SLANT PATH RAIN ATTENUATION PROFILE OBTAINED FROM RADAR DATA

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ABSTRACT

Many telecommunication systems are going towards high frequencies as such ranges are in great demand in nowadays' wireless devices. However, in high frequencies, the signal is subjected to rain attenuation. For that, in this study, rain rate intensity has been extracted from radar data. Then, the rain attenuation was computed along the way to (MEASAT 3) satellite starting from (Universiti Teknologi Malaysia). After that, the rain attenuation was obtained by a calculation in reference to a given ITU-R formula. AUTOCAD software was used to model the case and to facilitate computing some dimensions. Also, MATLAB software was responsible for processing the raw data and doing many complex calculations prior to rain intensity determination phase. Thus, the analysis employed the actual vertical rain intensity profile along the way between the two points mentioned. The novelty of this study is to assess the variation of the rain intensity obtained from radar readings and its impact on the satellite communication link in this rainy tropical region. The analysis of multi-elevation angle from radar data for slant path rain attenuation has been accomplished by means of rain intensity and attenuation data collected in Malaysia. As a final finding observed that the rain attenuation is about 18.87 dB at 0.01% of time. When the higher rain rate on the satellite link equal 93 mm/h at 2.430 km altitude and the effective rain height is between 4.301 km to 5.617 km and this result agreed with ITU-R G3 studies (5km).

ABSTRAK

Banyak sistem telekomunikasi yang akan menuju frekuensi quality rentang seperti itu banyak anda cari di dalam saat ini 'peranti wayarles. Namun, dalam frekuensi quality, isyarat mengalami redaman hujan. Untuk itu, dalam kajian ini, kadar keamatan hujan telah diekstraksi daripada data radar. Kemudian, hujan redaman dihitung sepanjang jalan untuk (MEASAT 3) satelit mulai dari (Universiti Teknologi Malaysia). Selepas itu, redaman hujan diperolehi dengan perhitungan dalam rujukan tertentu rumus ITU-R. AUTOCAD perisian yang digunakan untuk model kes dan untuk memudahkan komputasi beberapa dimensi. Selain itu, perisian MATLAB bertanggungjawab untuk memproses data mentah dan melakukan banyak perhitungan rumit sebelum tahap penentuan keamatan hujan. Dengan demikian, analisis yang digunakan sebenarnya keamatan hujan profil menegak di sepanjang jalan antara dua titik yang disebutkan. Kebaruan daripada kajian ini adalah untuk menilai variasi keamatan hujan yang diperolehi daripada radar pembacaan dan kesannya pada hubungan komunikasi satelit di kawasan tropika hujan. Analisis multi-sudut elevasi dari data radar untuk jalan miring redaman hujan telah dicapai melalui keamatan hujan dan redaman data yang dikumpul di Malaysia Sebagai menemukan akhir mengamati bahawa redaman hujan adalah sekitar 18,87 dB pada 0,01% dari waktu. Ketika hujan peringkat yang lebih tinggi pada link satelit sama dengan 93 mm / h pada ketinggian 2.430 kilometer hujan dan ketinggian yang berkesan adalah antara 4.301 kilometer -5.617 kilometer dan keputusan ini bersetuju dengan ITU-R G3 studi (5 kilometer)

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The use of higher and higher frequencies in telecommunication systems requires the investigation of the effects of troposphere on electromagnetic wave propagation, and particular attention must be paid to the attenuation induced by raindrops and other hydrometeors along the radio path.

So the study of radio link is very important in communication systems. Large number of parameters must be considered and optimized to build an efficient radio link. That is, radio signals must suffer minimum degradation possible. For reliable communication link, selection of operating frequency and possible atmospheric attenuation must be studied and understood. Since the governing body usually determines the operating frequency, attenuation, especially due to rain, has become the subject of numerous studies and researches. For good engineering and economic practice, it is always desirable to reduce cost of a system and avoid interference to other radio systems. Some factors which introduce attenuation to radio propagation are gaseous absorption, absorption and scattering due to clouds, fogs, precipitation, atmospheric turbulence and ionospheric effects. Since Malaysia is in the tropical region, studies of attenuation due to hydrometers are very important. Rain, hail, ice, cloud and snow are all types of hydrometers but raindrops cause the most attenuation by absorption and scattering of radio waves. Even though the International Telecommunication Union (ITU) recommends a technique to estimate rain attenuation, more studies for Ajayi et al(1988), Juy et al(1990), Yagasena et al(1995) have shown that results using this techniques does not agree with actual measurements done locally. This is understandable as the recommendation is meant to be applicable to wide area as possible and most studies were done using temperate region data. Thus, local studies are needed and based on these studies; a model for rain attenuation in Malaysia can be developed.

