Performance Analysis of Broadband Satellite in Equatorial Zone

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Abstract

This paper investigates the performance Ka-band signal on channel broadband satellite that interference from Atmospheric effect. This paper designed new transmission model and displays the effect channels in many factor, such as cloud, rain, oxygen and gaseous variable from Equatorial zone that enables poor system to performance system .Finally, it shows the performance caused by interference of the rain in the different rain rate. The Statistics characteristics of rain attenuation in the equatorial zone are consideration in this paper. A more reasonable performance depend on the weather conditions .This was accomplished by including a Gaussian probability density function to account for weather condition.

Keywords: Ka-Band , Broadband satellite , rain drop size distribution

I. Introduction

The merging of telecommunication and computer technologies has led to a high demand for data communication to support various services such as the internet and multimedia. Recently, the increasing interest of broadband satellite multimedia system has led to the consideration of the higher band operator, Ka-Band (30/20GHz) because of congestion of lower frequency bands such as C and Ku Bands. Propagation impairments have many factors for signal attenuation. Rain is the main effect of signal attenuation.

According to the need for telecommunication in Asia, Ka-Band and Millimeter wave are the latest beneficial frequency used in satellite communication. However, as a result from their qualifications which are sensitive with rainfall condition commonly occurred in a tropical zone and high cost of their equipments, Ka-Band frequency is limited in use for the telecommunication system in this continent. The same as in other countries, there are highly attempts to use Ka-Band in telecommunication system in Thailand. Due to the location of
Thailand, the high rain rate is the significant factor for frequency attenuation.
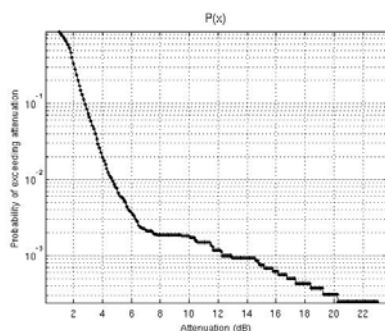

Figure 1 .Illustrated Cumulative rain attenuation

II. OFDM

A multiuser system can be efficient implemented in discrete time using an inverse FFT (IFFT) to act as a modulator and an FFT to act as a demodulator. The transmitted data are the "frequency" domain coefficient and the sample at the output of the IFFT stage are "time" domain Let $\mathbf{X} = \{x_0, x_1, \ldots, x_{N-1}\}$ denote the length N data symbol block. The IDFT of the date block $\mathbf{X}$ yields the time domain sequence $\mathbf{x} = \{x_0, x_1, \ldots x_{N-1}\}$

$$x_n = IFFT_N\{\mathbf{X}_K\}(n) \qquad (1)$$

To mitigate the effect of channel delay spread, a guard interval comprised of either a CP or suffix is appended to the sequence $\mathbf{X}$. In case of a CP, the transmitted sequence with guard interval is

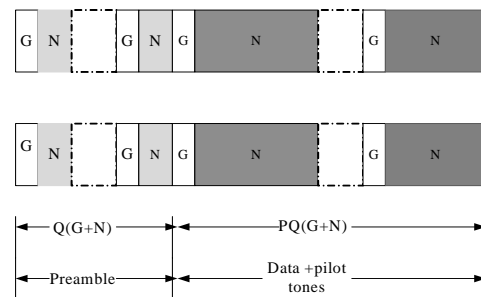$$x^g{}_n = x_{(n)N}, n = -G, \ldots, -1, 0, 1, \ldots N-1 \qquad (2)$$

Figure2. Frame structure for the $Q \times L$ OFDM system

Where G is the guard interval length in sample, and $(n)_N$ is the residue of n modulate N. The OFDM complex envelops is obtained by passing the real and imaginary components with sample rate $1/T$ s, and the analog I and Q signals are up converted to an RF carrier frequency. To avoid ISI, the CP length G must equal or exceed the length to the discrete-time channel impulse response M . The time required to transmit one OFDM symbol $T_s = NT + GT$ is called the OFDM symbol time. The OFDM signal transmitted over the pass-band RF channel, received and downconverted to base band. Due to the CP, the discrete linear convolution of the transmitted sequenced with the channel impulse response becomes a circular convolution. Hence, at the receiver the initial G samples from each received block are removed, following by a N point discrete Fourier transform (DFT) on the resulting sequence.

