FREQUENCY SCALING OF RAIN ATTENUATION

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To my beloved husband, Mohd Izhari Bin Ahmad
To my children, Siti Rakna Syafidah, Nur Muhammad Kamil
and Siti Mariam Ulfah.

For their love and understanding

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ABSTRACT

The most fundamental obstacle encountered in designing communication system at millimeter waves is attenuation due to rain especially at frequencies above 10GHz. Rain attenuation, however, increases approximately as the square of frequency. Rain attenuation will give greater impact on the satellite and terrestrial communication systems. It is therefore, very important to accurately predict rain attenuation for reliable incorporation into the design process based on the climate and geographical of the particular region. Frequency scaling of attenuation is the prediction of attenuation at a desired frequency from attenuation values at another frequency. The attenuation at the reference frequency is assumed to be known from prior measurements. Statistical frequency scaling is the use of statistics available from prior measurements at a base frequency to predict attenuation statistics at a desired frequency. Many scaling models have been developed from theory, empirical data, various propagation experiments, or from both. This project will focus on the results of an in-depth study on frequency scaling of attenuation. The investigation will begin with a thorough examination of one year of measured data for 23 GHz, 26 GHz and 38 GHz. In addition to being useful by themselves, these results will be used to evaluate the accuracy of available scaling models. The data were the value of signal received in volts. Processing of raw data were done by using ‘C’ programming, followed by the identification of dry period and wet period. The conversion of unit from volts to dBm , dB and dB/km and classification for cumulative distribution function also use the ‘C’ programming. All calculations and plotting of graphs involved were done in Microsoft Excell. The result of the analysis shows that the existing frequency scaling models cannot accurately predict the measured attenuation in the range of 23 GHz to 38 GHz in Malaysian tropical region even though they were good predictor in desert and temperate climate. The measurements demonstrated that statistical frequency scaling could be used to predict average instantaneous frequency scaling. Statistical frequency scaling can facilitate the

calculation of link power budgets for new systems operating at higher frequencies in tropical region.

ABSTRAK

Pelemahan hujan merupakan halangan utama dalam rekabentuk sistem perhubungan terutamanya bagi perambatan panjang gelombang pendek. Kewujudan hujan memberi kesan pelemahan yang ketara terhadap perambatan lebih-lebih lagi bagi frekuensi tinggi yang melebihi 10 GHz. Kesan pelemahan hujan terhadap perambatan gelombang akan memberi gangguan keatas isyarat penerimaan dan penghantaran dalam sistem perhubungan samada perhubungan satelit mahupun perhubungan secara ”terrestrial”. Oleh itu, adalah penting untuk mengukur kadar pelemahan hujan yang lebih tepat bagi kegunaan rekabentuk sistem perhubungan berdasarkan geografi dan juga iklim kawasan yang berkenaan. Penskalaan frekuensi keatas pelemahan adalah merupakan satu jangkaan pelemahan hujan keatas frekuensi yang di kehendaki melalui nilai bacaan yang ada pada frekeunsi yang lain. Nilai pelemahan pada frekuensi asas atau rujukan frekuensi telah diandaikan melalui ujikaji yang telah dijalankan sebelumnya. Dalam kajian ini, penggunaan model penskalaan frekuensi telah dicadangkan dan aplikasi kepada penskalaan ketika (instantaneous scaling) telah dibincangkan dari penghasilan data-data ujikaji bagi frekuensi 23 GHz, 26 GHz dan 38 GHz. Kebanyakan model penskalaan frekuensi telah dibangunkan samada secara teori, penghasilan data dari penyelidikan keatas berbagai ujikaji perambatan atau pun dari kedua-duanya . Projek ini memfokuskan kepada hasil penyelidikan yang dilaksanakan terhadap pengskalaan frekuensi keatas pelemahan hujan . Kajian yang teliti telah dijalankan terhadap bacaan bacaan data yang diperolehi bagi 3 nilai frekuensi iaitu 23,26 dan 38 GHz untuk tempoh 12 bulan. Selain berguna untuk kegunaan rekabentuk sistem perhubungan, data-data yang telah diproses akan digunakan untuk menilai ketepatan model-model penskalaan frekuensi yang sediada. Bacaan penerimaan paras voltan dalam unit volt telah diproses dan penukaran volt kepada unit dBm dan dB

telah diproses menggunakan program ’C’ , seterusnya penkelasan untuk taburan kebarangkalian telah dilaksanakan bagi setiap frekuensi. Kaedah pengiraan dan penghasilan geraf bagi setiap model penskalaan frekuensi dilakukan dengan menggunakan program ’excell’. Perbandingan diantara data-data statistik yang dihasilkan dari ujikaji dan data-data yang diperolehi melalui pengiraan secara teori telah dibandingkan. Selain itu juga kaitan diantara hujan dan pelemahan dikaji, penghasilan data ujikaji dipaparkan dan ukuran statistik yang dihasilkan telah dibandingkan dengan beberapa pilihan model penskalaan frekuensi. Keputusan dari analisis yang dilaksanakan menunjukan model penskalaan frekuensi sediada tidak berupaya menjangka dengan lebih tepat bagi pelemahan hujan untuk julat 23 GHz kepada 38 GHz .Meskipun, model-model yang digunakan telah membukti ketepatan jangkaan pelemahan hujan di kawasan yang mengalami iklim sederhana dan kawasan gurun, tetapi model-model ini tidak menunjukan ketepatan jangkaan bagi kawasan yang mengalami iklim tropikal seperti negara Malaysia. Pengukuran jelas menunjukkan bahawa data-data statistik untuk penskalaan frekuensi boleh digunakan untuk menjangka purata bacaan bagi penskalaan frekuensi segera (instantaneous frequency scaling). Statistik penskalaan frekuensi yang di perolehi boleh di aplikasikan keatas pengiraan pengiraan kuasa pautan (link power budgets) bagi sistem perhubungan dikawasan tropika yang beroperasi di tahap frekuensi yang tinggi .

