UNIVERSITI PUTRA MALAYSIA

PROPAGATION MODELS FOR TRAIN ENVIRONMENT OVER GEO SATELLITE NETWORKS IN MALAYSIA

ABDULMAJEED HAMMADI JASIM AL-JUMAILY

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By

ABDULMAJEED HAMMADI JASIM AL-JUMAILY

Thesis Submitted to the School of Graduate Studies,Universiti Putra Malaysia, in Fulfilment of the Requirements for Master of Science

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DEDICATIONS

قال تعالى

((قُلْ لَوْ كَانَ الْبَحْرُ مِدَادًا لِكَلِمَاتِ رَبِّي لَنَفِدَ الْبَحْرُ قَبْلَ أَنْ تَنْفَدَ كَلِمَاتُ رَبِّي وَلَوْ جِئْنَا بِمِثْلِهِ مَدَدًا))

الكهف 109

To my caring, lovely wife Saba Jasim Mohammed Al-Jumaily " May Allah bless her with her supreme benevolence " she is forever remembered and loving memory of my brother Abdulrahman Hammadi Jasim Al-Jumaily, May Allah bless him with his supreme benevolence who is forever remembered. To my caring, sisters and brothers and friends, who have supported me all the way since the beginning of my study to my dear friends for their moral support, inspiration and guiding hand on my life in Malaysia. ...

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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December-2014

Chairman : Aduwati Binti Sali, PhD

Faculty : Engineering

Recent advances in satellite communication technologies in the tropical regions have led to significant increase in the demand for services and applications that require high channel quality for stationary and mobile satellite terminals. The lack in reliable, accurate analysis and assessment for the stationary and mobile scenarios regarding the attenuation due to rain and power arch supply PAs. These is a need to determine and quantify these risk factors which, in its turn, leads to optimize service quality particularly in Malaysian region. Moreover, the current satellite propagation models are done at temperate regions which exhibit different environmental characteristics than seen in Malaysia. That makes their propagation models inaccurate and irrelevant to the tropical regions in general.

The propagation models for the stationary and mobile scenario of high speed train to produce a reliable analysis on the attenuation, due to rain and power arch supply, in tropical region, represents an interesting area to study for propagation impairment in Malaysia. The rainfall characteristics in the tropical region differ significantly from those in temperate regions, the rain effects problem is more crucial for tropical regions such as Malaysia because of their high intensity rainfall. This study presents for stationary scenario (Malaysia-PMSS) an analysis of experimental data compared against six existing rain attenuation prediction models namely, the ITU-R-618-11, ITU-R-618-5, DAH, Crane, Brazil, and SAM models. The data are analyzed in two ways. First, rain attenuation prediction models are statistically analyzed. Second, the measured data and existing prediction model are compared. A communication system design can estimate the exact rain attenuation for three locations Selangor, Penang, and Johor regions of Malaysia and can produce a suitable design for better communication service. Additionally, new method for developing measured data is suggested: the Exponential Moving Average (EMA).

Throughout the literature, the location Selangor and elevation angle 77.5° are not considered. Therefore, our new model takes into account the location and elevation angle to make it more applicable. Hence an extension for improving the performance assessment and analysis of satellite/Earth stations is achieved. Of all studied models, the Brazil, ITU-R-618-11, and DAH models gave the lowest root mean square (RMS) error for the three chosen states in Malaysia for stationary scenario. For the mobile scenario (Malaysia-PMMS), enables a first-hand coarse estimation of and an analysis attenuation because it is much simpler to obtain attenuation due to rain and power arch supply PAs. The attenuation rustled from rain either rain or power arch supply were measured independently.

The obtained output were statistically analyzed to calculate the total attenuation composite (PAs with rain) time series synthesizer. A parallel to that, attenuation resulted from power arch supply were compared with noise floor level. This comparison is useful to validate attenuation due to power arch supply measurement. Incorporating both phenomena to enable a more comprehensive study of relevant fade mitigation techniques (FMTs). The underlying analytical tool represents a first effort (to be validated by measurements) to dynamically model mobile satellite links operating higher than 10 GHz. In order to increase the quantitative and qualitative information database of the satellite signal performance under link impairments in tropical regions.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

MODEL PERAMBATAN PERSEKITARAN TETAP DAN KERETAPI LAJU MENGGUNAKAN RANGKAIAN SATELIT GEO DI MALAYSIA

Oleh

ABDULMAJEED HAMMADI JASIM AL-JUMAILY

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Kemajuan terkini dalam teknologi komunikasi satelit di kawasan tropika telah membawa kepada peningkatan yang ketara dalam permintaan untuk perkhidmatan dan aplikasi yang memerlukan kualiti tinggi untuk saluran terminal satelit pegun dan bergerak. Kekurangan dalam analisis yang tepat dan penilaian untuk senario pegun dan bergerak mengenai pengecilan kerana hujan dan bekalan kuasa gerbang (PAs). Ini adalah keperluan untuk menentukan dan mengukur faktor-faktor risiko yang, pada gilirannya, membawa kepada mengoptimumkan kualiti perkhidmatan terutamanya di rantau Malaysia. Selain itu, model perambatan satelit semasa dilakukan di kawasan sederhana yang mempamerkan ciri-ciri alam sekitar yang berbeza daripada dilihat di Malaysia. Model perambatan mereka mungkin tidak tepat dan tidak relevan kepada kawasan tropika amnya.

Model pembiakan untuk senario pegun dan bergerak untuk menghasilkan analisis yang boleh dipercayai pada pengecilan, kerana hujan dan kuasa gerbang bekalan, di rantau tropika, merupakan kawasan yang menarik untuk belajar untuk kemerosotan pembiakan di Malaysia. Memandangkan ciri-ciri taburan hujan di kawasan tropika yang sangat berbeza dari di kawasan beriklim sederhana, masalah kesan hujan adalah lebih penting bagi kawasan tropika seperti Malaysia kerana keamatan hujan yang tinggi.Kajian ini membentangkan untuk senario tidak bergerak (Malaysia-PMSS) analisis data eksperimen dibandingkan dengan enam sedia ada hujan pengecilan ramalan model-iaitu, ITU-R-618-11, ITU-R-618-5, DAH, Crane, Brazil, dan model SAM. Data dianalisis dalam dua cara. Pertama, model ramalan gangguan hujan yang dianalisis.