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The frame structure of a typical MIMO-OFDM system is shown in figure 2. The OFDM preamble consists of Q training symbol of length $N_I + G$ where $G \leq N_I \leq \leq N, N_I = N/I$ and I an integer that divides N. Often the length of the guard interval in the training period is double; for example, in IEEE802,16a to aid in synchronization, frequency offset estimation and equalization for channel exceeds the length of the guard interval.
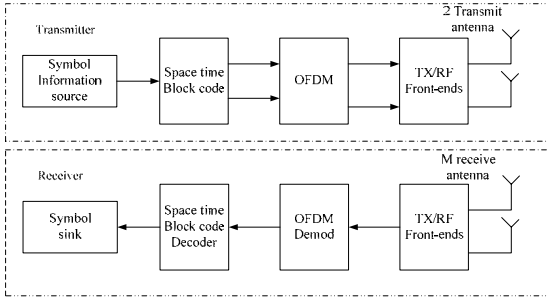

Figure 3. System block diagram model

III. Broadband Satellite Channel

A. Fixed satellite Channel

There have been several hardware and software channel simulator developed for the land mobile channel. However, the emphasis of this subsection is one computer generated channel model and, in particular, on the one developed at CRC. All computer models for the fading channel described in this subsection are based on the manipulation of a white Gaussian random process. This process is approximated by a sum of sinusoid with random phase angle. An expression for the Gaussian random process $a(t)$ is given below [1]

$$a = \text{Re} \sum_{k=-N/2}^{N/2} V_k \exp[j2\pi(f_c + kf_o)t + j\lambda_k] \quad (3)$$

Where v_k is the amplitude and λ_k is a random phase angel uniformly distribution between 0 and 2π. N is the number of sinusoid, $(f_c + kf_o)$ is the sinusoidal frequency, and Re denote the "real part of"

$$a = \text{Re}\{[a_c(t) + ja_s(t)]\exp(j2\pi f_c t)\} \quad (4)$$

Where

$$a_c(t) = \text{Re} \sum_{k=-N/2}^{N/2} V_k \exp[j(2\pi kf_o + \lambda_k)] \quad (5)$$

$$a_s(t) = \text{Im} \sum_{k=-N/2}^{N/2} V_k \exp[j(2\pi kf_o + \lambda_k)] \quad (6)$$

Denotes "the imaginary part of" $a_c(t)$ and $a_s(t)$ can be easily obtained using the FFT algorithm for given V_k and λ_k

1).Rayleigh Fading Channel: By definition [2] the envelope r of the two narrow-bands Gaussian random process is Rayleigh, and its phase ϕ is uniform. Therefore

$$r = \sqrt{a^2_c(t) + a^2_s(t)} \quad (7)$$

is Rayleigh and

$$\phi = \tan^{-1}\left(\frac{a_s(t)}{a_c(t)}\right) \quad (8)$$

Is uniform

2).Rician Fading Channel; When a fading process has a LOS component A_c together with multipath fading, the channel is model as Rician[3] . The Rice process is given by

$$a_r(t) = \text{Re}\{[A_c + a_c(t)] + ja_s(t)]\exp[j2\pi f_c t]\} \quad (9)$$

And its envelop r and ϕ are given by

$$r = \sqrt{[A_C + a_c(t)]^2 + a_s^2(t)} \quad (10)$$

$$\phi = \tan^{-1}\left(\frac{a_s}{A_c + a_s}\right) \quad (11)$$

3).Log-Normal Fading Channel: Local mean variation of cellular mobile channel and shadowing caused by foliage attenuation are usually modeled as a log-normal fading process.[4] [5] .[6] There are two methods of generating a log-normal fading process: one for slow fading and the other for fast fading

a).*Slow fading log-normal process:* The statistic of a log-normal process is generated from a normal (Gaussian) random process. For the slow-fading case, the normal random variate is generated from a nonlinear transformation of a uniform distribution [7] and is given by

$$x_p = \sqrt{-2\ln u}\cos(2\pi v) \quad (12)$$

Where u and v are uniform distribution between zero and one. x_p is a Gaussian variate with zero mean and unity variance .To convert this variate to actual mean and variance, the following transformation is required

