RAINFALL VERTICAL PROFILE VARIABILITY IN MALAYSIA BASED ON TROPICAL RAINFALL MEASURING MISSION (TRMM) USING NASA DATA

MAHIRAH BT MANSOR ADABI

UNIVERSITI TEKNIKAL MALAYSIA MELAKA (UTeM)

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MAHIRAH BT MANSOR ADABI

This report is submitted in partial fulfillment requirements for the Bachelor Degree of Electronic Engineering (Telecommunication Electronic) with Honours

Faculty of Electrical & Electronic Engineering (FKEKK)
Universiti Teknikal Malaysia Melaka
(UTeM)

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I declare that this thesis entitled "*Vertical Profile Variability in Malaysia Based on Tropical Rainfall Measuring Mission (TRMM) Using NASA Data*" is the result of my own research except as cited in the references.

Signature : ……………………………………..

Name : Mahirah Bt Mansor Adabi

Date : 6 June 2014

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering (Telecommunication Engineering) With Honour's.

Signature : ……………………………………..

Supervisor Name : En.Nor Azlan Bin Mohd Aris

Date : 6 June 2014

To my beloved parents, Mansor Adabi Shaari and Sharifah Yahya,
and my dearest family
and also my respectable supervisor, En Nor Azlan Mohd Aris.

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ABSTRACT

Rain along the transmission path is the major weather effect of concern for satellite communications operating at frequencies above 10GHz. Rain attenuation causes by absorb and scatter radio wave energy, which degrades the reliability and performances of the communications link. Furthermore, rain effect also depends on frequency, rain rate, drop size distribution and drop shape, which are determine by rain types. The precipitation radar (PR) on the Tropical Rainfall Measuring Mission (TRMM) satellites enables capture of the three-dimensional storm structure. Therefore vertical and horizontal distribution of rain are data wanted to investigate attenuation effect of rainfall rates, because the radar echo at the PR frequency of 13.8GHz suffer from significant attenuation. Two common rain types are convective rain and stratiform rain. The convective flows occur in a cell whose horizontal extent is usually several kilometers. For stratiform rain typically hundreds of kilometers cover large geographic areas durations exceeding one hour low rain rate. The estimation of rain height and rain rate attenuation required in the step by step calculation by ITU-R P.618-10. To observe the bright-band height is estimated from TRMM Precipitation Radar also relate in 2A23 and 2A25 algorithm. By assuming that lies 500 m above bright-band, the 0^0C isotherm height is calculated. Comparison with the TRMM collecting data shows quite good that indicates with ITU-R recommendation prediction model. This study shows better performances especially purpose of improving rain attenuation prediction model.

ABSTRAK

Hujan adalah factor utama sepanjang laluan penghantaran isyarat yang mempengaruhi sistem komunikasi satelit yang beroperasi pada frekuensi melebihi 10GHz. Ganguan hujan disebabkan oleh penyerap dan penyerakkan tenaga gelombang radio, yang menyebabkan kemerosotan pencapaian pada pautan komunikasi. Selain itu, kesan hujan juga bergantung kepada kekerapan, kadar hujan, taburan saiz dan bentuk, yang ditentukan oleh jenis hujan. Radar hujan (PR) di Misi Pengukuran Hujan Tropika (TRMM) dianggap salah satu alat satelit membolehkan struktur hujan tiga dimensi. Oleh itu taburan menegak dan mendatar hujan adalah data untuk mengkaji kesan pengecilan kadar hujan, kerana gema radar pada frekuensi *Precipitation Radar* adalah 13.8GHz mengalami pengecilan yang ketara. Dua jenis hujan ialah hujan perolakan dan stratiform hujan. Aliran perolakan berlaku dalam kawasan yang mendatar biasanya beberapa kilometer. Untuk hujan stratiform biasanya berlaku beratus-ratus kilometer meliputi kawasan geografi yang besar serta jangka masa melebihi kadar hujan yang rendah diantara beberapa jam. Anggaran ketinggian hujan dan kadar hujan pengecilan diperlukan dalam langkah dengan menggunakan pengiraan model oleh ITU-R P.618-10. Ketinggian *bright-band* dianggar daripada TRMM *Precipitation Radar* juga berkaitan di antara 2A23 dan 2A25 algoritma. Dengan menganggap jarak terletak 500 m di atas *bright-band*, ketinggian 0^0C isoterma ditentukan mengikut anggaran. Perbandingan dengan mengumpul data TRMM menunjukkan keputusan yang agak baik dengan ITU-R model. Analisis kajian ini menunjukkan keupayaan prestasi terutamanya tujuan penambahbaikkan model.

