ABSTRACT

Future satellite mobile communication systems designed for mobile user applications will use extremely high frequency carriers to provide more capacity and smaller equipment. At these frequencies, the extra attenuation due to rain is a primary cause of communications impairment on satellite-earth paths, especially above 10 GHz. Rain seriously influences the performance of a communications satellite link. The ability of radar to scan a wide area around the radar site and not just a particular path made it a very attractive for many types of investigations. Radar can be used to measure the rainfall rate indirectly. The main objective of this project is to find the rain rate, rain cell size distribution of local rain and compare the rain rate and rain cell size distribution with ITU-R recommendations. For this study, the data for 0.5^0 elevation angle and 0.5 km range bin is used by Plan Position Indicator (PPI) scan. This project gives the value of two important parameters in microwave or satellite link design. That is the rainfall rate ($R_{0.01}$) and the rain cell size ($D_{0.01}$) distributions. The results give an acceptable correlation with the international telecommunication union- radio communication sector (ITU-R) recommendations. The proposed rain rate distribution model can be used to determine the rain at the percentage of interest. This is useful for microwave link system planning and link budget estimation.

ABSTRAK

Masa depan satelit sistem komunikasi yang direka untuk aplikasi pengguna, pembekal khidmat akan menggunakan frekuensi sangat tinggi untuk menyediakan kapasiti yang lebih besar dan peralatan yang lebih kecil. Pada frekuensi-frekuensi ini, redaman tambahan kerana hujan adalah punca utama penurunan pada jalur komunikasi satelit-bumi, terutama frekuensi melebihi 10 GHz. Hujan lebat mempengaruhi prestasi saluran satelit komunikasi. Kemampuan radar untuk mengimbas wilayah yang luas di sekitar lokasi radar dan bukan hanya pusat tertentu membuatkan ia menjadi sangat menarik bagi pelbagai jenis penyelidikan. Radar boleh digunakan untuk mengukur tahap curah hujan secara tidak langsung. Tujuan utama projek ini adalah untuk mencari curah hujan, saiz sel hujan tempatan dan membandingkan curah hujan dan saiz sel hujan dengan cadangan ITU-R. Untuk kajian ini, data bagi sudut 0.5^0 dan 0.5 km bin rentang digunakan oleh sistem Plan Position Indicator (PPI) scan. Projek ini memberikan dua nilai parameter penting dalam ketuhar atau bentuk saluran satelit. Itu adalah peringkat curah hujan ($R_{0.01}$) dan saiz sel pengedaran hujan ($D_{0.01}$). Keputusan memberikan korelasi diterima dengan cadangan Sektor Kesatuan-Radio Komunikasi Telekomunikasi Antarabangsa (ITU-R). Model tingkat hujan yang dicadangkan boleh digunakan untuk menentukan hujan pada peratusan tertentu. Ia berguna untuk perancangan sistem perhubungan dan menilai anggaran perbelanjaan sistem perhubungan.

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LIST OF ABBREVIATIONS

ASCII	-	American Standard Code for Information Interchange
AZ	-	Azimuth angle (degree)
BB	-	Bright Band
CW	-	Continuous wave
DSD	-	Drop Size Distributions
EA	-	Elevation angle
EM	-	Electromagnetic
ISO	-	International Standard Organization
ITU-R	-	International telecommunication union – Radio communication sector
LOS	-	Line-of-site
PPI	-	Plan position indicator
PE	-	Permanent Echo
RADAR	-	Radio Detection And Ranging
RCS	-	Radar Cross Section
RHI	-	Range Height Indicator
RIU	-	Radar Interface Unit
RR	-	Resolution Range
SNR	-	Signal to Nose ratio
TRMM-PR	-	Tropical Rainfall Measuring Mission-Precipitations Radar
UK	-	United Kingdom
UTM	-	Universiti Teknologi Malaysia
VPR	-	Vertical profile of radar reflectivity
VRP	-	Vertical reflectivity profiles

σ_H - Backscatter cross section for horizontal polarization

σ_V - Backscatter cross section for vertical polarization

γ_g - Specific attenuation for atmospheric gases (dB/km)

γ_c - Specific attenuation for clouds (dB/km)

γ_p - Specific attenuation for precipitation (dB/km)

φ - Latitude of the earth-station location

ρ_{co} - Co-polar correlation

δco - Scattering differential phase

h_{bot} - Bright band region bottom height (km)

h_{peak} - Height of peak of bright band reflectivity

h_R - Rain height (km)

hT - Top border of bright band

h_{top} - Bright band region top height (km)

h_0 - 0°C isotherm height, peak of reflectivity

L - Losses of microwave measurement element

L_{DR}. - Linear depolarization ratio

N - Concentration of particles in certain size

$N(D)$ - The drop size distribution (DSD)

n - Complex index of refraction

$P_1(r)$ - Power transmitted in direction **r** (W)