Kedua, data diukur dan model ramalan yang sedia ada dibandingkan. Satu reka bentuk sistem boleh menganggarkan gangguan hujan yang tepat untuk tiga lokasi-Selangor, Pulau Pinang dan Johor negeri di Malaysia dan boleh menghasilkan reka bentuk yang sesuai untuk perkhidmatan komunikasi yang lebih baik. Selain itu, kaedah baru untuk membangunkan data diukur dicadangkan: yang eksponen Melangkah Purata (EMA). Sepanjang sastera, lokasi Selangor dan ketinggian sudut 77.5 ° tidak dianggap. Oleh itu, model baru kami mengambil kira lokasi dan ketinggian sudut untuk menjadikannya lebih berkenaan.Oleh itu lanjutan untuk meningkatkan penilaian prestasi dan analisis stesen satelit / Bumi dicapai. Semua dikaji model, Brazil, ITU-R-618-11, dan model DAH memberikan akar yang paling rendah kuasa dua (RMS) kesilapan untuk ketiga-tiga negeri di Malaysia dipilih untuk senario pegun. Untuk senario mudah alih (Malaysia-PMMS), membolehkan anggaran kasar dan pelemahan analisa kerana ia adalah lebih mudah untuk mendapatkan pengecilan kerana hujan dan bekalan kuasa gerbang (PAs).

The pengecilan rustled dari hujan sama ada hujan atau bekalan kuasa gerbang diukur secara bebas. Output yang diperolehi dianalisis secara statistik untuk mengira jumlah komposit pengecilan (PAs dengan hujan) siri masa pensintesis. Selari dengan itu, pengecilan menyebabkan bekalan kuasa gerbang dibandingkan dengan di tingkat bunyi. Perbandingan ini berguna untuk mengesahkan pengecilan kerana pengukuran bekalan kuasa gerbang. Mengandungi kedua-dua fenomena bagi membolehkan kajian yang lebih menyeluruh teknik pengurangan pudar berkaitan (FMTs). Alat analisis sandaran merupakan satu usaha pertama (untuk disahkan oleh pengukuran) untuk secara dinamik model pautan satelit mudah alih yang beroperasi lebih tinggi daripada 10 GHz. Untuk meningkatkan pangkalan data maklumat kuantitatif dan kualitatif prestasi isyarat satelit di bawah pautan kecacatan di kawasan tropika.

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I certify that an Examination Committee has met on 19 December 2013 to conduct the final examination of Abdulmajeed Hammadi Jasim Al-Jumaily on has Master of Science thesis entitled Propagation Models for Train Environment Over GEO Satellite Networks in MALAYSIA in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the degree of Master of Science.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CDF	Cumulative Distribution Function
PAs	Power Arch Supply
ETS	Electrifeed Train System
FTMs	Fade Mitigation Techniques
ITU-R	International Telecommunication Union Prediction Model
DAH	Dissanayake, Allnutt and Haidara Attenuation Model
CRANE	Crane Global Attenuation Model
BRAZIL	Brazil Attenuation Model
SAM	Simple Attenuation Model
DVB-S	Digital Video Broadcasting-Satellite
DVB-S2	Digital Video Broadcasting-Satellite-Second-Generation
DVB-RCS	Digital Video Broadcasting - Return Channel via Satellite
DVB-H	Digital Video Broadcasting - Handheld
QoS	Quality of Services
GEO	Geosynchronous Satellite
IP	Internet Protocol
TV	Television
RMS	Root Mean Square Error
STD	Crane Standard Division
Mean	Mean Error
EMA	Exponential Moving Average
LOS	Line-of-Sight
mm	Millimeters of Rainfall Accumulation
mm/hr	Millimeters of Rainfall Accumulation Per Hour
km/hr	Kilometer Per Hour
m/s	Meter Per Second
N	North
S	South
0°C isotherm	Line on a Map Connecting Points The Same Temperature
Malaysia-PMSS	Malaysia Propagation Model for Stationary Scenario
Malaysia-PMMS	Malaysian Propagation Model for Mobile Scenario
UPM	Universiti Putra Malaysia
USM	University Sains Malaysia
UTM	University Teknologi Malaysia
LNB	Low Noise Block
IDU	Indoor Unit
ODU	Outdoor Unit

a	Distance Between Obstacle and Antenna in Meter
b	Distance Between Satellite and Antenna in Kilometer
d	Diameter of Power Arch in Centimeter
D	Diameter of Antenna in Centimeter
f	Downlink frequency (GHz);
λ	Latitude of Ground Station in Degree
Hs	Altitude of Ground Station in Kilometer
θ	Antenna Elevation Angle in Degree
τ	Polarization Angle in Degree
k and α	Polarization and Frequency Dependent on ITU-R,Coefficients
P0	The Possibility of Exceeding the Intensity of Rainfall 0 mm/h [%]
P	Time percentage during year [%]
Rp(p)	Distribution Rate of Rainfall Point of an Average Year
R0.1	Indicates Rainfall at 0.1% of the Average Time of the Year
R0.01	Indicates Rainfall at 0.01%of the Average Time of the Year
HR	The average height of the rain effective of 1 Kilometer
H0(p)	The Average 0°C Isotherm height
Re	Effective Radius of the Earth