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LIST OF ABBREVIATIONS

CERES	-	Clouds and Earth's Radiant Energy System
DSD	-	Drop Size Distribution
DPR	-	Dual-Frequency Precipitation Radar
GPM	-	Global Precipitation Mission
GUI	-	Graphical User Interface
GMI	-	GPM Microwave Imager
HDF	-	Hierarchical Data Format
ITU-R	-	International Telecommunication Union, Radiocommunication Sector
JAXA	-	Japan Aerospace Exploration Agency
LIS	-	Lighting Imaging Sensor
MATLAB	-	Matrix Laboratory
NASA	-	National Aeronautics and Space Administration
PR	-	Precipitation Radar
THOR	-	Tools for High-resolution Observation Review
TMI	-	TRMM Microwave Imager
TRMM	-	Tropical Rainfall Measuring Mission
VIRS	-	Visible and Infrared Scanner

LIST OF SYMBOLS

f	-	Frequency
h_o	-	0^0C isotherm height
h_{BB}	-	Bright-band height
h_R	-	Rain height
h_s	-	Earth station latitude
$k(s)$	-	Specific attenuation
L_G	-	Horizontal projection of L_s
L_s	-	Slant-path length
Ø	-	Earth station latitude
R	-	Rain rate
$R_{0.01}$	-	Rainfall rate exceeded for 0.01% of the yearly time
R_e	-	Earth radius
Z_e	-	Effective radar reflectivity factor
ζ	-	Polarization angle
σ	-	Standard deviation
Ψ	-	Elevation angle
λ	-	Wavelength
C	-	Speed of light (approximately 〖3 x 10〗^8 m/s)
L_r	-	Rain attenuation in decibel (dB)
L	-	Equivalent path length (km)
γ	-	Specific rain attenuation ($\frac{dB}{km}$)

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Satellite communication links operating at 10 GHz are affected immensely by hydrometers such as rainfall [1]. With the increasing demand for high speed satellite transmission, the operating frequency of satellite systems is moving from the current Ku band (10GHz/20GHz) to Ka band (20GHz/30GHz). In engineering fields, especially for radio wave propagation, major interests are related to the transmission systems impaired due to rain. This affect are considered as more critical around the equatorial region such as Malaysia where tropical weather conditions are characterized by stratiform and convective rain and extremely high rainfall rates. Rainfall causes absorption, scattering and dispersion to the microwave signal which contribute to the rain attenuation. The major issue is the accuracy in the prediction of rain attenuation over Earth-space path arises from ambiguity in the structure of the rainfall over the path and uncertainty in estimating the attenuation due to melting layer[2].

In fact, measuring global rainfall through space based (i.e. satellite remote sensing) observation is one of the good alternative in addition to the ground-based measurement due to its wider coverage [3]. One of the most powerful space-based instruments is Tropical Rainfall Measuring Mission (TRMM) satellites are using currently. Nowadays, TRMM satellite has been continuously observing the tropical climatic since its launch in November 1997. Main purpose of the TRMM observation is to understand the tropical rainfall distribution and its effects to the global climate and therefore, several parameters which are required to deal with the estimation of rain attenuation could be obtained for the design of earth-space link. A variety of models exist for the prediction of the average yearly rain attenuation whereby, one of the most accepted and established worldwide is International Telecommunication Union recommendation ITU-R P.618-10 [4]. In the ITU-R P.618-10 recommendation, the effective rain height is currently estimated in relation to the 0^0C isotherm height level, usually obtain from data prediction methods required for Earth-space telecommunication systems (ITU-R P839-3)[5]. Most of the study to produce the ITU-R model is based on the data from temperate region whereby rain in tropical could show different behavior (i.e., the melting layer which contribute much towards the attenuation could be thicker compared to temperate region). Hence, it will be interesting to investigate the capability of TRMM in rain height information retrieval as well as compare and assuming the variable.

