RELIABLE COMMUNICATIONS AT FREQUENCIES BANDS ABOVE 25 GHz IN THE TROPICS

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To my beloved family especially my husband, Muzamir bin Isa and my daughters,
Zahirah binti Muzamir and Sakinah binti Muzamir

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ABSTRACT

The use of frequencies in the higher bands could tap upon the large spectrum available for communication use. However, it suffers greater propagation losses, making them unsuitable for long range communication. In addition, heavy tropical rain further reduces the reliability of the link and additional link budget has to be set aside for rain fade in order to improve its reliability. Rain attenuation model that has been used widely is currently base on ITU-R model. It gives same rain rate for all places in Malaysia. However, previous study in Malaysia conducted by researchers in UTM shows that rain rate is not the same for different places in Malaysia. It is localized where some places experience heavier rainfall compared to other places. Hence, the ITU-R model does not give an accurate prediction of rain attenuation in Malaysia, where the attenuation is supposed to be localized base on the data of the rain rate. This project is aimed to develop a computer program in order to predict localized rain attenuation. The analysis of calculation to produce rain attenuation is done. The best reduction factor model is chosen to get the most accurate result. Then, the planning is done, followed by the design phase. The most challenging part, which is the development of the program, is done next. To verify the program built, it is tested by entering significant inputs and the outputs are analyzed. As a result, a computer program to predict rain attenuation in Peninsular Malaysia is successfully built. The results produced by the program are compared to the ITU-R model of rain attenuation. The differences are calculated and the outcome shows that ITU-R model is not suitable to be used as a rain attenuation method in Malaysia.

ABSTRAK

Penggunaan frekuensi di jalur lebih tinggi membolehkan spektra yang lebih lebar digunakan untuk komunikasi. Walau bagaimanapun, ia mengalami kehilangan perambatan yang lebih banyak, menjadikan ia tidak sesuai untuk komunikasi jarak jauh. Hujan yang lebat di kawasan tropika lebih memburukkan lagi keadaan dan tambahan bajet laluan harus disediakan untuk memperbaiki kebolehpercayaan isyarat. Model pelemahan hujan yang digunakan secara meluas sekarang adalah model daripada ITU-R. Ia memberikan kadar hujan yang sama bagi semua tempat di Malaysia. Walau bagaimanapun, kajian mendapati kadar hujan adalah terhad kepada kawasan yang kecil dan semua kawasan tersebut mengalami kadar hujan yang berlainan. Dengan ini, model ITU-R tidak memberikan telahan yang tepat bagi nilai pelemahan hujan di Malaysia kerana satu-satu bacaan hanya terhad kepada satu kawasan kecil sahaja. Projek ini bertujuan untuk membangunkan program simulasi untuk menganggarkan tahap pelemahan hujan di satu-satu kawasan yang terhad. Perkara pertama yang dilakukan ialah menganalisa kiraan untuk mendapatkan tahap pelemahan hujan. Kemudian, model faktor pengurangan yang terbaik dipilih untuk mendapatkan hasil yang tepat. Selepas itu, perancangan yang rapi dilakukan untuk menjayakan program ini, diikuti dengan fasa merekabentuk. Bahagian yang paling sukar iaitu membangunkan program menggunakan perisian MATLAB dilakukan setelah fasa rekabentuk selesai. Untuk mengesahkan kebolehpercayaan keluaran progam ini, ia diuji dengan memberikan masukan-masukan yang sesuai dan keluarannya dianalisa. Hasil akhir yang diperolehi ialah satu program untuk menganggar tahap pelemahan hujan di Semenanjung Malaysia telah berjaya dibangunkan. Keluaran-keluaran yang dihasilkan oleh program ini telah dibandingkan dengan keluaran daripada model pelemahan hujan ITU-R. Perbezaan-

perbezaan nilai dikira dan didapati model pelemahan hujan yang telah dibangunkan ini lebih tepat untuk digunakan di Malaysia.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENTS	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	viii
	LIST OF TABLES	xi
	LIST OF FIGURES	xii
	LIST OF ABBREVIATIONS	xiii
	LIST OF SYMBOLS	xiv
	LIST OF APPENDICES	xv
1	**INTRODUCTION**	1
	1.1 Literature review	1
	1.1.1 Effects of High Frequencies to Electromagnetic Wave	1-3
	1.1.2 Effects of Rain to Electromagnetic Wave in High Frequencies	3-4
	1.2 Problem Statement	4-5
	1.3 Research Objectives	5
	1.4 Thesis Outline	5-6

