, M. Mauri,and C. Riva, “Relationship between scintillation and rain attenuation at 19.77 GHz,” *Radio Science*, vol 31, no. 2, pp. 273-279, March-April 1996.

[4] O. Sangaroon, V. Chutchavong, C. Benjangkaprasert, J. Nakasuwan, and Y. Moriya, “On design of adaptive IIR digital filter for extraction scintillation and rain attenuation phenomena,” *ICFS 2002*, pp. 16-12, March 27-28, 2002.

[5] R. Punchalard, P. Chumchu, C. Benjangkaprasert, N. Anantrasirichai, and O. Sangaroon, “The reduction of gradient-based algorithm by using variable step-size technique,” *APCCAS2000* , pp. 415-418, December 4-6, 2000.

[6] V.I. Tatarskii, “Wave propagation in a turbulent medium,” Mc-GHill, New York,1961.