1.2 Problems Statement

In the statements of the problems are summarized in this sub chapter. The reliability of TRMM in the radio wave propagation studies such as prediction of rain attenuation. In this research, estimation of rain height and melting layer are classified as rain attenuation studies due to their significance in the global rain attenuation prediction model by ITU-R recommendation model. Since the launch Precipitation Radar by NASA, several efforts have been carried out to take advantage of the capability of TRMM in the radio wave propagation field due to availability of other reliable database could provide longer-term of data observation. Validation of the rain height retrieved from TRMM with the other instrument is of important task. In the aspect of rain height variation, TRMM could provide wider data coverage in comparison with radiosonde and ground radar based on the previous researches.

Furthermore, TRMM also provides observation spatial resolution data compared to the ITU-R recommendation. The significance of rain height could be displayed through the estimated rain attenuation based on collected various rain height values. Since the work in improving current prediction model is a continuous effort, an availability of such high spatial resolution database as TRMM is expected to provide more accurate estimation or prediction, specifically in this case, prediction of rain rate attenuation statistics. To validate this assuming and hypothesis, a proposed method using TRMM database to provide input meteorological parameter should be tested with current global prediction model. Therefore, the results as research carried out in this thesis could also been viewed as pattern the TRMM capability towards rain attenuation studies.

1.3 Objectives

The error in estimating rain attenuation could be due to an inaccuracy of the effective rain height. Therefore, the objective of this study is to:

1) Analyzed and characterized the melting layer thickness through stratiform rain events based on TRMM PR observation.
2) Identify variations in attenuation prediction at Malaysia due to the variations of melting layer thickness.

1.4 Scope of Work

The main contribution in this research highlight that usage of TRMM database in the radiowave propagation studies, which in fact provides better spatial resolution data compared to the current database that has been relied on by ITU-R in several recommendations model. These analyses include the estimation of rain height and melting layer thickness to show the advantages of TRMM. In order to achieve the objective of this research while considering few scopes have been outlined.

Began of the step is use of TRMM database as resource to provide required data by NASA. The TRMM database consists of many datasets which are the products of its sensors observation algorithms. In this research, the data products originated from TRMM Precipitation Radar are used as main resources for estimating the required parameters. Since TRMM developed their own algorithm for their respective products, therefore all results are through accuracy of the algorithms. Next, rain height and melting layer are the two parameters which commonly close each other in the radiowave propagation studies to be estimated employing TRMM database. Studies on rain height are focused to the variation and its effect to the rain attenuation prediction model. It is estimated based on the knowledge of bright-band height, $0^{0}C$ isotherm height and melting layer which is provided by TRMM PR 2A23 and 2A25 datasets.

This research emphasizes on the melting layer considering its significance to the radiowave propagation studies. Comparison with ground measurement data which are taken from other researchers is carried out to highlight the validity of TRMM database. A modified prediction model of rain rate attenuation that originated from analytical formulation of ITU-R P.837-6 [6] is proposed which uses TRMM database as its source to extract the required meteorological inputs. While ITU-R P.839-3[5] study on the effective rain height is estimated in relation to the $0^{0}C$ isotherm height level and ITU-R P.618-10 focus on models exist for the prediction of the average yearly rain attenuation. The capability of the TRMM database to estimate useful parameters meant for radiowave propagation studies is shown through several assuming that involve selected areas or locations within tropical and equatorial regions. Therefore, ITU-R recommendations are used as main reference as well as other data from appropriate literatures for comparison purposes.