CHAPTER 1

INTRODUCTION

1.1 Background

There are many satellites rotating around earth which help us to communicate. The satellite communications role is increasing in our daily life use. The high definition television that we watch and the internet browse work through the satellite technology. The microwave signals being used in satellite communication can have very high frequencies in atmosphere. The increasing demand of satellite technology caused utilization of higher frequencies in order to have wider band for usage. Operation of higher frequency bands such as the Ku band for satellite communications provides a number of important benefits. It relieves congestion in the lower frequencies which are shared with terrestrial links, it exploits the larger bandwidths available at higher frequencies, and provides cheaper implementation of spectrum conservation techniques and a more efficient use of the geostationary curve Suresh and Madham (2011). A basic satellite communication consists of many earth stations on ground and a satellite in space. Satellite communication link can be divided in two different manners. They are uplink and downlink:-

Where for uplink earth stations function as transmitter (to send information signal) and satellite in space become the receiver (to receive information signal). For downlink earth station is receiver and satellites in space become the transmitter. The great distance between the transmitter and receiver will cause power reduction in information signal. When the power start to spread out, it will shrink the distance of the information signal travels, whereby the receiver at downlink only will able to receive weaker signal. Once the signal become weak it can be easily polluted and attenuated by the atmospheric effects. There are several impairments that can cause attenuation of the information signals, which are rain attenuation, gaseous absorption, cloud attenuation, melting layer attenuation, tropospheric scintillations, and low-angle fading.

It is well known that among all other impairments, rain is the dominant propagation impairment at the frequency above 10 GHz or higher frequency spectrum at the Ku-Band. The propagation effects over the earthspace path caused by rain are in the form of attenuation, depolarization, and scintillation. At such high frequencies, the sizes of falling raindrops are close to a resonant sub-multiple of the signal wavelength. The droplets, therefore, are able to absorb, scatter, and depolarize the radio waves passing through the earths atmosphere Das et al. (2011). Absorption and scattering by rain at frequencies above 10 GHz can cause a reduction in transmitted signal amplitude (attenuation), which in turn reduce the reliability, availability and performance of the communications link Omotosho and Oluwafemi (2009).This phenomenon is known as outage time where the amount of time during which the satellite system performance will be below the design threshold value and it will not be usable.

In order to overcome this problem, one-minute rainfall rate and rain attenuation need to be studied and used to calculate the expected amount of rain attenuation to prevent the unavailability or outage time from occurring Crane (1996); Green (2004); Barclay (2003). When considering parameters affected by propagation impairments factor, it is necessary to specify the parameters on a statistical basis, which are usually specified in percentage of time. This percentage of time is normally described as the percentage of time in a month, in a year or the parameter equals to or exceeds a certain value so that the link margin can be established. Link margin is the amount of extra power in the system to withstand propagation fades and misprinting losses Ahmad et al. (2004).

In different rainfall regions, earth stations are scattered. Even though the frequency is the same, rainfall rate at earth stations is different at any given time. Making real-time measurements at the preferred earth station is a very effective way to obtain rainfall rate value. It is not economically feasible to measure rainfall rate in this manner in all parts of the world in which it may be desired to use millimeter-wave communication links Pan et al. (2006). The lack of measured rainfall rate data from sites of interest resulted in the development of rainfall rate prediction models. These prediction models have been used to estimate rainfall rate in interest sites. Many prediction models are available for the use of communication designers to predict rainfall ratePestoriza et al. (2010). Few researchers have developed models that can be used to estimate one-minute rainfall rate distributions. Most of the rainfall rate models were developed based on the rainfall data collected in temperate regions and very few in tropical and equatorial which is famous for heavy rainfall such as Moupfouma Moupfouma (2009); Recommendation (2013a, 1997).

The reason why rainfall rate must be obtained first either by experiment or by using prediction models is to predict accurate rain attenuation. One-minute rainfall rate cumulative distribution plays an important role and an important input parameter as well in calculating the rainfall attenuation distribution. According to Recommendation (2013a, 1997, 1994). Crane Global prediction model Crane (1980), Brazil rain attenuation prediction model Paraboni et al. (1997), and Simple Attenuation Model (SAM) Stutzman and Dishman (1982). When operating at a high frequency, such as Ku band frequencies, satellite signal strength is reduced under severe rain conditions. Rainfall attenuation can be directly obtained from the measurement of beacon receiver or predicted from the drop-size distribution or knowledge of rainfall rate Crane (1996). Until now, the models of attenuation use the effective radio path length concept which is based on the rainfall rate distribution for the estimation of attenuation due to the rainfallSingh and Allnutt (2007). Therefore, one-minute rainfall rate cumulative distribution plays an important role in calculating the rainfall attenuation distribution. One-minute rainfall rate models are encouraged to be used to predict the local cumulative distribution of rain data for the locations where essential one-minute rainfall rate distribution cannot be obtained.

The reason why rainfall rate must be in one minute because the evaluation of the effects of rain on satellite system design requires a detailed knowledge of the attenuation statistics for each ground terminal location at the specific frequency of interest Crane (2003). Additionally, the amount of rain attenuation depends on several parameters. First of all, the transmission parameters (such as frequency, elevation angle) is the main source for mentioned losses. Second, the Earth station mobility and position parameters are included. Third, the atmospheric parameters are caused due to rain rate and rain height. Finally, the shadowing caused by Diffraction due to Power Arches supply (PAs), depending on geometry of the satellite link, and deep fading,(railroad side trees or high-rise buildings), multipath effect primarily caused by mountains or nearby buildings, (Doppler effect), which depends on the speed and direction of the movement, and (antenna tracking error). These four major causes of signal degradation prompt the satellite communication system designers to build well-formulated models to predict the QoS. As seen in Figure 1.1.

