RAIN ATTENUATION TIME SERIES SYNTHESIZER FOR SATELLITE LINK IN TROPICAL / EQUATORIAL REGION

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Alhamdullah that Allah give the power to finish this work. This project is dedicated to my parents, Mr.Omar Al-Amodui & Ms. Fatima Bin Afif ,,, to my brothers & sisters ,,, to my family ,,, and all my friends ,,, Thank you

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ABSTRACT

This paper presents and implements the Tropospheric attenuation time series synthesizer ITU-R P.1853 recommendation to simulate the time series rain attenuation of the propagation channel particularly in tropical/equatorial region. The accuracy and applicability of this recommendation will be validated by comparing long-term rain attenuation statistics produced with the currently available literature results. The primary objective of this paper is to investigate the performance of the rain attenuation time series synthesizer in terms of first and second order statistics (Rain Attenuation and Fade Duration). The 1st order statistic will produced by using to different values of rain rate for ITU-R 837 and the data of 3 years collected in Kuala Lumpur. Then comparison will be obtained for both ITU-R 1853 and ITU-R 618 to see the difference in 1st order statistic between them. Also, this thesis will show the effect of different elevation angles by using two different satellites (MEASAT 3A and TELSTAR 18). Moreover, the effect of different rain rate for two cities in Malaysia (Johor Bahru in the south, and Kedah in the north) will be investigated. On the other hand, 2nd order statistic fade duration will be observed in two ways. The first one is, to investigate the number of event of attenuation that occur during the rain for three different threshold attenuation points (4dB, 8dB and 12dB). The second one is, to investigate the probability of fade duration occurrence in Kuala Lumpur for two different satellites (MEASAT 3A and TELSTAR 18), and two threshold points (6dB and 10dB) for each satellite.

ABSTRAK

Kertas kerja ini membentangkan dan melaksanakan ”pengecilan siri masa Tropospheric pensintesis” ITU-R P.1853 syor kepada simulasi hujan siri masa pengecilan saluran penyebaran khususnya di rantau tropika / khatulistiwa. Ketepatan dan kesesuaian cadangan ini akan disahkan dengan membandingkan statistik gangguan hujan jangka panjang yang dihasilkan dengan hasil kesusasteraan yang ada sekarang. Objektif utama kertas ini ialah untuk menyiasat prestasi pensintesis siri gangguan hujan masa dari segi statistik tertib pertama dan kedua (Hujan pelemahan dan Duration luntur). Statistik 1 pesanan akan dihasilkan dengan menggunakan nilai-nilai yang berbeza kadar hujan ITU-R 837 dan data 3 tahun yang dikutip di Kuala Lumpur. Kemudian perbandingan akan diperolehi bagi kedua-dua ITU-R 1853 dan ITU-R 618 untuk melihat perbezaan dalam 1 perintah statistik antara mereka. Juga, tesis ini akan menunjukkan kesan sudut ketinggian yang berbeza dengan menggunakan dua satelit yang berbeza (MEASAT 3A dan Telstar 18). Selain itu, kesan kadar hujan yang berbeza untuk dua bandar di Malaysia (Johor Bahru di selatan, dan Kedah di utara) akan disiasat. Sebaliknya, statistik bagi 2 pudar tempoh akan diperhatikan dalam dua cara. Yang pertama, untuk menyiasat beberapa peristiwa yang pengecilan yang berlaku semasa hujan untuk tiga mata yang berbeza pengecilan ambang (4dB, 8dB dan 12dB). Yang kedua, untuk menyiasat kebarangkalian berlakunya tempoh pudar di Kuala Lumpur bagi dua satelit yang berbeza (MEASAT 3A dan Telstar 18), dan dua mata ambang (6dB dan 10dB) untuk setiap satelit.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

FMT	–	Fade Mitigation Techniques
ITU	–	International Telecommunication Union
QoS	–	Quality of Service
M-B	–	Maseng-Bakken
E M-B	–	Enhanced Maseng-Bakken
RR	–	Rain Rate
ATPC	–	Adaptive Transmit Power Control
CCDF	–	Complementary cumulative distribution function
	–	