$$x = \sqrt{d_o x_p} + \mu \quad (13)$$

Where μ and d_o are the mean and variance, respectively. The slow-fading log-normal process is given by

$$A_c = \exp[x] \quad (14)$$

b).*Fast-fading log-normal process:* For the fast-fading log-normal model, the normal (Gaussian) process is approximation by a sum of sinusoid with random phase angle. The effect of the fading bandwidth is included. The fast log-normal model is given by

$$A(t) = \exp[\mu + \sqrt{d_o}x_c(t) + j\sqrt{d_o}x_s(t)] \quad (15)$$

Where $x_c(t)$ and $x_s(t)$ are narrow-band Gaussian random process, which can be obtained using expression given in [8],[9] and with appropriate amplitude and phase

Table1. Fixed Satellite channel Phase model –ka-band

Weather conditions	Mean	Variance
Clear sky	0.0072	0.00357
Intermittent light rain	0.0088	0.00546
Thunder shower	0.0068	0.00414
rain	0.0089	0.03077

Table2. Fixed Satellite channel –Envelope model ka-band

Weather conditions	Mean	Variance
Clear sky	0.413	0.00087
Intermittent light rain	0.483	0.00003
Thunder shower	0.436	0.01386
rain	0.662	0.0200

B. Land Mobile Satellite Channel

Land Mobile Satellite Fading Channel*:* This channel model [10] assume*s* that the LOS component under shadowing is log-normal distribution and that the multipath effect is Rayleigh distribution. The two process are additive. Thus, the channel model is given by the combination of log-normal and Rayleigh model described previously. As given below

$$a(t)=\text{Re}\{[\,y_c(t)+a_c(t)+j(y_s(t)+a_s(t))]\exp[\,j2\pi f_c t]\} \quad (16)$$

And $a_c(t)$ and $a_s(t)$ are Gaussian random process whose magnitude is related to the input sinusoid amplitude V_k of [8] and[9], which ,in turn, is related to the multipath power b_o as

$$b_o = \sum_{k=1}^{N} V^2_k /2 \quad (17)$$

Similarly, $y_c(t)$ and $y_s(t)$ are log-normal random processes whose values are related in the following way. From [11] $A(t)$ can be rewritten as

$$A(t) = y_c(t) + jy_s(t)$$
$$= \exp[\mu\sqrt{d_o}x_c(t).[\cos(\sqrt{d_o}x_c(t)) + j\sin(\sqrt{d_o}x_s(t))] \quad (18)$$

The values of $x_c(t)$ and $x_s(t)$ are related to the amplitude v_k of the sin wave of and [8] and [9] with the x replacing the a. For this case, however the power of the sum of the sine wave is normalizes to unity

$$\sum_{k=1}^{N} V^2_k /2=1 \quad (19)$$

The signal envelope and signal phase are given by[12] and[13] , respectively

$$r(t)=\sqrt{[\,y_c(t)+a_c(t)]^2+[\,y_s(t)+a_s(t)]^2} \quad (20)$$

$$\phi(t)=\tan^{-1}\left(\frac{y_s(t)+a_s(t)}{y_c(t)+a_c(t)}\right) \quad (21)$$

5).Shaping of the Fading Spectrum: Two spectral shaping filters are used to shape the fading spectrum of the computer-generated model. One shaping filter is based on the land cellular mobile channel [5] and [6] and the other has a Butterworth frequency response in the pass band [14]

Table3. LMS Satellite channel Phase model –ka-band

Channel condition	μ	$\sqrt{d}$	b_o
Light to medium shadowing	-0.230	0.0115	0.1585
Medium to heavy shadowing	-2.30	0.046	0.10
Heavy shadowing	-1.95	0.46	0.0398

