LONG-TERM RAIN ATTENUATION PROBABILITY AND SITE DIVERSITY GAIN PREDICTION FORMULAS

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DEDICATIONS

To
My beloved parents and brothers for their unwavering love, sacrifice and inspiration.

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ABSTRACT

The increasing growth of wireless communication systems has caused the usage of higher frequencies in order to have wider bands. However the increase of frequency will lead to the degradation of satellite communication performance. Rain attenuation is one of the most fundamental reasons of the degrading quality of services. Thus fade mitigation techniques will be used in order to compensate for excessive attenuation such as diversity protection schemes, power control and adaptive processing techniques. Among these techniques the most efficient is site diversity (SD). The aim of this project is to determine the effect of SD under the rain conditions, combine both categories for the estimation of slant path rain attenuation and SD gain. It includes the designing of algorithm flow which incorporated into MATLAB programming software. Also, the SD gain calculation in Skudai – Malaysia is included too. It is hoped that with the availability of data, the design process of fade mitigation techniques is greatly simplified. The ITU-R study Group 3 database is used in this project.

ABSTRAK

Pembangunan dalam teknologi sistem komunikasi tanpa talian telah menyebabkan penggunaan frekuensi yang lebih tinggi supaya lebar jalur yang lebih besar dapat diperolehi. Namun demikian, peningkatan frekuensi ini telah membawa kepada kemerosotan dalam prestasi komunikasi satelit. Pengecilan hujan merupakan salah satu faktor terpenting yang mengakibatkan berlakunya fenomena ini. Justeru itu, teknik mitigasi pemudaran seperti skema perlindungan kepelbagaian, kawalan kuasa, dan teknik pemprosesan penyesuaian digunakan untuk mengimbangi kelemahan tersebut. Di antara teknik-teknik tesebut, teknik yang paling berkesan adalah kepelbagaian tempat (SD). Objektif utama projek ini adalah untuk menentukan kesan SD dalam keadaaan hujan, menggabungkan kedua-dua kategori untuk penganggaran pengecilan hujan laluan condong dan penggandaan SD. Ini termasuklah mereka aliran algoritma yang dimasukkan ke dalam perisian program MATLAB. Pengiraan peningkatan SD juga dilakukan di Skudai, Malaysia. Dengan tersedianya data tersebut, proses mereka teknik mitigasi pemudaran belaku dengan lebih mudah. Pangkalan data kajian kumpulan 3 ITU-R digunakan dalam projek ini.

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LIST OF SYMBOLS

A	Attenuation
$A_{0.01}$	Attenuation at 0.01% of time
A_m	Measured attenuation
A_p	Predicted attenuation
dB	Decibel unite
d	Separation (km) between the two sites
f	Frequency
GHz	Giga Hertz
ho	Rain freezing height
H_R	Rain height (km)
H_s	Height above mean sea level of the earth station (km).
k, α	Regression coefficients
km	Kilometer
L*eff*	Effective Path length
LG	Horizontal projection of the slant path
L_o	Rain cell diameter
L	path length
m	Meter
mm	Millimeter
P	Probability
P (%)	Percentage in time of the year
P1	percentages of time for an average year with no site diversity
P2	percentages of time for an average year with site diversity
$R_{(p)}$	Rain rate at percentage in time of the year
$r(P)$	Horizontal reduction factor of percentage in time of the year
$r_{0.01}$	Horizontal reduction factor for 0.01% time of the year
$R_{0.01}$	Rain rate at 0.01% of time of the year
$v_{0.01}$	Vertical reduction factor for 0.01% time of the year
γ_R	Specific attenuation