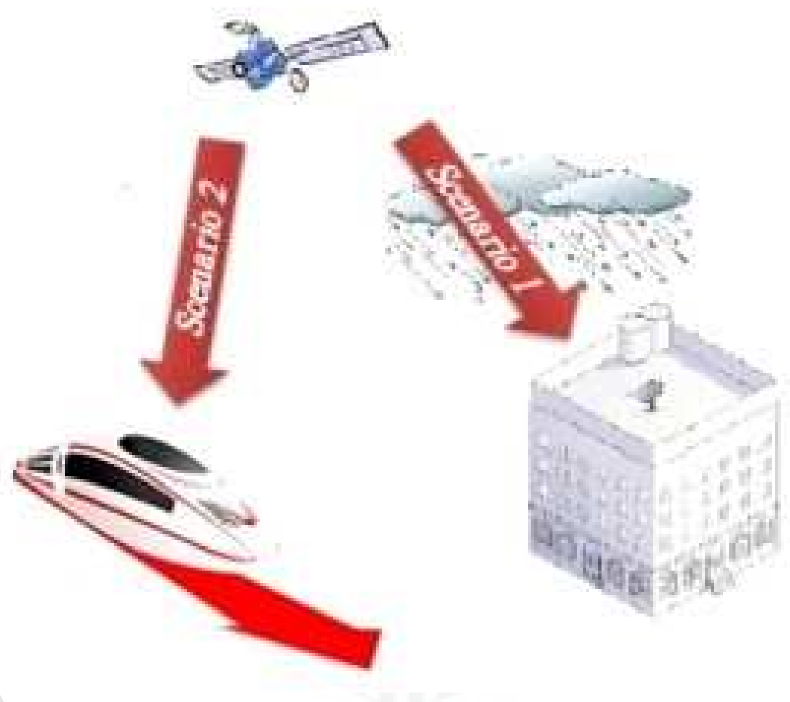

Figure 1.1 Expected scenario for high speed train environment

From a convention opinion, the related system specification normally will answer to digital video broadcasting and the second-generation, return channel via satellite standards (DVB-S/DVB-S2, DVB-RCS), for stationary scenario and video digital broadcasting for handheld (DVB-H) standard in mobile scenario-Faria et al. (2006); Morello and Mignone (2006). In recent year, the boundary among these standards is becoming ambiguous, because of their necessity in some situations like vehicular, maritime, aeronautical, and railway scenarios. The standards above provided some improvements in advanced applications like high speed train internet access, video, audio, and file transmitting to trains, aero-planes, and shipsThorp et al. (2011); Morlet et al. (2007).

1.2 Problem statement

A satellite propagation models for stationary and mobile scenarios near-equatorial and tropical regions is needed in a matter of urgency because it currently shows certain impairments. The lack in reliable, accurate analysis and assessment for the stationary and mobile scenarios regarding the attenuation due to rain and power arch supply (PAs). These is a need to determine and quantify these risk factors which, in its turn, leads to optimize service quality particularly in Malaysian region. Moreover, the current satellite propagation models are done at temperate regions which exhibit different environmental characteristics than seen in Malaysia. That makes their propagation models inaccurate and irrelevant to the tropical regions in general. The propagation models for the stationary and mobile scenario to produce a reliable analysis on the attenuation, due to rain and power arch supply, in tropical region, represents an interesting area to study for propagation impairment in Malaysia. Given that rainfall characteristics in the tropical region differ significantly from those in temperate regions, the rain effects problem is more crucial for tropical regions such as Malaysia because of their high intensity rainfall.

Few studies have been conducted in Malaysia Mandeep (2009); Mandeep et al. (2008b); Chebil and Rahman (1999) on rain attenuation. But none looks for mobile scenario such as high speed train. The high speed train environment presents some peculiar fading events, like short repetitive fading events due to the power arch supply (PAs). Fading resulted by the power arch supply in Malaysia at Ku band leads to a reduction of the quality of receiving signals at the receiver terminals. Because, the open areas characterized by Line of Sight (LOS) suffer from a variety of channel phenomena; (Diffraction because of Power Arches (PAs)). That is depending on geometry of the link and deep fading, (shadowing) as a results of the mobility, such as frequent fade and depth due to metallic obstacles and electricity trails, and (shadowing or blockage) because of the underground tunnel stations, (multipath effect) primarily caused by mountains or nearby buildings,(Doppler effect). All of that depend on the speed and direction of the movement, and antenna tracking error.

These major causes of signal degradation prompt the satellite communication system design to build well-formulated models to predict the QoS in tropical regions. The accurate assessment of attenuation, due to rain and PAs, has been the foremost goal of some studies in Malaysia. This analysis is associated with the new measurement database provided worldwide for stationary and mobile scenarios in the tropics. In our study, new propagation models for mobile scenario was presented. To the best of our knowledge, this is the first mobility experiment onto high speed train done to assess the signal quality, under the above mentioned cases, for satellite communication in Malaysia as a tropical region.

1.3 Aim and objective

The main objective of this research is to design and develop the propagation models for stationary terminal and high-speed train scenarios for analysis and simulating the signal degradation effects and predicting the optimal fade mitigation technique. The models involve measurements of the rain rate and rain attenuation for the stationary and mobile scenarios. Most of the studies on the rain attenuation have been carried out in temperate regions such as Europe and North America. Most of the designed models have been based on the data obtained mainly from the non-tropical regions. Indeed, the characteristics in the tropical differ from that of the temperate regions. Because the tropical regions have high intensity rainfalls, the problem seems to be more crucial.

i- To measure the rain rate and rain attenuation in Malaysia of propagation model of stationary scenario (Malaysia-PMSS).

ii- To compare and analyze rain attenuation for stationary scenario using six prediction models.

iii- To validate composite dynamic model of high speed train in Malaysian.

1.4 Thesis Scope

The scope of this research focuses on the satellite propagation models for the stationary and mobile scenarios to counteract only the relevant attenuation due to rain and PAs in both scenarios in Malaysia. Furthermore, this study will deal with the analysis of the attenuation due to rain and PAs in Malaysia and its impact as the total attenuation on the GEO satellite transmission considering the rain sequence on top of the other factors such as the attenuation of the satellite channel at the Ku-band and higher. In practice, two broad propagation scenarios Malaysia-PMSS and Malaysia-PMMS were produced. The scope of stationary scenario consists of investigation on existing rain attenuation prediction models and to analysis the prediction model of rain attenuation in tropical region. The methodology diagram of overall research is illustrated in Figure 1.2. The scope of this project is phased to the following steps.