Table4. LMS Satellite channel –Envelope model ka-band

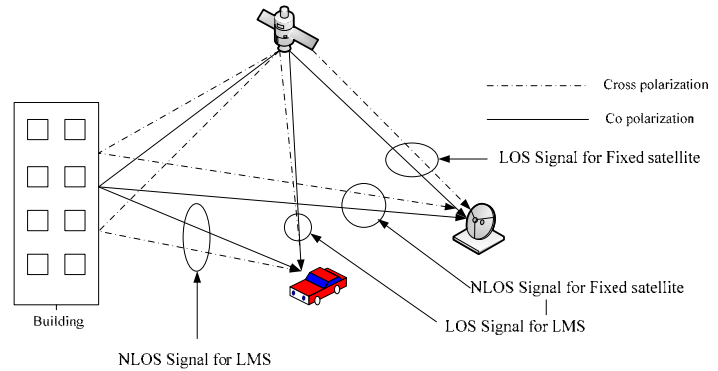| Channel condition	Mean	Variance
Light to medium shadowing	0.0068	0.0262
Medium to heavy shadowing	-0.01447	0.1124
Heavy shadowing	-0.0111	0.1934

Figure 4. Polarization LOS, NLOS in Fixed satellite and LMS
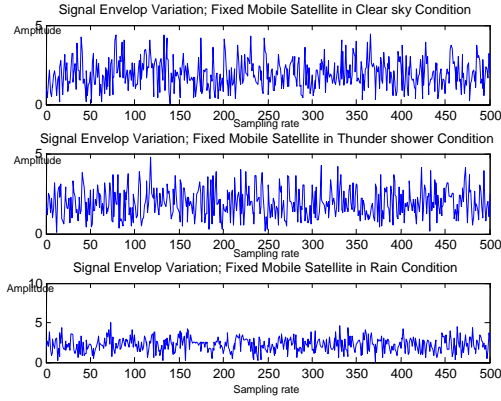
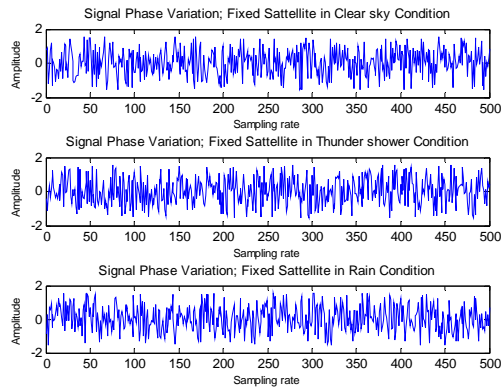Figure 5 signal Envelop for Fixed Satellite
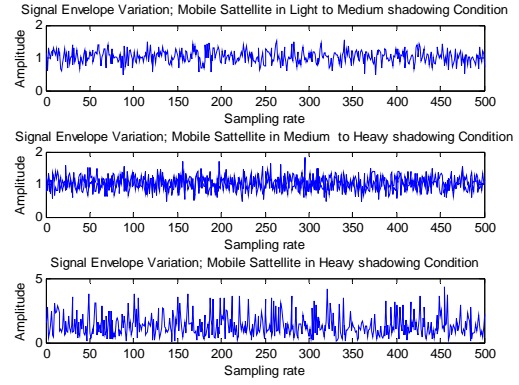

Figure 6 signal Envelop for LMS Satellite

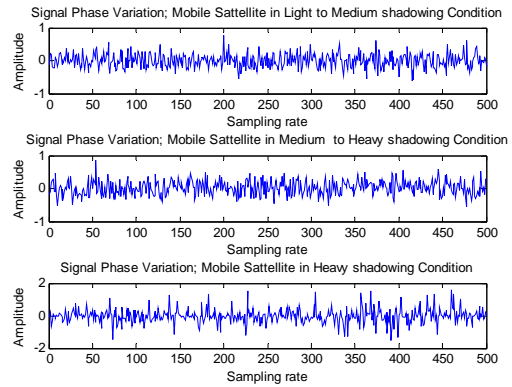Figure 7 signal Phase for Fixed Satellite

Figure 8 signal Phase for LMS Satellite

IV. Atmospheric Loss in Broadband Satellite Channel

A. Rain Drop size Distribution

This paper considered rain attenuation from rain drop size distribution and the specific attenuation A in dB/km due to rain. This is calculated by integrating over all of the drop size as

$$A=4.343 \int Q(D,\lambda,m)N(D)dD \qquad (22)$$

Q is the attenuation cross section which is a function of the drop diameter. D is the wavelength of the radio wave λ and the complex refractive index of the water drop, which is a function of the function and temperature. And N(D) is the drop size distribution. The attenuation cross section Q is found by applying the classical scattering theory of Mie's for a plane wave impinging upon a spherical absorbing particle. N(D) for Gamma distribution can be written

$$N(D)=N_T A^{n+1} D^n \exp\left[-AD/\Gamma(n+1)\right] \; (m^{-3}.mm^{-1}) \quad (23)$$