θ	Elevation Angle
ψ	baseline-dependent angle
Φ	Latitude of the earth station

LIST OF ABBREVIATIONS

AC	Adaptive Coding
AGCV	Automatic Gain Control Voltage
AM	Adaptive Modulation
C	Centigrade
dB	Decibel
dBm	Decibel mili watt
DBSG5	ITU-R Study Group Three Data Bank
DDR	Data Rate Reduction
DLPC	Down-Link Power Control
DTH	Direct to Home
EEPC	End-to-End Power Control
EHF	Extremely High Frequency
EIRP	Effective Isotropic Radiating Power
FMT	Fade Mitigation Technique
FSS	Fixed Satellite Service
G_d	gain contributed by the spatial separation
GEO	Geosynchronous Earth Orbit
G_f	frequency gain
GHz	Giga Hertz
G_{SD}	site diversity gain
GUI	Graphical User Interface
G_θ	gain term dependent on elevation angle
G_ψ	baseline-dependent gain
IEEE	Institute of Electrical and Electronic Engineering
ITU-R	International Telecommunication Union Radio-Broadcasting
LEO	Low Earth Orbit
MEO	Medium Earth Orbit

mm/h	milimetre per hour
MMS	Malaysia Metrological Services
OBBS	On-Board Beam Shaping
RF	Radio Frequency
RMS	Root Mean Square
S	second
SD	Site Diversity
SHF	Super High Frequency
TRMM	Tropical Rainfall Measuring Mission
ULPC	Uplink Power Control
U.S	United State of America
UTM	Universiti Teknologi Malaysia
VSAT	Very Small Aperture Terminal

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The increasing growth of wireless communication system has caused the usage of higher frequencies in order to have wider band. However the increase of frequency will lead to the degradation of satellite communication performance. To combat rain attenuation, several fade mitigation techniques have been developed the most efficient one is the site diversity (SD) ESA Publication (2002).

Rain attenuation is one of the most fundamental limitations to the performance of satellite communication links, causing large variations in the received signal power. Although a lot of research has been conducted overseas to reduce the effect of rain fading such as investigation in fade duration statistics, these research efforts are really carried out in tropical countries, especially in the frequency 38GHz radio link communication.

Fade duration indicates the time length between two consecutive crossings of the received signal on the same attenuation threshold. This parameter is important for communications systems where length of time is a critical parameter. The fade duration is usually presented as statistics of the number of fade events at a given fade duration which is useful for the design of fade mitigation techniques.

SD (Site Diversity) takes advantage of the spatial characteristics of the rainfall medium by using two earth stations to exploit the fact that the probability of attenuation due to rain occurring simultaneously on the alternative Earth-space paths is significantly less than the relevant probability occurring on either individual path. Though the cost effectiveness of SD remains questionable, the interest on SD has been renewed, due to the significant reduction of ground terminal antennas and other hardware sizes. Nowadays, terminals can be installed in customers' premises and the use of public terrestrial networks to carry out signaling seems possible ESA Publication (2002). Moreover, SD is considered for alternative feeder links of a satellite network.

1.2 Problem Statement

The problem statement of this project is stated in the following points:

i- The incapability of the published prediction models to be sensitive of the available knowledge of rainfall on Malaysia climate.

ii- The lakes in the dynamic fade information (fade duration, depth, slop and interfade).

iii- The lack of satellite propagation studies in Malaysia, especially for higher frequency band.

iv- A diversity control unit coordinating the signal flow and a signal processing unit must be incorporated at the master and the other earth station, respectively.

v- There is no previous calculation for diversity gain in Malaysia.

1.3 Objective

The objectives of this project is to determine the effects of site diversity under the rain conditions and calculate the diversity gain. will be done by using experimental data as well as ITU-R study group 3 databank, and analyze in an easy to use environment features by using Mat-lab program.

The objective main approach is to enhance the existing satellite services at Ku-band under the rain conditions, study the rain and fade effect on the satellite, then the site diversity and try to get a new parameter for future satellite site diversity systems to get the data from higher frequency band such as Ka-band and above then transfer it to other satellite. The local experimental data will be used as function to enhance the prediction techniques for satellite path instead of using the theoretical models, which mainly based on experimental data of temperate regions.