The first and second steps are studying the existing attenuation prediction models respectively. The objective of this research is to analyze and develop the most efficient attenuation prediction model of rain attenuation using available rainfall rate and rain attenuation measurement data. Therefore, the fundamental knowledge of six types of existing rain attenuation models such as ITU-R Recommendation (2013a, 1997) DAH Dissanayake et al. (1997), Crane Crane (1980), Brazil Paraboni et al. (1997) and SAM Stutzman and Dishman (1982) models were collected. Summary of the comparison between measured rain attenuation data with the rain attenuation prediction models is shown chapter 4.

The assumption on choosing the right rainfall rate and rain attenuation models are made based on root mean square (RMS) method. The RMS method used for testing was suggested by ITU-R Rec (2003). The ITU-R model is simple to understand, easier to use and widely accepted by many researchers. However, the model underestimates measured rain attenuation when applied to tropical regions.The last step is test the proposed models for other measurement site. The purpose of this project is to propose an efficient and unification rain attenuation prediction model for tropical region.

Therefore the proposed model was tested for other measurement sites that are located in Malaysia. The sites that were chosen Penang and Johor. The purpose of this test is to ensure the model is can be applicable for other site in Malaysia rather than only giving accurate prediction within the measurement geographical domain. Basically all the steps as mentioned above were applied in the research. This proposed model fits the measured data obtained from Malaysia as tropical region. The scope of mobile scenario consists of investigation on measurements to determine the attenuation due to rain and the power supply arch (PAs), because of the high speed train. From these measurements, a statistical analysis was performed. The output of this activity is the semi-empirical satellite propagation channel for mobile scenarios communications, taken into account the operating frequency, the weather inducement, and trees shadowing and most importantly fast fading due to power arch supply.

Accordingly, the new model named as a Malaysian propagation model for mobile scenario (Malaysia-PMMS) was produced and our mobile scenario was carried out to reduce the communication failures as a result of the terrestrial infrastructure in availability. Statistical analysis computed from the Malaysia-PMMS was compared with the other satellite propagation models for the railway communications obtained from Italy as a temperate region. Respectively, building upon this method our work was extended to recent intense research on furnishing a reliable analysis attenuation for stationary and mobile scenario that the rain attenuation and attenuation due to PAs time series. Additionally the core assumption of the proposed dynamic model of attenuation due to rain and PAs over LOS mobile satellite links is that the total attenuation time series synthesizer.

1.5 Research Contributions

The role of satellite in our daily life is increasing day by day. The satellite technology is, in fact, used at all places where the use of cables and wireless is practically impossible once the wireless technology can be called. Wireless technology puts information at your fingertips from practically anywhere in the world. Modern technology has given us easy and convenient ways to transfer information, communicate and entertain ourselves. With wireless technology, we can send and receive information without using wireless or cables. When we talk about wireless technology, we mean electronic devices that are linked or networked together.

These devices can send and receive large amount of information over radio waves Pahlavan (2011) unless radio waves are used, both communication and navigation satellites would not be possible. Wireless networks, Television broadcasts, Cordless phones, AM and FM radios broadcasts and etc., are examples for these technologies which depend on radio waves. The fast growing in the technology and its applications pushed us to keep ourselves to be on up-to-date and therefore, follow the technology trends. Evaluation for two main scenarios; stationary and mobile of high speed train, are workable issue.

i- For stationary scenario, Malaysia-PMSS, UPM Faculty of Engineering campus, Serdang, Selangor was the field or the area where our study has been perform with the technology trend. (Rain attenuation prediction models were modified to accommodate UPM site). Propagation measurements have been made to give more accurate results regards rain attenuation. The Exponential Moving Average (EMA) is a new measurement technique proposed for measuring the extensions of rain attenuation measured, and throughout the literature, the location Selangor and elevation angle 77.5 are not considered. Therefore, our new model takes into account the location and elevation angle to make it more applicable we used it, in order to improve calculation when satellite communication links. The measurements were statistically analyzed compared with six prediction rain attenuation models as following:- ITU-R-618-11, ITU-R-618-5, DAH, Crane Global, Brazil, and SAM were identified and analyzed.

ii- For mobile scenario of high speed train, Malaysia-PMMS, enables a first-hand coarse estimation of attenuation because it is much simpler to obtain attenuation due to rain and power arch supply PAs. The attenuation resulted from either rain or power arch supply are measured independently. The obtained output were statistically analyzed to calculate the total attenuation composite (PAs with rain) time series synthesizer. A parallel to that, attenuation resulted from power arch supply were compared with noise floor level. This comparison is useful to validate attenuation due to power arch supply measurement. Moreover, rain attenuation measured for stationary scenario performed in three locations in Malaysia. These measurements reflects the effect of rain on communication systems. For mobile scenario, the effect of heavy rainfall on communication system is measured when high speed train is used. Its shown that the rain attenuation is high in stationary scenario compared to mobile scenario.

1.6 Study Module

The summary of general steps studied in this research is illustrated in Figure 1.2.