$P_2(r)$ - Power transmitted by omni-directional antenna in direction **r** (W)

P_t - Transmitted power (W)

P_r - Received power (W)

R, r - Range, distance or radius (m)

Tx - Transmitter

V - Resolution volume (m^3)

W - Power density (W/m^2)

Z - Effective reflectivity factor (mm^6/m^3)

Z_{DR} - Differential reflectivity

Z_H - Reflectivity measured at horizontal polarization

Z_V - Reflectivity measured at vertical polarization

Z_e - Effective radar reflectivity factor (mm^6/m^3)

Z_{peak} - Peak of bright band reflectivity

Z_{rain} - Reflectivity of rain

Z_{snow} - Reflectivity of snow

Ω - Antenna solid angle

Φ_{DP} - Differential phase shift

η - Radar reflectivity ($m^2\ m^{-3}$)

λ - Wavelength (m)

τ - Pulse duration (second)

σ - Effective area of the radar target (m^2)

LIST OF SYMBOLS

A	-	Area (m^2)
A	-	Total Attenuation (in dB)
A_g	-	Geometric area
A_{eff}	-	Effective area (m^2)
AS_{in}	-	Inner average slope
AS_{out}	-	Outer average slope
BB_H	-	Radar bright-band height (km)
BB_{th}	-	Bright band thickness (km)
C_R	-	Radar calibration constant
c	-	Velocity of propagation (m/sec)
D	-	Diameter (m), size of particles
D_o	-	Outer diameter (m)
D_i	-	Inner diameter (m)
dBZ	-	dB $Z= 10 \log_{10} Z$
e	-	Relative dielectric constant
e_m	-	Dielectric constant of the medium
e_{in}	-	Dielectric constant of the inclusions or embedded particles
FH	-	Freezing height (km)
f	-	Fraction of the total particle volume
f	-	Frequency (Hz)
$G_t(r)$	-	Gain of the transmitted antenna in direction **r**
$G_r(r)$	-	Gain of the received antenna in direction **r**
$H (t-\tau)$	-	Impulse response of the radar receiver
h	-	Length of square-wave pulse in Radar
hB	-	Bottom border of bright band

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Wireless communication has seen a tremendous amount of growth. No doubt that the advancement in RF technology and the miniaturization of handheld devices has popularized the appeal of such devices among public and commercial users. Microwave links are an important part of telecommunication.

However, a major concern for microwave links is the attenuation due to rain. For a tropical country like Malaysia, rain occur almost yearound and in most instances, the rainfall rate is much higher when compared to temperate regions. Thus, a proper model based on local study is needed to predict the rainfall rate in order to estimate the rain attenuation. This information is useful for microwave applications such as microwave link budget planning.

The rain attenuation also can affects for path reliability. It contributes in power budget and fade margin considerations. Thus, it is very important to properly quantify rain attenuation. A rain event occurring in an area is not constant. Rain does angle with same azimuth from next 10 minutes until the end of level. When calculated the rain rate for all azimuths, the Matlab software can not start array from 0. Due to that, there were shifting in the azimuth angle by one from 1 to 360^o instead of 0 to 359^o. Add to that, from the radar specification will not read the first 4 Km. Also, only the 500 m range been where selected to be consider. The determination of the rain rate for 0.01 percent of the time or ($R_{0.01}$) comes from the fact that a good system must provide at least 99.99% reliability. Design and system engineers use this value to construct communications system such that the link is available for 99.99% of the time. Any communication system built with this value to ensure customer satisfaction. This project followed the ITU-R recommendation which estimated the rain rate for Malaysia is 120 mm/hr.

4- Calculate the rain cell size:

The step of this processing is loading the levklg.mat file generates during rainfall rate calculations. The processes to calculate the rain cell size ($D_{0.01}$) depend on level distance. After finish running the program, we can use the curve fit tool to get the result. The link budget for all wireless communication systems at Ku band frequencies and above should consider this novel computation for successful RF planning.

5- Compare the results:

Compare the results of rainfall rate and rain cell size with other research papers and International Telecommunication Union (ITU-R) recommendation.

Rain cell size distribution is also obtained from radar data. However, rain cell size distribution from radar data is limited to 500m integration size. This is due to the fact that the radar uses a range-bin size of 500m.

1.5 Project Methodology

1- Selecting data:

The study had been done according to one year tropical radar data, by selecting Kluang data considering the terrestrial path (elevation angle 0.5^o) and for each 500m range been.

2- Decoding data:

To decode the data must understand the ASCII Encoding mechanism. Sixteen characters that define the absolute levels and forty-nine characters that define the deviation encoding. The run length encoding is utilized to improve the compression of radials. A number occurring after a letter implies that the last encoded video level repeats for the next number of range bins. To do that, Matlab software had been applied on filtered data.