2	**RAIN ATTENUATION PREDICTION**		8
	2.1	Rain Attenuation Calculation	8
		2.1.1 Rain Attenuation Calculation for LOS (Terrestrial) microwave path	8-10
		2.1.1.1 Path Length Reduction Factor	10-11
		2.1.1.2 Moupfouma Model As a Reduction Factor	11-12
	2.2	Some Models of Rain Attenuation Prediction	12
		2.2.1 ITU-R Model of Rain Attenuation	12-16
		2.2.2 Crane Model	17-18
		2.2.3 Comparison of ITU-R and Crane Model	18-19
3	**RESEARCH METHODOLOGY**		20
	3.1	Phases of Methodology	20
		3.1.1 Analysis of Calculation	20
		3.1.2 Planning	21
		3.1.3 Design Phase	21
		3.1.4 Development and Testing Phase	21
	3.2	Introduction to MATLAB	23-26
4	**RESULTS AND ANALYSIS**		27
	4.1	Introduction	27
	4.2	Visual Design	28-29
	4.3	Implementation	30-32
	4.4	Program Limitations	33
	4.5	Program User Guide	34-36
	4.6	Additional Features of the Program	37
	4.7	Example of Program Output for Predicted	37-38

		Rain Attenuation	
	4.8	Analysis of the Results	38
		4.8.1 Comparison of the Output of RAPS1 with Results from ITU-R Model of Rain Attenuation	39-40
		4.8.2 Comparison of the Output of RAPS1 with Results Produced Utilizing ITU-R Reduction Factor but Using the Local Data Rain	41-43
5		**CONCLUSION AND PROPOSED FUTURE WORKS**	44
	5.1	Conclusion	44
	5.2	Proposed Future Works	45
REFERENCES			46-48
APPENDIX A-E			49-91

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Some of frequency dependent coefficient to calculate specific attenuation	15
4.1	Example of program output at three different locations in Peninsular Malaysia	37
4.2	Comparison between output from RAPS1 and ITU-R model of rain attenuation at 26 GHz	39
4.3	Comparison between output from RAPS1 and ITU-R model of rain attenuation at 38 GHz	39
4.4	Comparison of the output of RAPS1 with results produced utilizing ITU-R reduction factor at 26 GHz	41
4.5	Comparison of the output of RAPS1 with results produced utilizing ITU-R reduction factor at 26 GHz	42

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
1.1	Electromagnetic wave	2
1.2	Rain rate (mm/h) exceeded for 0.01% of the average year	6
3.1	Program design	21
3.2	Flow Chart of the Methodology	22
3.3	Screenshot of MATLAB	23
3.4	Screenshot of guide	25
4.1	Locations of rain rate collected	27
4.2	Introductory window	28
4.3	Main working window	29
4.4	Example of output (1)	31
4.5	Example of output (2)	32
4.6	‘Error’ message box (1)	34
4.7	‘Error message box (2)	34
4.8	‘Error’ message box (3)	35
4.9	‘Error’ message box (4)	35
4.10	‘Help’ message box	35

LIST OF ABBREVIATIONS

MHz, *MHz*	-	Mega Hertz
GHz	-	Giga Hertz
RF	-	Radio Frequency
LOS	-	Line of Sight
ITU	-	International Telecommunication Union
UTM	-	Universiti Teknologi Malaysia
ITU-R	-	International Telecommunication Union Radio Section
GUI	-	Graphical User Interface
MATLAB	-	Matrix Laboratory
RAPS1		Rain Attenuation Prediction Software

LIST OF SYMBOLS

d, l, L	-	path length
f, F	-	frequency
Ls	-	Loss
λ	-	wavelength
c	-	speed of light
γ_R	-	specific attenuation
k, α	-	functions of frequency for ITU model
d_{eff}, L_{eff}	-	effective path length
r	-	reduction factor
$A_{0.01}$	-	rain attenuation exceeded for 0.01% of time
A_p	-	rain attenuation exceeded for p% of time
p	-	annual time percentage
p_w	-	worst-month time percentage
R_p, R	-	rain rate in millimeter per hour at p% probability
e	-	natural logarithm
$p1$	-	modified probability of occurrence
km	-	kilometers
dB	-	decibel

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	MATLAB Self Generated Code for Introductory Window	48-54
B	MATLAB Self Generated Code for Main Working Window	55-72
C	MATLAB Code Associated with ‘Predict’ Pushbutton of Main Working Window	73-79
D	MATLAB Code Associated with ‘Calculate and Plot’ Pushbutton of Main Working Window	80-87
E	MATLAB Code for Hoplength Window	88-90

CHAPTER 1

INTRODUCTION

This chapter covers the literature review and the significance of this project. It also tells about the outline of this thesis.

1.1 Literature Review

1.1.1 Effect of High Frequencies to Electromagnetic Wave

Since communication at lower frequencies is getting congested, the use of frequencies in higher spectrum band is currently in demand by the designers. Higher bands provide wider spectrum for communication but in contrast it suffer greater propagation loss. This can be easily determined by the below mathematical formula for free space loss:

$$Ls = 32.45 + 20\log dkm + 20\log fMHz$$

Higher bands from 1 GHz to 300 GHz are call microwave. Microwave is form of electromagnetic energy and can be described with the term of radio frequency or RF. RF emission and associated phenomena can be discussed in terms of energy, radiation or fields. In term of radio wave propagation, we can define radiation as the propagation of energy through space in the form of waves or particles [1]. Figure 1.1 below illustrated radiation as waves of electric and magnetic energy moving together through space.

