RAIN MODELS FOR THE PREDICTION OF FADE DURATION AT MILLIMETER WAVELENGTHS

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"To my beloved mother, father, fiancé and family…"

Thank you.

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ABSTRACT

The planning of radio communications system requires an estimate of the average annual outage due to fading, which at millimeter wavelengths, is generally dominated by the effects of rain attenuation. Current ITU-R recommendations provide algorithm for estimating the exceedance static of rain-induced attenuation on terrestrial links. Another factor of interest, not currently covered by ITU-R recommendations is the distribution of the durations of rain fades. Hence this project involved an extensive review on the available models describing annual rain fade distributions on line-of-sight links. Also, analysis on the rain attenuation data conducted on an experimental 350m, and 38GHz in frequency in UTM campus for 1 year will be used to obtain information on the rain fade statistic. Previous researches pointed out that the distribution of the durations of rain events at different intensities is more fundamental than distributions of link fades. Thus, this project aim is to establish an expression for the average number of events per year of rain intensity greater than a given threshold. This could be achieved from the detail analysis of the 38GHz link signal level profile database. Thus, the rain fade statistic describing annual rain fade distributions on line-of-sight could be developed. To predict rain attenuation on complex multi hop or route diverse links, it is necessary to have a statistical representative of rainfall in time and space, which is accurate over wide ranges of spatial and temporal scales. Various available statistical models will be used to demonstrate the influence of the developed rain fade statistic when applied for more complex microwave links.

ABSTRAK

Pada masa kini, perkembangan dalam bidang telekomunikasi adalah amat memberangsangkan. Untuk menghasilkan system telekomunikasi radio, perkara penting yang amat dititikberatkan ialah kesan isyarat radio terhadap hujan. Di mana seperti yang kita sedia maklum, bagi isyarat yang lebih daripada 10 GHz, kesan hujan terhadap isyarat ini adalah sangat tinggi. Dengan itu ITU-R telah memperkenalkan algorithm bagi menganggarkan kesan hujan ini. Tetapi ada satu lagi faktor yang tidak kelaskan oleh ITU-R, iaitu masa semasa isyarat ini menjadi lemah disebabkan oleh kesan hujan. Oleh itu, projek ini akan merangkumi analisis terhadap data yang diamabil di UTM kampus bagi tempoh 1 tahun iaitu pada 1999, 350m, 38GHz serta mengenal pasti model kesan hujan terhadap isyarat yang telah dicadangkan oleh beberapa penyelidik. Model hujan yang sesuai dengan data yang sedia ada akan diambil sebagai rujukan dan pemalarnya akan diubah mengikut kesesuaian data hujan di Malaysia. Tujuan projek ini dilaksanakan adalah untuk mencari nilai purata ‘event’ ini berlaku bagi tempoh setahun. Ini membolehkan kita membuat ramalan berapa lama isyarat akan menjadi lemah bergantung kepada jumlah hujan yang turun. Maka dengan itu sebuah model yang baru akan dihasilkan untuk meramalkan kesan hujan terhadap isyarat radio ini.

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LIST OF ABBREVIATIONS

DTH	-	Direct To Home
FMT	-	Fade Mitigation Technique
MEASAT	-	Malaysia East Asia Satellite
WCC	-	Wireless Communication Centre
AGC	-	Automatic Gain Control
UTM	-	Universiti Teknologi Malaysia
CD	-	Cumulative Distribution
ITU-R	-	International Telecommunications Union - Radiocommunications
sec	-	seconds

LIST OF SYMBOLS

f	-	frequency
φ	-	elevation angle
A	-	attenuation
σ	-	standard deviation
γ	-	power law distribution
Dt	-	boundary time
k	-	fraction time
Q	-	standard cumulative distribution function
N	-	number of fade events
R	-	rain rate
r	-	path reduction factor
L	-	path length
V	-	AGC value (volt)
$R_{0.01}$	-	rain intensity at 0.01% of time
dBm	-	decibel meter

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CHAPTER I

INTRODUCTIONS

1.1 Project Background

The planning of radio annual outage due to fading at millimeter wavelengths is generally dominated by the effects of rain attenuation. This is usually determined from long-term statistic of annual rainfall rates, applying the procedures in ITU-R Recommendation P.530 for terrestrial links.

In the design of a variety of telecommunication systems, the dynamic characteristics of fading due to atmospheric propagation are of concern to optimize system capacity and meet quality and reliability criteria. Examples are fixed networks that include a space segment and systems that apply fade mitigation or resource sharing techniques.

Several temporal scales can be defined, and it is useful to have information on fade slope, fade duration and interfade duration statistics for a given attenuation level (Figure 1.1).