1.2 Background and History of the study

Rain attenuation researches were began by Ryde studies (1945) carried out in the year immediately following World War II. Lin (1977) developed a published prediction model based on experimental data in United State. Crane (1980) presented a model for estimating rain attenuation on either terrestrial or slant satellite paths. The development of these models has proceeded from these early studies to the present with further enhancement and improvement.

The primary goal of a rain attenuation prediction method is to achieve acceptable estimates of the attenuation incurred on the signal due to rain. According to Lin (1977), in order to predict a reliable and accurate rain prediction model, it is required to determine the one minute integration time of rain fall rate together with direct measurements of rain attenuation. Therefore, unavailability of time for reliable communication systems in a year (Outage time) has to be kept at 0.01 percent of time. This corresponds to 99.99 percent of time availability for one year (ITU-R, 1997).

Stutzman et al. (1986) developed a simple rain attenuation model for earth-space radio links operating at 10-35 GHz. The model takes into account the effect of wave polarization and was verified by observations in a database created from 62 experiments conducted in the U.S.A., Europe, and Japan. Goldhirsh et al. (1992) computed rain rate statistics and rain distributions at 20 and 30 GHz derived from a network of rain gauges along the mid-Atlantic coast over a five-year period. Dissanayake et al. (1997) combined rain attenuation and other types of propagation impairment along earth-satellite paths in a prediction model whose estimates of propagation impairment were compared with simultaneous-beacon and radiometer measurements. While numerous studies have demonstrated good agreement between model predictions and field measurements in the estimates of propagation impairment, most of them have primarily focused upon regions in the middle and high latitudes such as United State of America and European countries. Those are mainly applicable to use in the regions of higher latitude.

The effect of rain is more critical for countries located in tropical and equatorial regions which experience a high rainfall rate throughout the year. According to Moupfouma (1994), when those models are applied to tropical regions the performances are lower than accepted, and the results of these researches indicate poor agreement between the measured and predicted attenuations. This has been considered due to significant climatic difference between temperate region and the tropical region. Therefore, researches have been conducted at tropical countries such as, Brazil, Singapore, and Malaysia (Chebil, 1997), in order to get a better performance in term of more accurate results and well suited to the local climatic conditions in tropical countries. As well as before that Moupfouma (1984) indicates that since the rain drops in tropical regions are larger than the temperate regions, the incidence of rainfall becomes more critical as low as 7 GHz.

In 1997, the Tropical Rainfall Measuring Mission (TRMM) satellite was launched as a joint project between the U.S.A. and Japan that carries the first space borne rain radar. Because of the rapid progress in space borne sensor technology, many studies on space-based remote sensing have also been performed in recent years.

Malaysia has a tropical climate weather which experiences a high rainfall rate throughout the year. The mean annual rain fall ranging between 2400 mm to 3200 mm per year (Chebil,1997). Geographically the rainfall pattern is greatly influenced by its oceanic surrounding. Therefore, Malaysia was involved in the world researches competition toward to the satellite system technology in order to enhance the existing satellite services and to access the globalization for the future satellite technology.

Researchers have been carried out in the early 1990's at Universiti Teknologi Malaysia (UTM) by Din (1997), Chebil (1997), Rafiqul (2000), Kareem, (2000) and other. Almost all of these studies were focused on the signal propagation of the microwave links, and only limited experiments were conducted for satellite link. Recently, it has become increasingly important to develop sophisticated prediction model to improve the satellite communications services in Malaysia.

The parameters investigated in this project are mainly rain attenuation beyond the rain rate modeling. The problem of predicting attenuation by rain is quite difficult, because of non-uniform distribution of rainfall rate along the entire path length (L. A. R. Silva Mello et al, 2002). According to Lin (1977), the path is divided into small incremental volumes, which the rainfall is approximately uniform. The rainfall rate in each small volume is associated with a corresponding attenuation called specific attenuation, and the multiplication of the specific attenuation along the rainy path presents the total attenuation along the path.

Actually, for this project the main concern is to calculate the rain attenuation along the satellite path which is known as slant path. The rain has non-uniform distributions in both horizontal and vertical directions along the slant path. That caused more difficulties to consider the horizontal reduction factor concept within the variation of the vertical structure of the rain height. Therefore, according to Bandera et al. (1999), it is more applicable to use a vertical adjustments factor on the calculation of an effective path length for the slant path. Furthermore, this effective path length used to establish an accurate prediction model of the rain attenuation over the satellite path. Generally, a few studies have been conducted on the vertical adjustment factor comparing to horizontal reduction factor, these studies mainly based on meteorological radar reflectivity.

Practically, the number of terrestrial links experimental available is much higher than the satellite experimental data, which it has given the opportunity to study the usage of the horizontal reduction model as a function to develop an accurate prediction model of the slant path.