N(D) for Log normal distribution can be written

$$N(D)=\frac{N_T}{\sigma D\sqrt{2\pi}}.\exp\left[-\frac{1}{2}\left(\frac{\ln(D)-\mu^2}{\sigma}\right)\right] \; (m^{-3.}mm^{-1}) \quad (24)$$

Consider in Log normal distribution terms and forms

$$P=F(\ln A)=\int\limits_{\ln A}^{\alpha} \frac{1}{\delta\sqrt{2\pi}}.\exp\left[\frac{-\left(x-\mu^2\right)}{2\delta^2}\right].dx=Q\left(\frac{\ln A-\mu}{\delta}\right)$$

And (22), (23),(24) [15], [16], [17]

$$A=4.343\int Q(D,\lambda,m).N(D)dD$$

The cross section Q is expended as

$$Q(D,\lambda,m)=\frac{\lambda^2}{2\pi}.\sum_{n=1}^{\alpha}(2n+1)\operatorname{Re}\left[a_n+b_n\right]$$

$$A=(4.343)\left(\frac{\lambda^2}{2\pi}\right).\sum_{n=1}^{\alpha}(2n+1)\operatorname{Re}\left[a_n+b_n\right].\frac{N_T}{\sigma D\sqrt{2\pi}}.\exp\left[-\frac{1}{2}\left(\frac{\ln D-\mu^2}{\delta}\right)\right] \quad (25)$$

$$\gamma_r=kR^\alpha \qquad (26)$$

and

$$A=a_n R^{b_n} \qquad (27)$$

was found from rain with the rain rate at 50mm/hr and the diameter of rain at 10 mm a_n and b_n are the Mie scattering coefficients and analysis in Bessel function [18], [19], which are the complex function of m, D and λ. In the equation (22), A is rain attenuation analysis in rain drop size distribution having log normal distribution term. We can find N(D) for log normal distribution[20] and it can be written as

$$N(D) = \frac{N_T}{D(2\pi)^{\frac{1}{2}}\ln\sigma} . e^{-\left[\ln\left(\frac{D}{D_M}\right)/2\ln\sigma\right]^2}$$

Case 1 (Showers) $5\langle R\langle 50 mm/hr$

$$N_T = 40R^{0.64}$$

$$D_M = 1.14 + 0.18\ln R$$

$$\sigma = e^{0.29 - 0.001R}$$

Case 2 (Showers) $5\langle R\langle 50 mm/hr$

$$N_T = 46R^{0.55}$$

$$D_M = 0.222 + 0.397\ln R$$

$$\sigma = e^{0.5--.0035R}$$

Case 3 (Thunderstorms) $50\langle R\langle 200 mm/hr$

$$N_T = 8.8^R$$

$$D_M = 1.76 + (7.33*10^{-4}).\ln R$$

$$\sigma = 1.37$$
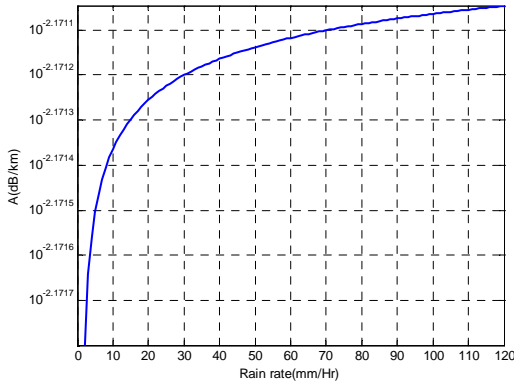
Figure 9.Attenuation at Broadband satellite (20 GHz) due to DSD
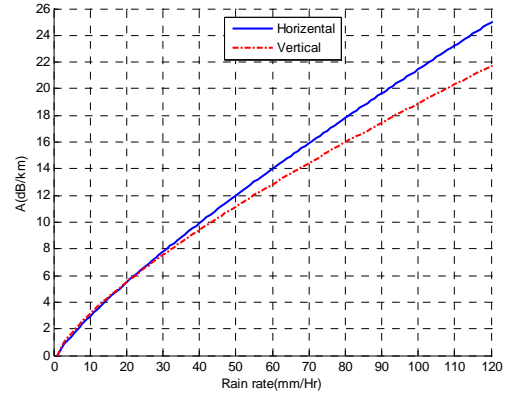
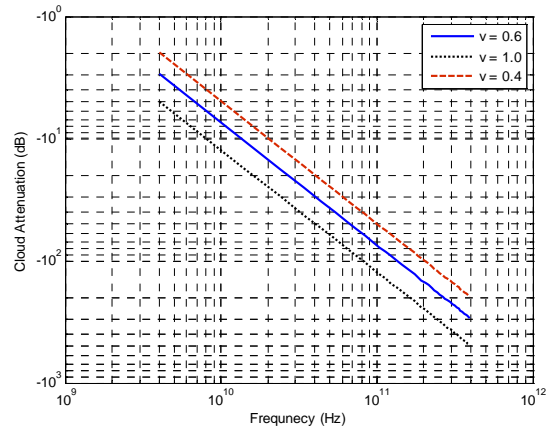Figure 10.Rain attenuation at Broadband Satellite (20 GHz) in Linear polarization