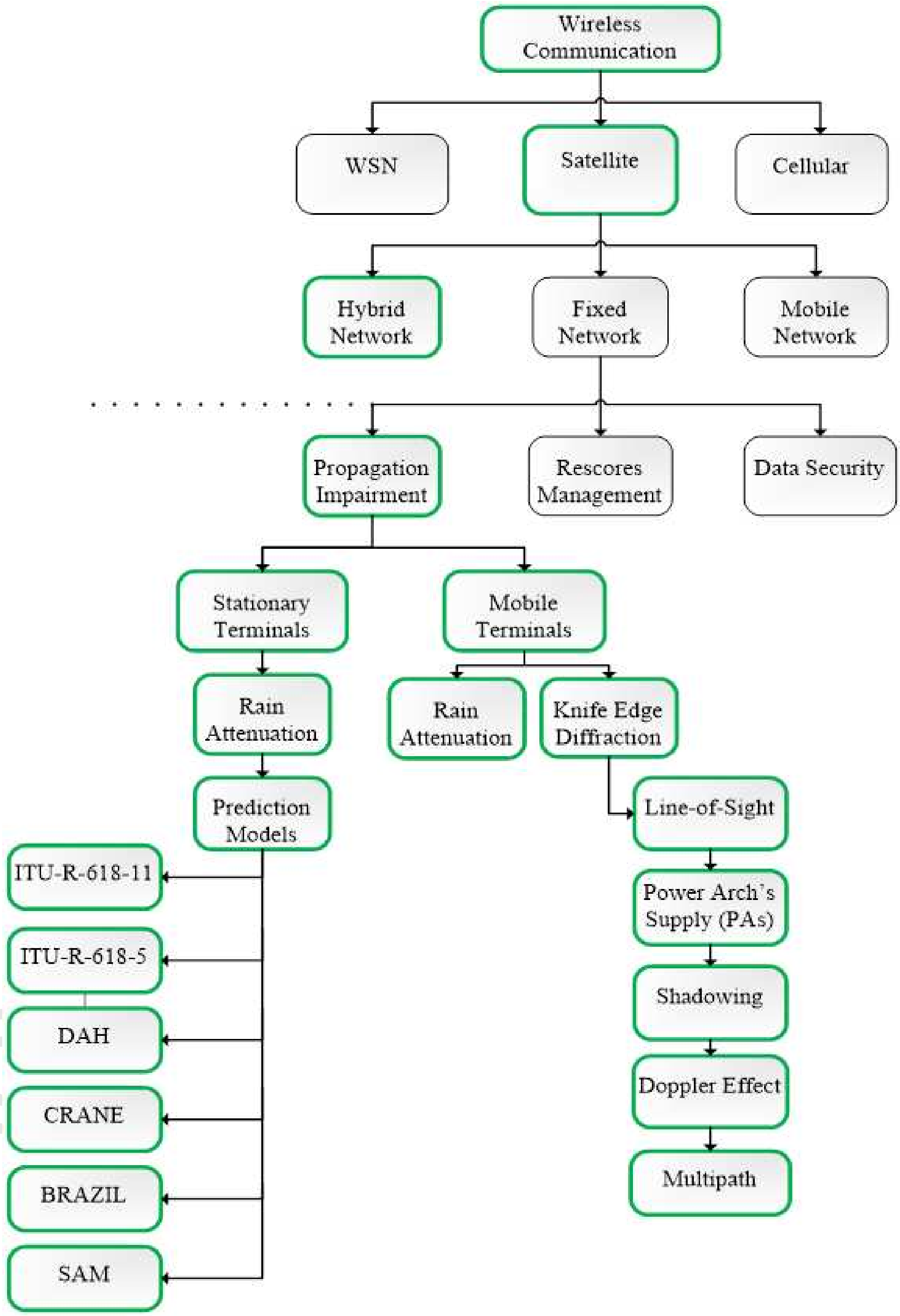

Figure 1.2 Study Module

1.7 Thesis Organization

The content of this thesis includes a complete literature review of the necessary information needed to carry out the research. The thesis is divided into 5 parts as described below:

Chapter 1 is about a brief introduction on the background and the problem statement which motivated the research to be conducted.

Chapter 2 discusses research regarding rain and knife-edge diffraction in tropical region. It also describes how rain attenuates radio-wave and some information about the existing rainfall rate, rain attenuation prediction models and knife-edge diffraction.

Chapter 3 focuses on the methodology of this research. The measurement of rain attenuation data and attenuation due to power arch supply are used for this study. Moreover, the instruments that are used for this type of experiments are also explained in this chapter.

Chapter 4 is about analysis of data. The rainfall rate, rainfall attenuation data and attenuation due to power arch supply obtained from experiment will be represented in graphical form with complete justifications. Furthermore, a comparison between the measured attenuation due to power arch supply, rainfall rate and rain attenuation are established with the existing models. Also, presents the comparison was done between existing models with the measured data in terms of percentage errors and RMS values is performed. The existing models was used for the prediction at different measurement site, to determine whether the model can be applicable to the tropical site are also discussed in details at this chapter.

Finally, Chapter 5 gives a summary of the work that has been performed. Contributions, and conclusions of the thesis, along with suggestions for future work are given in this chapter.

REFERENCES

Abdulrahman, A. Y., Rahman, T. A., Rahim, S. K. B. A., and Rafi Ul Islam, M. (2010). A new rain attenuation conversion technique for tropical regions. *Progress In Electromagnetics Research B*, 26:53–67.

Ahmad, K. A., Jones, W. L., and Kasparis, T. (2004). Application of quikscat radiometer rain rates to near-real-time global precipitation estimates: a global precipitation mission pathfinder. In *Geoscience and Remote Sensing Symposium, 2004. IGARSS'04. Proceedings. 2004 IEEE International*, volume 5, pages 3547–3550. IEEE.

Al-Jumaily, A. H., Sali, A., Ismail, A., Mandeep, J., and Al-Saegh, A. M. (2013). Performance analysis of rain attenuation at ku-band in malaysia. In *Space Science and Communication (IconSpace), 2013 IEEE International Conference on*, pages 160–163. IEEE.

Alasseur, C., Núñez, A., Fontán, F., Husson, L., Fiebig, U.-C., and Mariño, P. (2005). Two approaches for effective modelling of rain-rate time-series for radiocommunication system simulations. *Space communications*, 20(1):69–83.