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A (f)	Attenuation at desired frequency
$A_{0.01}$	Attenuation at probability of 0.01%
Ar	Attenuation due to rain
A_s	Specific Attenuation
AP	Attenuation exceeded percentage value of p
A	Regression Coefficient
a_h	Regression Coefficient with horizontal polarization
α	Regression Coefficient
AGC	Automatic Gain Control
b	Regression Coefficient
b_h	Regression Coefficient with horizontal polarization
CDF	Cumulative Distribution Function
DSD	Drop Size Distribution
FMT	Fade Mitigation Technique
f	Frequency
GHz	Giga Hertz
h_r	effective rain height
L_g	horizontal projection
k	attenuation coefficient
L_0	Measured length of the rainfall
RAS	Statistical Attenuation Ratio
R_o	Peak rainfall rate along the propagation path
R_p	Rain rate with different percentage of time
x	Position on the path

CHAPTER 1

INTRODUCTION

1.0 Introduction

Rain attenuation is the most significant propagation mechanism for Communication systems operating above 10 GHz. Ku band (14/12 GHz) is becoming heavily used, and future expansion will be toward Ka band (30/20 GHz). However, rain attenuation increases approximately as the square of frequency through these bands. It is therefore, very important to accurately predict rain attenuation for reliable incorporation into the system design process.

Rain attenuation data for Ku band are available at moderate amount, while little has been reported in Ka band. Thus, models that permit accurate scaling of rain attenuation statistics are valuable in system design. Due to the limited amount of reliable long-term rain, attenuation statistics are available, frequency scaling method of rain attenuation can be used to obtain a rough estimate of the attenuation values measured at another frequency.

1.1 Problem Statement

The planning of radio linker annual outage due to fading at millimeter Wavelengths are generally dominated by the effect of rain attenuation. The effects become more significant as the frequency increases.

The attenuation experienced by a microwaves link is principally a consequence of the rainfall along the link. However, there are other relevant factors, such as humidity, temperature and multiple effects.

Rain attenuation is a function of frequency, elevation angle, polarization angle, rain intensity, raindrop size distribution and raindrop temperature. This is the interference caused by raindrops on electromagnetic signals traveling through the atmosphere.

1.1.1 The Need of Measuring the Effect of Rain Attenuation on the Radio Links.

Radio wave propagation through the earth's atmosphere will experience reduction in signal level due to the rain parameter present in the transmission path.
Accurate estimation of radio waves propagation impairments that affect link quality and availability and determination of the signal performance are essential to design a reliable satellite or terrestrial communication systems and earth terminals networks. However, the transmission quality at higher frequencies (above 10 GHz) and shorter wavelengths is greatly influenced by rain resulting in signal attenuation and decreased link availability especially in tropical region such as Malaysia.

Therefore, studies are needed to characterize the propagation effects on earth-satellite or terrestrial links paths in order to provide guidelines and indications to the design of future reliable system on higher frequency bands.

1.2 Objective of Research Project

The objective of this study is to perform a prediction and comparative analysis on the results of rain attenuation values collected in Malaysia.

The Cumulative Distribution of measured rain attenuations are compared to those scaled using existing frequency scaling models, thus to evaluate and investigate the accuracy of the prediction of rain attenuation in tropical climate.

1.3 Scope of Work

This thesis focus on rain attenuation only and using a collection of rain attenuation data taken annually at UTM, Skudai from April 1999 to March 2000. The experimental microwave links are set-up at 23GHz, 26 GHz and 38GHz. All antennas are 0.6-meter diameter with horizontal polarization and a separation distance of 300 meter. Since the propagation path length is short, therefore the measured attenuation for 300-meter length is to be used to verify the frequency scaling models.

1.4 Organization of the Thesis

The thesis is organized as follows:
Chapter 1 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 and chapter three. In chapter 2, a few established techniques for rain attenuation prediction has been discussed. At the end of the chapter, established frequency scaling of rain attenuation were discussed and the unique of each type of frequency scaling also being mentioned.

Chapter 3 is concerned about prediction of cumulative statistics for rain attenuation. This chapter provides a guide to prediction methods and related propagation results for the evaluation of earth-space paths operating above 10 GHz.

The methodology procedure of research project is described in chapter four. This chapter will describe the method of how to convert the raw data of rain attenuation to dB, dB/km and the cumulative distribution of the rain attenuation.

Chapter 5 will explain the expected result based on the earlier researchers. A conclusion is made in chapter six, followed by recommendations for future work.