According to Goldhirsh (1979), there are high correlation between attenuation on the terrestrial path and the slant path at low elevation angel. Furthermore, for low and medium elevation angles, the horizontal variability of the specific attenuation is greater than that in the vertical plane. Therefore, an overall concentration of this project has taken into account the slant effective rainy path concept to overcome the limitation of the horizontal reduction factor which can cause the effective path to be more than the actual slant path.

According to Bandera et al, (1999), for high elevation angles the fixed specific attenuation concept approximation cannot be applied and the better approach is using vertical adjustment factor for the prediction of rain attenuation along the slant path. Therefore, the ultimate concern of this study is to address this issue and propose an appropriate prediction model to calculate rain attenuation for Malaysia tropical climate based on point rainfall rate.

1.3 Problem Statement

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. The reason of this study is to solve and cover the follow points.

- The incapability of the published prediction models to be sensitive of the available knowledge of rain intensity on Malaysia climate.
- The lack of satellite propagation studies in Malaysia, especially for higher frequencies band.
- There is no previous calculation to extract the vertical rain intensity profile in Malaysia.
- There is no previous calculation for rain attenuation step by step along the slant path in Malaysia.

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

1.4 Objectives of the Study

The objectives ensure that the aim of this study is achieved. These objectives are contributions accomplished during this study. The objectives of this study are as follows.

- The main objective of this project is to assess the variation of the rain intensity obtained from the local weather radar data obtained from the Meteorological Department of Malaysia.
- Identified the required elevation angle, azimuth and range bin of Kluang radar data for the MEASAT satellite link at UTM station.
- Specified a suitable rain height by find the vertical profile of rain intensity distribution along the slant path link from different radar elevation angle.
- Prediction of rain attenuation distribution along the MEASAT3 satellite link at UTM station.

1.5 Scope of work

The scope of study indicates the basic guidelines and techniques that this study examined in achieving the objectives. It also ensures that the work done stays within the intended study.

- Used AUTOCAD software to model the case and to facilitate computing some dimensions.
- Extraction of rain intensity data taken from Kluang radar station. (Kluang Meteorological S-band radar belongs to the Meteorological Department of Malaysia, which is located in Kluang (Latitude=2.02°, Longitude=103.320° and height=88.1 m above MSL))
- The used data covers 64 days collected over the period from 2nd October to 4th December 2007 (1.30 GB on disk) with 0ne range (500 m) with 15 elevation angles of 0.5°, 0.8°, 1.1°,1.4°,1.9°, 2.5°, 3.3°, 4.4°, 5.8°, 7.7°, 10.3°, 13.6°, 18.1°, 24.1°and 32.0° .
- Development of programs to sort out, filter, decode the radar data and plot the vertical profile of radar reflectivity from the decoded data over the radar ranges using MATLAB program.
- Computation of rain attenuation along a given satellite link.
- Obtain similar rain attenuation profile from ITU-R method.

Traditionally, during the flow of the project these six points has been used and verified based on previous experiments of slant path and the new methodology has been proposed to use the milt-elevation angle as well, so the rain attenuation suffered can be accurately determined along the MEASAT satellite link at UTM station.

1.6 Highlights on Project Methodology

To carry out this project, the following methodology is follow

- AUTOCAD software was used firstly to determine the dimensions and specified the wanted and important per of azimuth an elevation angle which covers all UTM station - MASAT3 link.
- Build up of the vertical reflectivity profile (VRP) based on radar data, which includes the following tasks:
    - Preprocessing tasks, which include sorting out and filtering the meteorological radar data.
    - Decoding the radar data, and calculation of its reflectivity intensity in decibel (dBZ) for related range of Azimuth for the specific elevation angles.
- Determination the statistic rain rate in different altitude points from different elevation angles to used in next step.
- Calculate the rain attenuation
    - First time by use local results.
    - Second time by use ITU-R standard values.
- Finally compassion between two results

1.7 Thesis outline

Chapter one consists of introduction to the study. In this section, a brief general background is presented. The objectives of the project are clearly phased with details. The research scope and some light spots in the methodology are also presented.

Chapter two presents the first part of the literature review. There are two sections in this chapter. Section one presents an introduction to the satellite communication systems, frequency spectrum, and satellite propagation impairments are also provided. Section two explains brief details about Rain attenuation and it is parameters and models, background on the characteristic of rainfall structure, included Malaysia climates and the vertical profile of rainfall are presented also.

Chapter three is the second part of the literature review, presents the RADAR principles and characteristics, by focusing on meteorological radar, as conceder it the attenuation data source used in this study.

Chapter four represents the methodology of the project, including the details handling and the flow of processing for each step of the methodology for rain rate modeling, specific attenuation and finally the rain attenuation calculation.

Chapter five presents the results and discussions for the methodology steps; comparison is also done in this chapter for verification. Discussion of the rainfall rate and rain attenuation models performance is presented.

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

1.8 Summary

This chapter defines the importance of this research, the aims and objectives, scope of work as well as the problem statement observed. The outline of the proposal has been described too.

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