Figure 11.Cloud attenuation at 20GHz

V is cloud liquid water content (g/m) V
V=0.6   Cumulonimbus
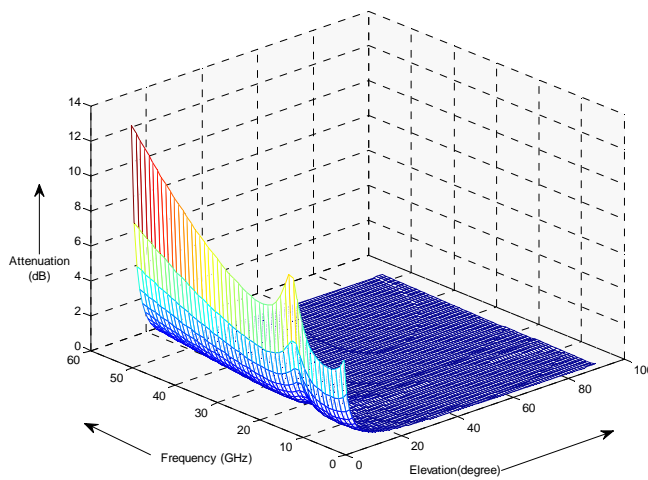V=1.0   Cumulus
V=0.4   Stratus

Figure 12.Water and Oxygen attenuation at millimeter wave

B. Gaseous Absorption

A method for predicting absorption due to atmospheric gases (oxygen and water vapor) is given in ITU-R recommendation [21] .The input parameter required for the calculation include frequency, path-elevation, height above mean sea level, and the water vapor density. The oxygen attenuation is considered a background effect with every little temporal variation; variations in gaseous absorption arise from changes in the amount of water vapor in the atmosphere. In order to estimate the distribution of gaseous absorption on an annual basis, the annual distribution of water vapor density is required. It is generally observed that the water vapor density distribution follows the normal probability law[22] .If a complex characteristics of the distribution is not available, an approximate distribution can be constructed is not available average water vapor density as the mean value and quarter of that as the standard deviation.

C. Cloud attenuation effect

Troposphere propagation impairment that affect satellite communication signal increase in severity with the increase of frequency. Precipitation effects are than main impairment for millimeter wave signal propagation through the atmosphere. However, many stations in ka-band service use small terminals. But cloud attenuation, that may cause deep fades in ka-band, is one of the components that need to be considered for low availability satellite links owing to its higher probability of occurrence. The annual cumulative contributions of clouds attenuation from the various cloud formation encountered at different heights along a zenith path a given location are obtained from the annual average total cloud cover. Individual cloud cover amount for the four cloud types, their vertical dimensions, and the specific attenuation. This provides the

zenith cloud attenuation distribution, with the distribution beings conditions to the total cloud cover.