1.5 Thesis Outline

The first chapter of this thesis presents overview of the research and briefly explained on the significance of this work is stated in the background of study and problem statement. Most important target need to be achieved objectives and scopes of work are highlighted. In chapter two is literature review which reviews the Tropical Rainfall Measuring Mission (TRMM) and the two rainfall parameters; rain height and melting layer. This chapter provides explanation on the TRMM mission and its reliability. It is useful to mention here that Precipitation Radar on board of TRMM satellite is the main focus in this chapter. Next is the review on the rainfall parameters which divided into two subsections which are rain height and melting layer. Rain height studies provide understanding on several rain height terms especially in tropical region. Explanations on ITU-R global prediction model is described in details. Methodologies in this research work are described in chapter three. Description on data selection, data processing and assuming the variables are also explained in this chapter. Chapter four shows the results from rain height and rain attenuation analyses. At last Chapter five concludes the finding of the research which contributions are highlighted based on the results obtained. Recommendations and finalized for future works are also included in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 TRMM Satellite

Precipitation is probably one of the most difficult variables to be measured rainfall due to its high variability in space and time. Due to the problems statement, space-based instrument such as radiometer and space borne sensors have been introduced to provide global rainfall data by NASA cooperate with JAXA. Satellite remote sensing is one of the good alternatives to measure global rainfall. With technology developments, the most powerful sources of instruments for rainfall measurement are space borne precipitation radar on board of Tropical Rainfall Measuring Mission (TRMM) satellite has been determined. Regarding the information of the TRMM background, its equipment on board especially the Precipitation Radar (PR), the data products and details on its reliability will be reviewed in detailed in this chapter.

The Tropical Rainfall Measuring Mission (TRMM) satellite is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to monitor and study tropical rainfall. The Precipitation Radar (PR) can see through the precipitation column, providing new insights into tropical storm structure and intensification. The TRMM Microwave Imager (TMI) measures microwave energy emitted by the Earth and its atmosphere to quantify the water vapor, the cloud water, and the rainfall intensity in the atmosphere. TRMM precipitation measurements have made and continue to provide critical inputs to tropical cyclone forecasting, numerical weather prediction, and precipitation climatology. TRMM is particularly devoted to determining rainfall in the tropics and subtropics of the Earth.

Therefore, TRMM satellite mission has three main sensor packages which involve the three instruments on board had been launched on November 27, 1997 at Tanegashima Island. The satellite observation coverage falls within 35^0 North and 35^0 South of the equator. At each sampling area in the tropics, it is visited about twice daily at different hour of the day or about 16 times orbiting daily (TRMM official website – trmm.gsfc.nasa.gov). The sensors working while orbital the earth which is Precipitation Radar (PR), TRMM Microwave Imager (TMI), and Visible and Infrared Scanner (VIRS). Lightning Imaging Sensor (LIS) which have different responsible on the global complemented them to improve the understanding on the climatology of global lightning flash rates.

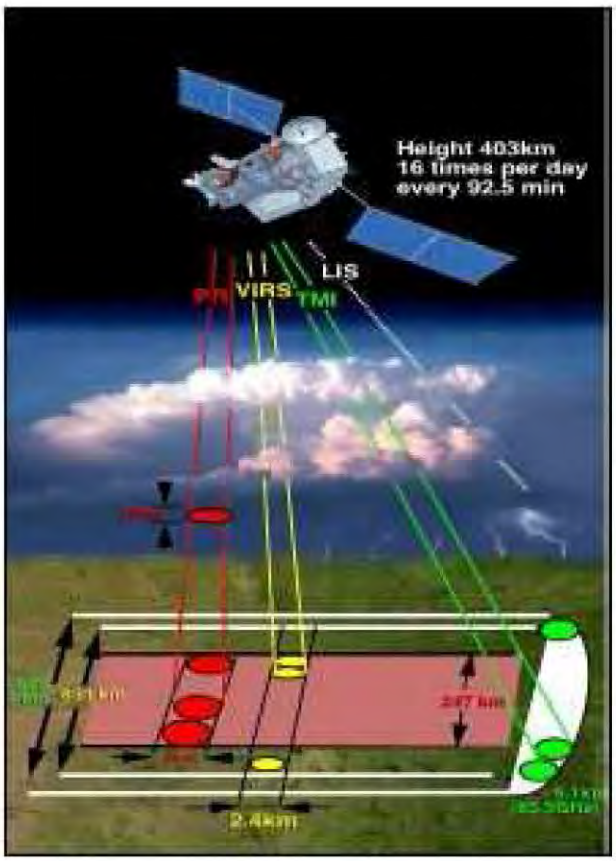

Figure 2.1: Sensors provided by TRMM Satellite (Credit: NASA)