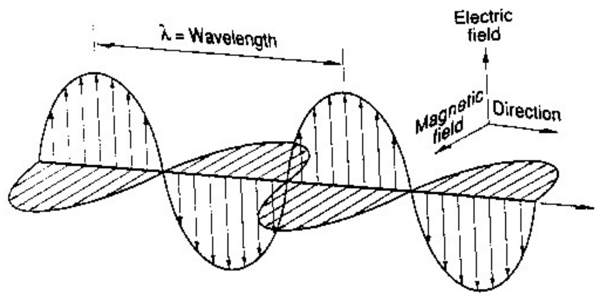

Figure 1.1 Electromagnetic wave

Electromagnetic energy can be characterizes by a wavelength and a frequency. The wavelength is the distance covered by a complete electromagnetic wave cycle, while the frequency is the number of electromagnetic waves passing a given point in a second. Electromagnetic waves travel through space at the speed of light. The wavelength and frequency of an electromagnetic wave are inversely related by a simple mathematical formula given below:

$$\lambda = \frac{c}{f}$$

where:

λ = wavelength

c = speed of light

f = frequency

The speed of light in a given medium does not change, resulting in shorter wavelength for high frequency electromagnetic waves. Hence, when operating at high frequencies, rain becomes a major obstacle as it will scatter the signals when the size of the raindrops is larger than the waves. To make it worse, places experiencing heavy rainfall will suffer greater interference and consequently degrading the signal or waves.

1.1.2 Effect of Rain to Electromagnetic Wave in High Frequencies

When it comes to tropical countries like Malaysia, Indonesia and Thailand, the losses become higher because of heavy rain. It can degrade the radio wave propagation at frequencies 10 GHz and above [2]. To be more specific, propagation of radio waves through the atmosphere above 10GHz involves not only free space loss and loss due to rain, but other factors listed below also contribute to the additional loss [3]:

i) The gaseous of the homogeneous atmosphere due to resonant and nonresonant polarization mechanism.
ii) The inhomogeneties in the atmosphere
iii) The particles due to fog, mist and haze (includes dust, smoke and salt particles in the air)

Earlier approach to deal with rain is on a basis of rainfall given in millimeters per hour. This was usually done with rain gauges, using collected rain averaging over a day or even periods of days. However, for path design above 10 GHz, such statistic are not sufficient where designers may want path availability better than 99.9% and do not want to design using conservative procedures.

A researcher, Hogg, suggests that the use of high speed rain gauges with outputs ready available in computer analysis [3]. These gauges can provide minute by minute analysis of the fall rate, unlike the conventional type of gauges. But it is desirable to have several years' statistics for a specific path to provide necessary and accurate information on fading caused by rainfall that will determine the parameters such as LOS repeaters, size of antenna and so on.

Realizing the importance of this rainfall data, a large body of information on point rainfall and rain rates has been accumulated since 1940 [3]. This information shows a great variation of short-term rainfall rates from one geographical location to another.

Researchers in countries experiencing heavy rain especially in South East Asia countries including Malaysia have been doing active research regarding rain and its effect to communication system for the past 10 years. The tropical climate makes the research topic relevant to get a better quality of communication in microwave bands throughout the country.

1.2 Problem Statement

Rain attenuation model that has been used worldly is currently base on ITU model. It gives same rain rate for all places in Malaysia. It classified Malaysia under P climatic region where the rain rate for 0.01% of the year ($R_{0.01}$) is given as 145 mm/h [3], [5], [6]. The latest ITU Recommendation notes peninsular Malaysia experiences 120 mm/h rain rate and West Malaysia 100 mm/h for 0.01% of the year [7]. Figure 1.2 shows the latest rain rates in Malaysia and in its neighbours given by ITU.

However, previous study in Malaysia conducted by researches in UTM shows that rain rate is not the same for different places in Malaysia. It is localized where some places experience heavier rainfall compared to other places.

Therefore, the ITU-R model does not give an accurate prediction of rain attenuation in Malaysia, where the attenuation is supposed to be localized base on the data of the rain rate

1.3 Research Objectives

In accordance with active researches in rain that are being done in Malaysia and its relationship with communication, this project is aimed to develop a computer program in order to predict localized rain attenuation for terrestrial microwave links in Peninsular Malaysia. This program will be based on given data. Once the program has been developed, the result from that simulation of the program is compared with ITU-R rain attenuation model.

1.4 Thesis Outline

This thesis consists of five chapters. Chapter 1, which is this chapter, covers the literature review, the significance of this project and the outline of this thesis.

Chapter 2 gives a brief theory of rain attenuation prediction methods. This includes rain attenuation calculation for terrestrial microwave path, path length reduction factor models and rain attenuation models that are widely used nowadays. Comparison between those models is also done and the reasons why the appropriate models are chosen to complete this project are stated.

In Chapter 3, all the methodology adopted in making this project a success is explained. The phases of methodology are written one by one and are also explained briefly. A little bit of the MATLAB software that is used to build the program is also mentioned and explained.

Chapter 4 covers the results obtained from this project. The results include the program visual design, implementation, testing and user guide to use the program. Analysis of the results is also done by comparing them with the output from ITU-R model.

Conclusion about the research and the results obtained is discussed in Chapter 5. It also covers the proposed future works that can be implemented by future researchers to further enhance this project.

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