V. MODELING CONSIDERATIONS

From Figure 8 as the review model analysis for consider in this paper. A signal made by modulation a QPSK and 16 QAM, OFDM will be exported to the channel Ka-band, which was Interrupted by loss in atmospheric example, attenuation by cloud, and rain. Attenuation of oxygen and gaseous in the air that causes a signal change occurs.
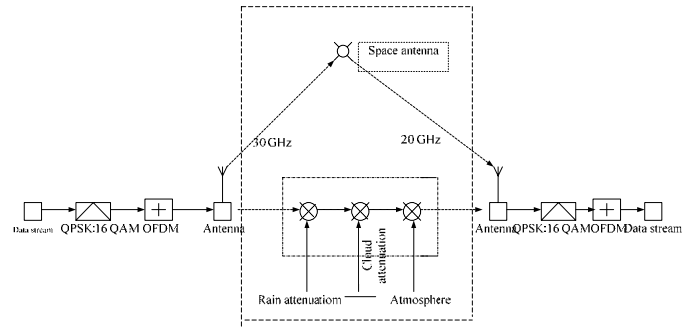
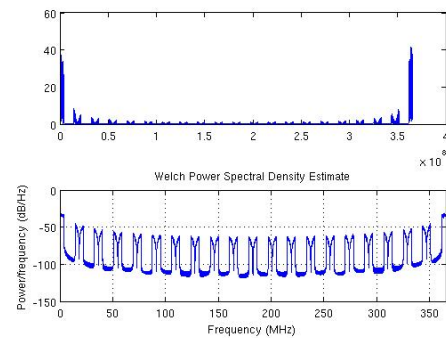

Figure 13 Model for analysis

VI. RESULTS MODEL

Figure 14 Illustrated Spectrums OFDM (Transmission)

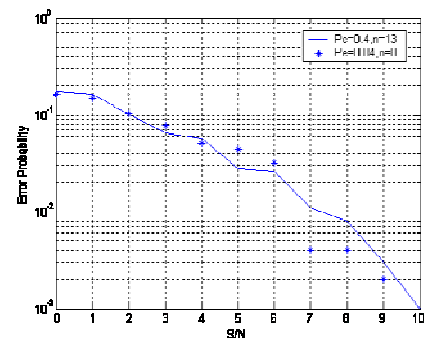Figure 15. Probability and S/N Pe (0.4and 0.04)

The result from taking noise with error probability, (Pe) at 0.4 and 0.04 was illustrated in figure 6. The system with Pe (0.4) needed to re-transmit the data 13 times in total whereas the one with Pe (0.04) did 8 times. In addition, the output error probability around the lower zone of S/N (0.1-4 dB) did not have a big different when it was with Pe (0.4) and Pe (0.04). When the S/N got higher (more than 5 dB), the output error probability with Pe (0.4) would be tentatively lower than the one with Pe (0.04)
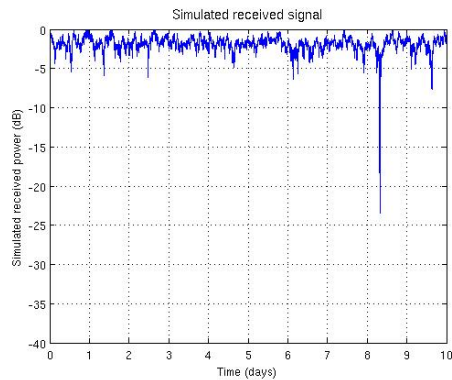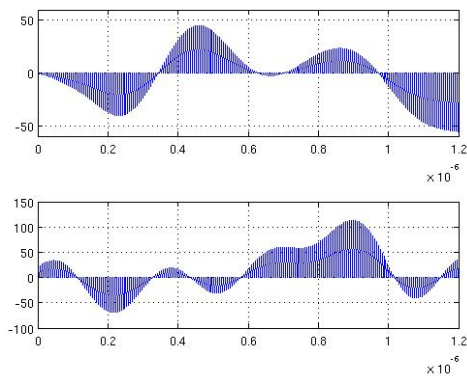
Figure 16 Receives signal (Receiver)
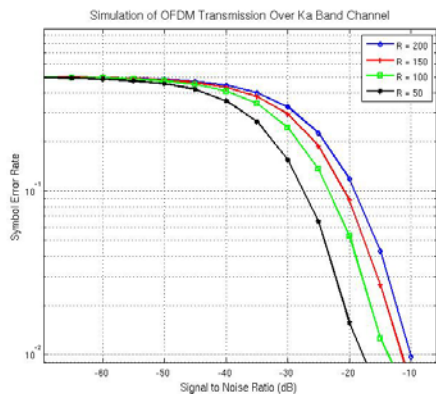