1.4 Scope of work

- Specify rain attenuation data collected from Ericsson Microwave Link in (WCC) at UTM.
- Conversion of the terrestrial rain attenuation data for satellite application.
- Perform the Site Diversity based on available collective data.
- Obtain Similar profile from ITU-R group 3 databank.
- Calculate the fade duration statistics.
- Evaluate the effect of SD and compare it with various SD equations [1].
- Diversity improvement factor and diversity gain calculation.

- Calculate the site diversity gain.

1.5 Methodology

The main contribution of this project is to propose of combine the estimation of slant path rain attenuation and SD gain. It includes the designing of algorithm flow which incorporated into MATLAB programming software. It is hoped that with the availability of data, the design process of fade mitigation techniques will be greatly simplified. The ITU-R study Group 3 database will be use.

Therefore, the scope of this project consists of three parts, rain attenuation prediction techniques of slant path and terrestrial path, fade mitigation techniques and site diversity gain. The methodology diagram of overall project is shown in figure 1.1.

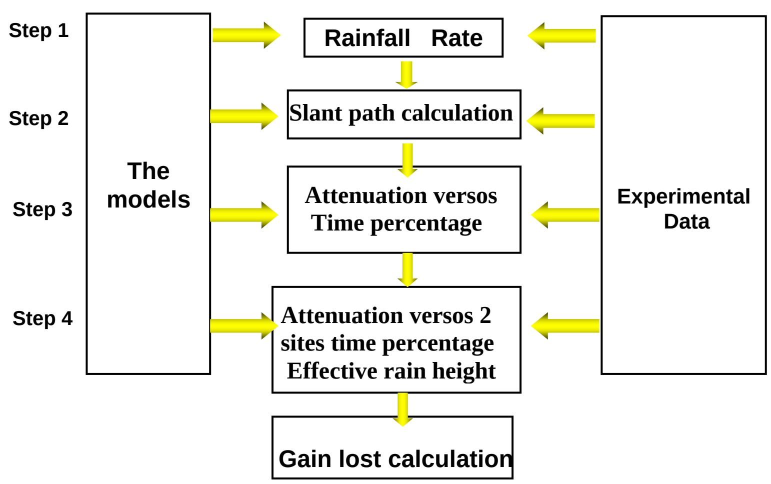

Figure (1.1) Methodology diagram of overall project

Step 1

- Depend on the yearly and average one year (between February 2001 and February 2002) UTM skudai data.
- Various locations in Malaysia data and concentrate on Johor.
- Tropical data from international data bank (DBSG5).

Step 2

- Calculate the specific attenuation, reduction factor and slant path for effective vertical and horizontal length for the collected data in Skudai.
- Calculate the vertical and horizontal slant path by using ITUR data for Skudai and Johor baharu.
- Simulate the slant paths calculated data against different time percentage for vertical and horizontal data.

Step 3

- Calculate and simulate the relationship between percentages of time with and without diversity for the same attenuation according to improvement factor formula.

Step 4

- Calculate the Fade duration statistics.
- Calculate and simulate the relationship between attenuation and percentage of time for two sites in different distance depending on the improvement factor table, fade duration statistics and site diversity formula.

Step 5

- Calculate the gain lost from the formula :

$$G = G_d \cdot G_f \cdot G_\theta \cdot G_\psi \qquad \text{dB}$$

1.6 Thesis Outline

Chapter 1: Consists of introduction of the project. The objectives of the project are clearly phased with detailed. The research scope and methodology background are also presented.

Chapter 2: Included introduction to the satellite communication, begins with an overview of propagation effects. Explain brief details about Malaysia climate characteristic. Rainfall distribution and rain vertical profile structure characteristics and its type also presented.

Chapter 3: include fade Durations in tropical climates, explained about fade duration modeling, overviewed of fade mitigation technique and explained accumulative distribution functions.

Chapter 4: Present site diversity and site diversity gain equations.

Chapter 5: Methodology and resents the results, analysis and discussion for the simulation program, the calculation of the attenuation, fade duration statistics, site diversity and site diversity gain calculations.

Chapter 6: Concludes the thesis. The conclusion is given based on the analysis of results from the previous chapter. Recommendations for future works are also presented.