ATTENUATION PREDICTION FOR SATELLITE PROPAGATION FROM POINT TO POINT MICROWAVE LINK MEASUREMENTS

ZUHANIS BINTI MANSOR

UNIVERSITI TEKNOLOGI MALAYSIA

To my husband, Muhammad Shahril Ahmad;
for his love, support and understanding
To my mother, Zainab Bt. Othman;
To my sons and daughter, Safuan, Sulaiman, Zulaikha and Suffian;
for their understanding and scarifies.

ACKNOWLEDGEMENTS

Verify! Allah will not change the good condition of a people as long as they do not change their state of goodness themselves…

Surah Ar-Ra'd (11)

"Kalau tidak dipecahkan ruyung, mana nakkan dapat sagunya." This thesis would not have been possible without the Grace of Allah and His Guidance. Thank you God, for giving me the strength to face hardship, the patience to complete and the joy of knowledge.

First and foremost, I would like to thank my supervisor, Associate Professor Dr Jafri Bin Din for his precious guidance and time. His inspiring ideas and constructive comments have contributed greatly in the writing of the thesis. His advice has become the beacon of light to this humble effort.

I would also like to thank *MARA* for the financial support that has enabled me to pursue my studies. I would also like to acknowledge *Mak* for her attention and affection, my husband, Shahril, for his patience and encouragement, my children, Safuan, Sulaiman, Zulaikha and Suffian, for their understanding (I am sorry for having to leave you at home most of the days and nights).

This acknowledgement would seem odd without mentioning these few names. Ainor, Zura, Bambang, Muza, Fiza, Rohaida and KB, thank you for the support and much needed comic relief. Lastly, I would like to thank all the individuals who have been directly or indirectly involved in the process of completing the thesis.

ABSTRACT

This project will look into the prediction of satellite performance by analyzed and convert the summarized collected data on rain attenuation. The summarized data are taken from point to point microwave link measurements at Skudai, Johor Bahru, Alor Setar, Ipoh, Kuantan and Kota Bahru. The data needs to be taken into considerations on many aspects that will involve in wave propagation phenomena on the satellite points of view. The transformation of the data will then be used to predict the performance of the satellite propagation. As we can see, satellite communication has a very important function in the whole coverage area due to its several advantages compared to the terrestrial measurement. Reliability analysis is done by comparing the attenuation with the path attenuation calculated using ITU-R standard. The transformation of the measured point to point microwave link rain attenuation time series into satellite attenuation time series has been carried out. Thus, the prediction on satellite communications performance operating in Malaysia could be implemented by employing locally collected data.

ABSTRAK

Projek ini mengkaji secara mendalam kepada kesan kelemahan perambatan gelombang satelit dengan menganalisa dan menggunakan kaedah penjelmaan data-data hujan yang telah di proses. Data yang diambil dari satu tempat ke satu tempat jalur gelombang di beberapa lokasi seperti Skudai, Johor Bahru, Alor Setar, Ipoh, Kuantan and Kota Bahru akan dianalisa terlebih dahulu. Data-data tersebut perlu di ambil kira terlebih dahulu kepada perkara-perkara yang memberi kesan kepada penurunan jalur gelombang satelit. Penjelmaan data tersebut kemudian akan digunakan dalam kaedah meramal kesan kelemahan perambatan gelombang satelit. Pada masa kini, sistem perhubungan satelit memainkan peranan yang amat penting terhadap mutu hubungan dan pencapaian, dan penentuan prestasi isyarat tepat di dalam mereka bentuk sebuah rangkaian sistem perhubungan satelit. Kadar rosotan perambatan telah dinilai dan diramal semula berdasarkan model *Radio Communications Sector of the International Telecommunications Union* atau ITU-R. Oleh itu, kajian kaedah penjelmaan dengan menggunakan data-data pada satu jalur gelombang di satu kawasan ke satu kawasan yang lain di dalam menentukan kesan kemerosotan isyarat oleh hujan dapat dijalankan. Maka, di dalam meramal prestasi isyarat tepat pada sistem perhubungan satelit di Malaysia, dapat dilaksanakan dengan menggunakan maklumat dan data-data yang didapati pada isyarat jalur gelombang penghubung kawasan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

A_s	-	Specific Attenuation in *dB/km*
$A_{0.01}$	-	Predicted attenuation exceeded for 0.01% of an average year
A_P	-	Total path attenuation in *dB/km*
$A_S(t)$	-	Transformed rain attenuation time series for the satellite link
$A_T(t)$	-	Measured rain attenuation time series of the terrestrial link
B	-	Brightness temperative in the distance of dr in $Wm^{-2}\,sr^{-1}$
d_0	-	Reduction factor
dr	-	Incremental distance
f	-	Frequency in GHz
f_S	-	Frequency of the satellite link
f_T	-	Frequency of the terrestrial link
H	-	Frequency and attenuation dependent factor
h_R	-	Effective rain height in *km*
h_s	-	Altitude of the station in *km*
Ke	-	Specific attenuation $dBkm^{-1}$
L_G	-	Horizontal projection
L_R	-	Effective path length
L_s	-	Slant-path length under the rain height
L_S	-	the slant path length of the satellite link
L_T	-	the length of the terrestrial link
r	-	Reduction factor
R	-	Rain rate in */h*
$R_{0.001}$	-	Rainfall rate of 0.001 % means that the rainfall rate would be exceeded for 0.001
$R_{0.01}$	-	Point rainfall rate for the location for 0.01% of an average year in *mm/h*