Figure 17 I/P Multiplex (Receiver)

Figure 18 Compare Symbol Error Rate S/N and rain rate

VII Conclusion

This paper considers the simulation system performance Broadband satellite affected to remind cloud, rain, oxygen and gaseous in the air. In figure 14 to see that the value system performance is poor when the rate of the rain that 200 mm/hr

REFERENCE

[1] C.Loo. "TWT noise suppression due to the presence of a large saturating carrier, Can Elect.Eng J.Vol 3,no.4,pp14-16,1978

[2] A.Papoulis,Probability,Random Variables and Stochastic Process. New York: McGraw-Hill 1965

[3] K.A.Norton, L.E.Vogler ,W.V.Mansfield, and P.J. Short. "The Probability distribution of the amplitude of a constant vector plus a Rayleigh distribution vector" Proc IRE, vol 43,pp 1354-1361, Oct 1955

[4] C.Loo. "A statistics model for a land mobile satellite link" IEEE Trans.Veh.Technology, Vol.VT-34,pp 122-127 Aug1985

[5] W.C.Y.Lee, Mobile Communications Engineering. New York:McGraw-Hill ,pp 69-73.169-177.1982

[6] W.C.Jakes,Ed Microwave Mobile Communication .New York.Wiley,1974

[7] G.M.Dillard "Generating random numbers have probability distribution occurring in signal detection problems "IEEE Trans Inform, Theory vol IT-,pp 616-617 Oct 1967

[8] J.Goldhirsh and W.J,Vogel. "Roadside tree attenuations at UHF for land mobile satellite syatem. IEEE Trans Antenna Propagation vol AP-35, pp 589-596 May 1987

[9] W.J,Vogel and J.Goldhirsh "Fade measurements at L-band and UHF in mountainous terrain for land mobile satellite systems, IEEE Trans Antenna Propagation vol 36,PP104-113 Jan 1988

[10] C.Loo and J.S. Butterworth, "Land mobile satellite channel measurement and modeling" Proc IEEE, vol 86,no7,pp1442-1463,July 1998

[11] G.Butt, B.G.Evans and M.Richaria , "Narrowband channel tom high from multiband propagation measurements applicable to high angle land mobile satellite system" IEEE J. Select Area Commu, vol 10, pp 1219-1226 Oct 1992

[12] Y.Matsumo,R,Suziki, K,Kondo and M,H,Khan "Land Mobile satellite propagation experiments in Kyoto city" IEEE Trans Aerosp.Electron System Vol.28,pp718-727 July 1992

[13] N.Obara, K,Tanaka S .Yamamoto and H,Wakana "Land mobile satellite propagation measurements in Japan using ETS-V Satellite" in Proc Int Mobile Satellite Conf 1993 pp313-318

[14] C.Loo and N.Secord "Computer model for fading channels with applicaton to digital transmission, "IEEE Trans,Veh Technology vol 40,pp 700-707 Nov 1991

[15] A.Maitra "Three-Parameter Rain Drop Size Distribution Modeling at Tropical Location" Electronics Letters 11th May 2000, Vol36,No10

[16] Matsuo Sekine,Chii-Dong Chen and Toshimitsu Musha " Rain Attenuation from Log-Normal and Weibull Rain Drop Size Distributions"

[17] M.A.Awang and J.Din " Comparison of the Rain Drop Size Distribution Model in Tropical Zone" 2004 RF and Microwave Conference, October 2004

[18] Dusan Cermak,Onderj Fiser and Vladiimir Schejbal "Electromagnetic Scattering by rain drops" Cost 280

[19] ITU-R Recommendation 838 P-series "Specific Attenuation Model for Rain for Use in Prediction Methods"

[20] Matsuo Sekine,Chii-Dong Chen and Toshimitsu Musha " Rain Attenuation from Log-Normal and Weibull Rain Drop Size Distributions"

[21] ITU-Recommendation ITU-R RPN 618-4 ,1996

[22] Reports of the CCIR "CCIR 17th Plenary Assembly ,Dusseldorf Germany ,May 1990 Rep563-4