Alwarfalli, A. A. (2005). *The effect of rainrate modeling for the prediction of satellite propagation in Malaysia*. PhD thesis, Universiti Teknologi Malaysia, Faculty of Electrical Engineering.

Arapoglou, P.-D., Liolis, K. P., and Panagopoulos, A. D. (2012). Railway satellite channel at ku band and above: Composite dynamic modeling for the design of fade mitigation techniques. *International Journal of Satellite Communications and Networking*, 30(1):1–17.

Barclay, L. W. (2003). *Propagation of radiowaves*, volume 502. Iet.

Barry, R. G. and Chorley, R. J. (2009). *Atmosphere, weather and climate*. Routledge.

Booth, E., Mount, J., and Viers, J. H. (2006). Hydrologic variability of the cosumnes river floodplain. *San Francisco Estuary and Watershed Science*, 4(2).

Bousquet, M., Castantet, L., Féral, L., Pech, P., and Lemorton, J. (2003). Application of a model of spatial correlated time-series into a simulation platform of adaptive resource management for ka-band obp satellite systems. In *Proceedings of the 3rd COST 280 Workshop*. Citeseer.

Bryant, G., Adimula, I., Riva, C., and Brussaard, G. (2001). Rain attenuation statistics from rain cell diameters and heights. *International journal of satellite communications*, 19(3):263–283.

Capsoni, C. and Luini, L. (2008). 1-min rain rate statistics predictions from 1-hour rain rate statistics measurements. *Antennas and Propagation, IEEE Transactions on*, 56(3):815–824.

Chebil, J. and Rahman, T. (1999). Development of 1 min rain rate contour maps for microwave applications in malaysian peninsula. *Electronics Letters*, 35(20):1772–1774.

Cioni, S., Niebla, C. P., Granados, G. S., Scalise, S., Vanelli-Coralli, A., and Castro, M. A. V. (2007). Advanced fade countermeasures for dvb-s2 systems in railway scenarios. *EURASIP Journal on Wireless Communications and Networking*, 2007(2):15–15.

Crane, R. K. (1980). Prediction of attenuation by rain. *Communications, IEEE Transactions on*, 28(9):1717–1733.

Crane, R. K. (1982). A two-component rain model for the prediction of attenuation statistics. *Radio Science*, 17(6):1371–1387.

Crane, R. K. (1996). *Electromagnetic wave propagation through rain.* Wiley New York.

Crane, R. K. (2003). *Propagation handbook for wireless communication system design.* CRC press.

Da Silva Mello, L., Pontes, M., De Souza, R., and Garcia, N. P. (2007). Prediction of rain attenuation in terrestrial links using full rainfall rate distribution. *Electronics Letters*, 43(25):1442–1443.

Dairaku, K., Emori, S., and Oki, T. (2004). Rainfall amount, intensity, duration, and frequency relationships in the mae chaem watershed in southeast asia. *Journal of Hydrometeorology*, 5(3):458–470.

Das, S., Maitra, A., and Shukla, A. K. (2011). Melting layer characteristics at different climatic conditions in the indian region: Ground based measurements and satellite observations. *Atmospheric Research*, 101(1):78–83.

Data, P. (2003). Prediction methods required for the design of earth-space telecommunication systems. *Recommendation P. 618-8, ITU-R P Sers.*

Dissanayake, A., Allnutt, J., and Haidara, F. (1997). A prediction model that combines rain attenuation and other propagation impairments along earth-satellite paths. *Antennas and Propagation, IEEE Transactions on*, 45(10):1546–1558.

Emiliani, L. D., Luini, L., and Capsoni, C. (2009). Analysis and parameterization of methodologies for the conversion of rain-rate cumulative distributions from various integration times to one minute. *Antennas and Propagation Magazine, IEEE*, 51(3):70–84.

Faria, G., Henriksson, J. A., Stare, E., and Talmola, P. (2006). Dvb-h: Digital broadcast services to handheld devices. *Proceedings of the IEEE*, 94(1):194–209.

Green, H. E. (2004). Propagation impairment on ka-band satcom links in tropical and equatorial regions. *Antennas and Propagation Magazine, IEEE*, 46(2):31–45.

Mandeep, J. (2009). Slant path rain attenuation comparison of prediction models for satellite applications in malaysia. *Journal of Geophysical Research: Atmospheres (1984–2012)*, 114(D17).

Mandeep, J. (2011). Rain rate analysis and total rain accumulation in the north of malayan peninsula. *annals of telecommunications-annales des télécommunications*, 66(5-6):377–381.

Mandeep, J., Hassan, S., and Ain, M. (2008a). Rain rate conversion for various integration time for equatorial and tropical climates. *International Journal of Satellite Communications and Networking*, 26(4):329–345.

Mandeep, J., Hassan, S., and Tanaka, K. (2008b). Rainfall measurements at ku-band satellite link in penang, malaysia. *IET microwaves, antennas & propagation*, 2(2):147–151.

Mandeep, J., Nalinggam, R., and Bt Ismail, W. (2011). Analysis of rain attenuation models for south east asia countries. *Journal of Infrared, Millimeter, and Terahertz Waves*, 32(2):233–240.

Matricciani, E. (2008). Global formulation of the synthetic storm technique to calculate rain attenuation only from rain rate probability distributions. In *Antennas and Propagation Society International Symposium, 2008. AP-S 2008. IEEE*, pages 1–4. IEEE.

Mohammed, H., Sibley, M., and Mather, P. (2012). Investigation of doppler effects on high mobility ofdm-mimo systems with the support of high altitude platforms (haps). In *Journal of Physics: Conference Series*, volume 364, page 012048. IOP Publishing.

Mohorčič, M., Javornik, T., Lavrič, A., and Jelovčan, I. (2005). *Selection of broadband communication standard for high-speed mobile scenario.*

Morello, A. and Mignone, V. (2006). Dvb-s2: the second generation standard for satellite broad-band services. *Proceedings of the IEEE*, 94(1):210–227.