R_e	-	Effective radius of the Earth=(8 500 km
$v_{0.01}$	-	Vertical adjustment factor
γ_R	-	Specific attenuation in *dB/km*
θ	-	Elevation angle in *degrees*
τ	-	Polarization tilt angle relative to the horizontal
Φ	-	Latitude of the earth station in *degrees*

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

In a global coverage vision, satellite communication has several advantages compared to the terrestrial radio systems. Whole continents can be covered and connected to each other.

The rain attenuation by a particular rain event can be calculated knowing the rain intensity distribution along the slant-path of the satellite communication. ITU-R has proposed maps divided the world into several regions, and recommends rain intensity values of the regions. If local measured rain intensity values are available, they must be considered by calculations of rain attenuation instead of recommended values given by ITU-R [1].

However, when operating at the higher frequency Ku-band, the strength of the satellite signal may be temporarily reduced under severe rain conditions systems. To compensate for these potential effects, earth stations located in heavy rain areas are designed with more transmit power. C-band transmissions are virtually immune to adverse weather conditions. Rain attenuation is one of the most fundamental limitations to the performance of satellite communication links. For the design of communication systems with a required availability statistical knowledge of propagation effects is essential.

This paper presents a transformation study of rain attenuation statistics of terrestrial and satellite communication channels based on terrestrial rain rate and rain attenuation measurement. Results will be presented for different locations in Malaysia such as Johor Bahru, Alor Setar, Ipoh, Kuantan and Kota Bahru where rain attenuation and rain intensity time series measurement data are available.

1.2 Problem Statements

Attenuation due to rain has long been recognized as a major limitation to reliable communication system operation at frequencies above 10 GHz [2]. Satellite communication is affected, of course. At high carrier frequencies the radio channel is highly influenced by precipitation especially by rain [3]. Rain attenuation is one of the most fundamental limitations to the performance of satellite communication links. These disturbances can plague the channel for a long outage probability [4].

The rainfall can give up to several decibels of total attenuation thus causing severe outages. For the design of communication systems with a required availability statistical knowledge of propagation effects is essential. Many rain attenuation studies on satellite are based on the rainfall data collected at the satellite receiver [5][6][7]. This has resulted in urgent needs to perform satellite rain attenuation study in Malaysia using point to point microwave link measurements. Our goal is to analyze and transform the most accurate rain attenuation model in satellite links, in order to determine the satellite propagation, which must be known for system planning purposes.

1.3 Objective of Research Project

The aim of this project is to study the performance of satellite propagation communication system using the available point to point microwave link measured attenuation profile through the transformation method from terrestrial rain attenuation time series to satellite rain attenuation time series.

1.4 Scope of Work and Methodology

The scope of work for this study is to transform and analyze the measured terrestrial rain rate and rain attenuation measurement collected data into satellite attenuation time series. Results are calculated at UTM, Skudai in Johor, where the rain attenuation and rain intensity time series measurement data available.

The methodology of the study has been established by applying the model of the Radio Communications Sector of the International Telecommunications Union (ITU-R) to evaluate and predict the performance degradations particularly due to rain attenuation [8][9]. Thus several locations in Malaysia have been selected for the study namely Ipoh, Alor Setar, Kuantan and Kota Bahru.

The study is focused on receiving part and the analysis of the downlink. All computations are done using the MATLAB version 6.5 programming software.

1.5 Organization of the Thesis

The thesis is organized as follows:

Chapter one is a brief introduction on the background and objective of the study, scope of work and the organization of the thesis.

Literature reviews are described in chapter two, chapter three and chapter four. Chapter two explains the rain and attenuation and its impact on satellite performance. At the end of the chapter discover the factors that contribute to attenuation.

Chapter three reviews the property of propagation that affects the terrestrial and satellite link including rain attenuation, rain scatter, ducting causing long range interference. Chapter four is concerned about the satellite communications, i.e. frequency allocation for satellite. It will give a better understanding of radio frequencies, polarization and the earth station components.

Chapter five described the methodology procedure of research project. The results of measured and predicted rain rate and rain attenuation data in time series for terrestrial link are being transformed into satellite attenuation time series. The viability of measured and predicted data on rain rate of satellite using transformation Method A and Method B is being determined.

Chapter six discovers analyses of the results. A final conclusion is made in chapter seven that is the discussion on the outcome of the research project, followed with recommendations for future work.