LIST OF SYMBOLS

λ	–	Wavelength
α	–	Alpha
β	–	Beta describes the time dynamics
L_s	–	slant path length
γ_R	–	Specific attenuation
C/N	–	Carrier to Noise ratio
A_{rain}	–	Rain Attenuation
p_0	–	State of no rain
p_1	–	State of rain
p_{10}	–	Transition from state rain to state no rain
m	–	mean of the log-normal rain attenuation distribution
σ	–	standard deviation of the log-normal rain attenuation distribution
A_{offset}	–	offset that adjusts the time series to match the probability of rain
h_R	–	Rain height
h_o	–	Height of earth station above the sea level
θ	–	Elevation angle
L_G	–	horizontal projection
$R_{0.01}$	–	Rainfall rate
$r_{0.01}$	–	horizontal reduction factor
f	–	Operation frequency
$v_{0.01}$	–	vertical adjustment factor
L_E	–	effective path length

$A_{0.01}$	–	The predicted attenuation exceeded for 0.01 of an average year
φ	–	latitude of the earth station
	–	

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

In tropical and equatorial areas, the terrestrial telecommunications infrastructure is less developed than in temperate regions and there is a strong need to implement satellite communication systems in the next few years. These systems have the advantage of serving wide regions with a short deployment time and the possibility to reach a large market size for economic profitability [1]. With the various frequency bands as shown in Table 1.1, C-band is unattractive because the deployment of new systems with small terminals is incompatible with the large antennas required to protect the existing systems [2]. So, Ku band is required in this area, and in future toward Ka band.

Table 1.1: Frequency bands

Frequency band	Range of frequencies
L band (used by mobile)	1.6/1.4 GHz
C - band	6/4 GHz
X - band (used by Military only)	8/7 GHz
Ku - band	14/12 GHz
Ka - band	30/20 GHz
V - band	50/40 GHz

Rain attenuation is the predominant signal impairment on satellite-earth communications above 10 GHz as clarify in Figure 1.1 [3]. The fade margin, that is, the system gain insuring the necessary Quality of Service (QoS) against various transmission and other impairments, must be significantly increased to compensate for the severe signal fading occurring at frequencies above 10GHz. The larger fade margins required are not feasible either technically or economically [4]. Under these conditions, appropriate fade Mitigation technique (FMT) must be adopted, because of Enhancing a satellite system with a FMT leads to realistic fade margins both economically and technically.

Figure 1.1: Effect of Rain on the Satellite Link

Current trend of research in propagation channel modelling is to develop a Fade Mitigation Techniques (FMT) control algorithm that based on the detection of real time propagation impairment to compensate the fade in real time. To design and optimize FMT, the knowledge of the spatio-temporal dynamic behaviour of the propagation channel is required. This lead to the development of time series synthesizer that capable to reflect both the long and short-term dynamics of signal attenuation due to rain. Several time-series synthesizer has been developed few years back and still ongoing research topic for fixed satellite services.

In the absence of experimental propagation data for every possible Earth-Space configuration, the synthesis of rain attenuation time series becomes an interesting solution to allow for the reproduction of the long-term dynamic characteristics of rain attenuation [2]. This need can be fulfilled by the introduction of time series of propagation impairments in system simulation [5], by using of climatological characteristics and geometrical, and radiowave parameters of the link.

ITU-R P.1853 recommendation released on the year 2009 provided one of the most latest and comprehensive method to synthesize rain attenuation time series. This model developed from the Enhanced Maseng-Baken model by ONERA/CNES, France. Further development and validation of this model would be crucial steps to make the model work globally. This is particularly true for the tropical and equatorial region that exhibit significantly higher rainfall rate with regards to temperate region.

Also, the fade duration of the rain attenuation event is considered in the second order statistic. Recommendation ITU-R 1623 will concentrate in this field. Fade duration and fade slope statistics are used to describe the dynamic behavior of attenuation experienced by terrestrial and satellite radio links. They provide essential information for the design of fade mitigation techniques such as up-link power control, adaptive coding and modulation, and data throughput reduction.