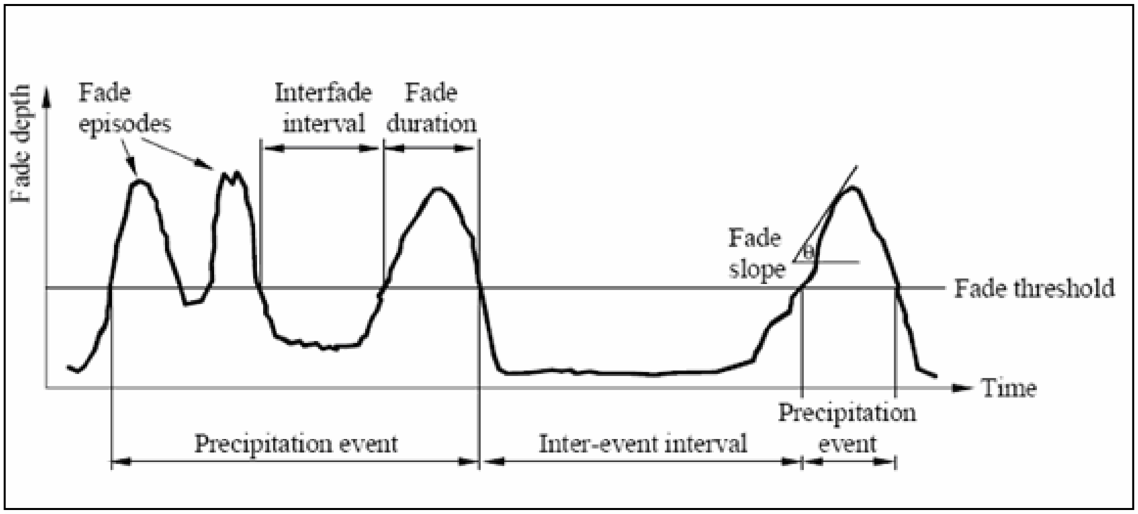

Figure 1.1: Features characterizing the dynamic of fade events [1]

Fade duration is defined as the time interval between two crossings above the same attenuation threshold whereas interfade duration is defined as the time interval between two crossings below the same attenuation threshold. Fade slope is defined as the rate of change of attenuation with time. Of particular interest in the context of availability criteria is the distinction between fades of shorter and longer duration than 10 s. Knowledge of the distribution of fade duration as a function of fade depth is also a prerequisite for the application of risk concepts in the provision of telecommunication services.

In addition, information about the expected fade slope is essential to assess the required minimum tracking rate of a fade mitigation system.

1.2 Problem Statement

Nowadays, the advancement in microwave communication technologies especially in telecommunication and broadcasting has resulted in congestion for frequencies below 10GHz. This has forced microwave designers to look for higher frequencies. Unfortunately for the frequencies that greater than 10GHz, rain become the main factor of attenuation especially for tropical and equatorial countries that experience high rainfall rate throughout the year such as in Malaysia. Where is for the frequencies above 10GHz, it will lead to outages that compromise the availability and quality of service, making this one of the most critical factors in satellite link design. Thus, in some cases the use of suitable compensation techniques to counter excessive attenuation will be needed to maintain reliable system operation. The proper design of fade mitigation techniques on satellite links requires not only knowledge of long-term statistics, but also of second-order statistics describing the dynamic behavior of attenuation, such as duration of fades, duration between fades and fade rate. So due to this circumstance it is important to have a predication of fade duration.

Usually, fade duration statistics are presented as conditional distributions of the number of fades exceeding certain durations, given that specified fade threshold has been exceeded. This representation provides information on the number of outages and system availability due to propagation on a link, given a fade margin and an availability specification.

1.3 Objective

The main objective of this project is to estimate of the average number of events per year of rain attenuation greater than a given threshold. As we know, the cumulative probability distribution of the system (take Astro as an example) will down for one year is about 0.01%. This downtime is equal to 52mins/year that the signal will drop due to the attenuation of rain. In this case we don't know the exact number of events occur per year, how much the signal drop and also the duration for one event occurs. Hence, this project is expected to answer all of the questions stated previously.

1.4 Scope Of Project

This project will involve an extensive review on the available models describing annual rain fade distribution on line-of-sight links. There are many fade duration models that was published in order to predict the rain fade duration. The examples of the published prediction models of fade duration are;

- ITU-R Model [1]
- Chris J Gibbins and Kevin S Paulson [2]
- Zsolt Kormanyos/ Lena Pedersen/ Cyril Sagot/ Janos Bito [3]
- Mopfouma [4]
- A two component rain model [5]

Details on ITU-R Model [1], Chris J Gibbins and Kevin S Paulson [2] and Zsolt Kormanyos/ Lena Pedersen/ Cyril Sagot/ Janos Bito [3] will be discussed in the next chapter.

Secondly, do analysis on the available rain attenuation data in UTM. This data was conducted on an experimental 350m, 38GHz by Wireless Communication Center (WCC) [6]. At first, the purpose of these rain attenuation data is to produce cumulative distribution (CD) of rain attenuation data. And for the purpose of this project, these data will be used to obtain information on the rain fade statistics.

This rain fade statistics will be developed by using Matlab software. The result from this rain fade statistics will be used to compare with the available empirical models. The best empirical models that suit to the obtained rain fade statistic will be adopted as rain fade model in Malaysia.

1.5 Importance Of The Project

Fade duration is an important parameter to be taken into account in system design for several reasons;

- System outage and unavailability: fade duration statistics provide information on number and duration of outages and system unavailability due to propagation on a given link and service;

- Sharing of the system resource: it is important from the operator's point-of-view to have an insight into the statistical duration of an event in order to assign the resource for other users. For example, nowadays most of the telecommunication systems are based on bandwidth on demand. In this case, when signal is dropped then we must assign small bandwidth to users in order to make sure that C/N

(Carrier to Noise ratio) is high. If not, user will no longer receive any signal during that event;

- FMT (Fade Mitigation Technique): fade duration is of concern to define statistical duration for the system to stay in a compensation configuration before coming back to its nominal mode. This FMT will be discussed in more detail later;

- System coding and modulation: fade duration is a key element in the process of choosing forward error correction codes and best modulation schemes; for satellite communication systems, the propagation channel does not produce independent errors but blocks of errors. Fade duration impacts directly on the choice of the coding scheme (size of the coding word in block codes, interleaving in concatenated codes, etc.).

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