Morlet, C., Alamanac, A. B., Gallinaro, G., Erup, L., Takats, P., and Ginesi, A. (2007). Introduction of mobility aspects for dvb-s2/rcs broadband systems. *Space Communications*, 21(1):5–17.

Moupfouma, F. (2009). Electromagnetic waves attenuation due to rain: A prediction model for terrestrial or los shf and ehf radio communication links. *Journal of Infrared, Millimeter, and Terahertz Waves*, 30(6):622–632.

Ojo, J. and Sarkar, S. (2008). Rainfall dynamics over two indian tropical stations for radio communication. *International Journal of Infrared and Millimeter Waves*, 29(7):649–656.

Omotosho, T. and Oluwafemi, C. (2009). Impairment of radio wave signal by rainfall on fixed satellite service on earth–space path at 37 stations in nigeria. *Journal of Atmospheric and Solar-Terrestrial Physics*, 71(8):830–840.

Pahlavan, K. (2011). *Principles of wireless networks: A unified approach.* John Wiley & Sons, Inc.

Pan, Q., Allnutt, J., and Tsui, C. (2006). Evidence of atmospheric tides from satellite beacon experiment. *Electronics Letters*, 42(12):706–707.

Pan, Q. W., Allnutt, J. E., and Tsui, C. (2008). Evaluation of diversity and power control techniques for satellite communication systems in tropical and equatorial rain climates. *Antennas and Propagation, IEEE Transactions on*, 56(10):3293–3301.

Paraboni, A., Martellucci, A., and Polonio, R. (1997). A probabilistic model of rain and ice depolarisation based on the experimental estimation of the atmospheric ice content. In *Microwave and Optoelectronics Conference, 1997. Linking to the Next Century. Proceedings., 1997 SBMO/IEEE MTT-S International*, volume 2, pages 707–712. IEEE.

Pardo, J. R., Cernicharo, J., and Serabyn, E. (2001). Atmospheric transmission at microwaves (atm): an improved model for millimeter/submillimeter applications. *Antennas and Propagation, IEEE Transactions on*, 49(12):1683–1694.

Pestoriza, V., Nunez, A., Marino, P., Fontán, F., and Fiebig, U. (2010). Rain-cell identification and modeling for propagation studies from weather radar images. *Antennas and Propagation Magazine, IEEE*, 52(5):117–130.

Pontes, M., de Miranda, E., da Silva Mello, L., de Souza, R., and de Almeida, M. (2003). Rainfall-induced satellite beacon attenuation in tropical and equatorial regions. *Electronics Letters*, 39(11):874–876.

Ramachandran, V. and Kumar, V. (2004). Rain attenuation measurement on ku-band satellite tv downlink in small island countries. *Electronics Letters*, 40(1):49–50.

Rec, I. (2003). P. 311-11, acquisition, presentation and analysis of data in studies of tropospheric propagation.

Recommendation, I. (1994). 837-1. *Characteristics of precipitation for propagation modelling.*

Recommendation, I. (1997). 618-5,propagation data and prediction methods required for the design of earth-space telecommunication systems. *ITU-R Recommendations.*

Recommendation, I. (2013a). 618-11,propagation data and prediction methods required for the design of earth-space telecommunication systems. *ITU-R Recommendations.*

Recommendation, I. (2013b). 676-10: Attenuation by atmospheric gases.

Recommendation, I. (2013c). 678-2," characterization of the natural variability of propagation phenomena.

Recommendation, I. (2013d). 839-4. *Rain height model for prediction methods.*

Sauvageot, H., Mesnard, F., and Tenório, R. S. (1999). The relation between the area-average rain rate and the rain cell size distribution parameters. *Journal of the atmospheric sciences*, 56(1):57–70.

Scalise, S., Mura, R., and Mignone, V. (2006). Air interfaces for satellite based digital tv broadcasting in the railway environment. *Broadcasting, IEEE Transactions on*, 52(2):158–166.

Sciascia, G., Scalise, S., Ernst, H., and Mura, R. (2003). Statistical characterization of the railroad satellite channel at ku-band. In *Proceedings of the International Workshop of Cost Actions 272 and*, volume 280.

Singh, M. (2007). Equatorial rainfall measurement on ku-band satellite communication downlink. *Progress In Electromagnetics Research*, 76:195–200.

Singh, M. and Allnutt, J. E. (2007). Rain attenuation predictions at ku-band in south east asia countries. *Progress In Electromagnetics Research*, 76:65–74.

Stutzman, W. and Dishman, W. (1982). A simple model for the estimation of rain-induced attenuation along earth-space paths at millimeter wavelengths. *Radio Science*, 17(6):1465–1476.

Suresh, S. and Madham, M. (2011). An experimental study of rain attenuation at ku band frequencies for an earth space path over chennai. *Proceedings of International Journal of Computer Application*, pages 1–5.

Tham, M. (1998). Dealing with measurement noise. *University of Newcastle, Londres (1998 b).*

Thorp, J. H., Thoms, M. C., and Delong, M. D. (2011). railway satellite channel at ku band and above: composite dynamic modeling for the design of fade mitigation techniques. *International Journal of Satellite Communications and Networking*.

Van De Kamp, M. M. (2003). Statistical analysis of rain fade slope. *Antennas and Propagation, IEEE Transactions on*, 51(8):1750–1759.

Wallace, J. M. and Hobbs, P. V. (2006). *Atmospheric science: an introductory survey*, volume 92. Academic press.

Yang, S. and Smith, E. A. (2006). Mechanisms for diurnal variability of global tropical rainfall observed from trmm. *Journal of climate*, 19(20):5190–5226.

Zhou, Z., Li, L.-W., Yeo, T.-S., and Leong, M.-S. (2000). Cumulative distributions of rainfall rate and microwave attenuation in singapore's tropical region. *Radio Science*, 35(3):751–756.