1.2 Problem Statement

The paper started with the stated limitations below which effect on the studying of the link propagation behaviour. So the first problem that be noted in this research is that, the existing experimental results for link behaviour are just for specified locations, satellite and elevation angles. While the second problem can be noted in the thesis is that, study of the link behaviour for rain attenuation require long time (years) to get exact results. Finally, the last point can be summarized in the research is that, there are no sufficient information about satellite link behaviour and impairments in tropical and equatorial region, especially with respect to rain attenuation.

1.3 Objectives

The objectives and goals of this paper can be briefly summarized in the following points:

- To investigate the performance of the rain attenuation time series synthesizer currently included in recommendation ITU-R P.1853 (EM.B) in terms of firs statistic for Measat 3A and Telstar 18 satellites.
- To investigate the second order statistics fade duration ITU-R P.1623 in equatorial Malaysia to verify the QoS design.
- To investigate the impact of low elevation angle with respect to rain attenuation time series performance in equatorial area, and also the effect of local rain rate for different locations.

1.4 Scope

This project will be divided into four phases, they are described as follows:

- This study will concentrate on ITU-R 1853 Enhanced Masang-Bakken model, since its widely used, and it is recommended by many studies.
- Provide crucial information for the calculation of fade duration, to improve the quality and reliability of service.
- Observe the performance of time series synthesizer rain attenuation on the low elevation angle.

1.5 Organization of thesis

At the beginning, chapter one shows the introduction of the time series synthesizer rain attenuation, with take into account the discussion about the different of frequency bands, and the effect of the rain on the frequencies above than 10 Ghz, such as Ku and Ka bands. Also, this chapter talks about the definition of second order statistic fade duration. Then in will highlight the problem statement of the thesis, objectives and scopes.

While in chapter two, the literature review of the thesis will be stated. First, after the introduction, it will talk about the rain and the variations of rainfall rates, even more; it will show the rain zone map. Later, it will give a brief description about time series. After that, it will talk secondly about the fade mitigation techniques and it will give a definition about each method like Power Control, adaptive Methods, diversity and fading Detection. Then, time series synthesizer models will explain briefly by mentioned all models and its parameters such as Maseng-Bakken mode, Enhanced Maseng-Baken model and two state markov chain models (Macroscopic and Microscopic).

After that, the model which will be used in the simulation of this result (Enhanced Maseng-Bakken model) which was recommended and proposed by International Telecommunication Union Recommendation ITU-R P.1853 will be briefly described and discussed. Also, the reasons of chosen the Enhance Maseng-Bakken model will be mentioned. Lastly, the second order statistics fade duration will covered in details according to the probability and number of event for different satellites and different locations inside Malaysia.

Chapter three will talk about the methodology of the research and how the thesis had been organized and how the data had collected from IEEE, ITU-R recommendations and other resources to write the literature review and later to create a data bank for how to extract the parameters of the simulation work. Also, it will cover how the material and parameters that had been investigated for both recommendations ITU-R P1853 and ITU-R P. 1623.

Chapter four will cover the results and the discussion of the results which had obtained by using matlab software. Such as, the comparison between the rain rate in both ITU-R 837 and the data collected for 3 years in Kuala Lumpur. Also, the first order statistics rain attenuation by using both recommendations; ITU-R 1853 and ITU-R 1623, and then, to make a comparison between both recommendations to see the performance variation.

Moreover, the effect of the different elevation angles by fixing the location of earth station in Kuala Lumpur, and use two different satellites (MEASAT-3A and TELSTAR-18) with different elevation angle. Then, it will show the effect of local rain rate in the rain attenuation values for different satellites and different locations in Malaysia (Kedah in the north part of Malaysia, and Johor Bahru in the south part). Finally, it will show the results of the second order statistics fade duration according to the number of fade events and the probability of fade occurrence due to the rain attenuation, by using different threshold points and two different satellites.

Chapter five will talk about the conclusion of the thesis according to the result which had been obtained. Also, it will list the point that could be covered in future work for the other research.

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