3- Calculate the rainfall rate:

The radar takes the data from azimuth angle 0^o up to 359^o for every 10 minutes. Program done to add the rain events which occur in each azimuth

Thus, the aim of this thesis is to find the profile of rain rate distribution inside a rain cell and to determine the rain cell size distribution of local rain.

1.3 Project Objective

The main objective of this project is to find the rain rate distribution and to determine the rain cell size distribution of local rain.

Comparisons the rain rate distribution and rain cell size with ITU-R recommendations. The radar data is obtained from the Kluang Radar Station of the Meteorological Department of Malaysia.

1.4 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.

Radar data gives the averaged rainfall rate for a range-bin size of 500m each. This rainfall data is used to calculate the rainfall rate, which is 4km to 20km path lengths. The radar data is obtained from the Kluang Radar Station of the Meteorological Department of Malaysia from November 2006 until March 2007.

A very important factor that affects path reliability is rain attenuation. It also contributes in power budget and fade margin considerations. Thus, it is very important to properly quantify rain attenuation. Due to the nature of rain events, a reduction factor is needed in order to calculate rain attenuation. A rain event occurring in an area is not constant. Rain does not distribute evenly in a region experiencing precipitation. Even though specific attenuation due to rain for a specific distance or per kilometer can be formulated; there arises a need to find a reduction factor to account for the non-uniformity of rain for larger distances. This is especially crucial in tropical regions as rain has been found to be more convective in nature rather than widespread. Tropical region also suffers heavier rainfall rates as compared to temperate regions.

To formulate the reduction factor, the experimental procedure would require several links with different path lengths to be set up in close proximity. However, this would be very difficult to be constructed. An alternative approach is to use radar data to obtain attenuation statistics for simulated links of various lengths. In addition, even after a proposed microwave link has been evaluated with regard to reliability, the calculations may show that it will not meet the required standards. Or a designer may want to improve the reliability of the telecommunication system. In this situation, mitigation techniques such as diversity may be employed.

One such technique is space diversity where an additional receiver may be constructed (Nor Hisham Khamis et al, 2000). By switching and/or combining the signals received by the two receivers, the reliability of the communication link is greatly increased. An important parameter to consider is site separation or the distance between the two receivers. When spacing is adequate between the two receivers, there should be little correlation between the two paths. Site separation or distance is used to determine the diversity improvement factor and diversity gain when employing diversity (ITU-R P.618-5, 1997). Knowing rain cell size distribution will help to determine site separation.

not distribute evenly in a region experiencing precipitation. There arises a need to find rain cell size distribution to account for the non-uniformity of rain for larger distances. This is especially crucial in tropical regions as rain has been found to be more convective in nature rather than widespread. Tropical region also suffers heavier rainfall rates as compared to temperate regions. To formulate the rain cell size distribution using rain gauges would requires many such devices to be installed. This would be very difficult and expensive. An alternative approach is to use radar data to obtain rain cell size statistics. The Meteorological Department of Malaysia operated several meteorological radars throughout the Malay Peninsular, Sabah and Sarawak. However, in this study, only the Kluang radar data, located in the southern part of the Malay Peninsular is utilized.

1.2 Problem Statement

Power budget and fade margin are important factors to be considered in designing microwave transmission systems. The world of telecommunication is very competitive such that when providing for a system, careful infrastructure planning is needed to avoid unnecessary costs.

Microwave links are designed to meet specific reliability factor. Reliability, or sometimes is known as availability of a system, is usually expressed as a percentage. It represents the percentage of the time the link is expected to operate without an outage caused by propagation conditions. It has been widely accepted that a good communication system must provide at least 99.99% reliability (IEEE, 2004; ITU-R SA 1414). In other words, the system can only be down for 0.01% of the time, which is usually referenced to a year. This means that the system can be unavailable for no less than 52.6 minutes per year [365.25*24*60*0.01/100]. (For emergencies, call 999; for no emergency, it is 99.99%!).

1.6 Project Outline

Chapter one concerns with the introduction of the study in hand, which starts with brief introduction, and continues stating the problem, the objective, the scope of the study and finally methods employed to achieve the goals.

Chapter two, which is the first chapter of the literature review, presents the RADAR principles and characteristics, by focusing on meteorological radar, which its data is used in this project.

Chapter three shows the methodology of the project. Introduction to radar data format, transmission of radar data and shown the flow chart for calculate the rainfall rate and rain cell size distribution.

Chapter four presents the obtained results and analysis data. The results were interpreted and compared with the ITU-R recommendations and other findings in the tropical region to measure the validity of the obtained results.

Chapter five concludes and emphasizes the obtained results and the contribution of the study. This chapter also proposes the future work that can be done.