RAIN FADE ANALYSIS ON EARTH –TO-SATELLITE LINK OPERATING IN COMOROS

BY

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ABSTRACT

Microwave link operates at high frequency approximately 10 GHz and above, and it suffers from high attenuation in the tropical region due to high rain intensity. Therefore, a microwave designer should consider this effect in the design so that the link can be operated with good quality of service, high availability and reliability. This study is about analysis of rain fade in a tropical country, Comoros, where the rain intensity was considered from ITU-R Recommendation. This rain intensity was used to determine the rain fade for earth-to-satellite of links operating in this country at L, C, Ka, Ku and V bands in horizontal, vertical and circular polarization for 0.001% to 1% of exceeded per year.Methods used for this study are the procedure of prediction attenuation (ITU-R P.618) and modulation techniques.From the analysis, it was found that the link has availability to work from 99.999% to 99% with least effects in all frequency bands at vertical polarization, except in V-band. At 99% of availability, it shows that B-PSK is the best technique for modulation to make the proposed link more reliable. To attain 10dB fade margin which allows the antenna to reach certain quality of services, the gain receiver, diameter and figure of merit were increased while the footprint was maximized. The outcome of this study will be useful resources used to upgrade the availability and reliability of earth to satellite microwave link in Comoros.

خلاصة البحث

رابط الميكروويف يعمل بتردد أعلى ؛ يعاني من الأمطار الغزيرة في المنطقة المدارية بسبب كثافة الأمطار العالية بسبب التوهين العالي .لذلك ، ينبغي لمصمم الميكروويف مراعاة هذا التأثير في التصميم بحيث يمكن تشغيل وصلة الميكروويف بجودة خدمة جيدة وتوفر عالي وموثوقية . تتناول هذه الدراسة تحليل تلاشي الأمطار في بلد استوائي ، جزر القمر ، حيث تم اعتبار شدة المطر من توصية قطاع الاتصالات الراديوية الخاصة بكثافة المطر .تُستخدم كثافة المطر هذه لتخرج مع تلاشي الأمطار لرابط الميكروويف من الأرض إلى القمر والذي يعمل في هذا البلد الاستوائي في نطاقات Lو Cو Kaو Kuو Vفي جميع الاستقطابات)الأفقية والرأسية والدائرية (بنسبة 0.001٪ إلى 1٪ من نسبة تجاوزت سنويا .والطرق المستخدمة في هذه الدراسة هي إجراءات التنبؤ للنقص الذي سيحدث (ITU-R P.618) وتقنيات التشكيل.كما تعتزم تصميم وتحليل أداء الوصلة هذا لجميع الترددات المذكورة أعلاه من خلال تقييم نسبة ضوضاء الإشارة (CNR)في الهواء الصافي وأثناء المطر عند الانقطاع الحرج 0.01)٪ (للتنبؤ بمعدلات الخطأ في البتات (BER)لكل منها للتشكيل التالي تقنيات . Bو Qو .8PSKولهذا ، يوضح تحليل الخبو الناجم عن المطر أن الوصلة لديها إمكانية العمل من 99.99٪ إلى 99٪ مع أقل التأثيرات في جميع نطاقات التردد عند الاستقطاب الرأسي ، باستثناء النطاق .Vعند الانقطاع ، تعد Bpskهي أفضل تقنية تعديل تم العثور عليها لتحليل أداء الارتباط في ظل هذه الآثار مع خسارة منخفضة في كل من الظروف البيئية ؛ هواء صاف ، وصل CNRإلى 20ديسيبل مع انخفاض معدل الخطأ في البتات بمقدار 5-10 * 7.6- 5-10 * 4.6وخلال المطر ، يكون معدل الإشعاع النووي أقل من 20ديسيبل في جميع نطاقات التردد ذات معدل الخطأ في البتات المرتفع خاصةً في النطاق kaو Ku . Vلإرسال إشارة جيدة عند إتاحة 99.99٪ مع أداء أفضل بهامش الخبو ، وجد أن الهوائي يصل إلى خصائص معينة من الخدمات تكون أكثر موثوقية مع نظام المحطة الأساسية .وبالتالي ، تم تحديد النسخة الاحتياطية السهلة من الألياف إلى الميكروويف دون خسارة كبيرة بسعة 100جيجابت 5)جيجا لاسلكي (وهي نطاق Vعند الاستقطاب الرأسي مع موجة ربع نموذج الهوائي .ستكون نتيجة هذه الورقة موارد مفيدة تستخدم لترقية توفر وموثوقية الأرض إلى وصلة الميكروويف عبر الأقمار الصناعية في جزر القمر

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Communication Engineering).

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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LIST OF ABBREVIATIONS

I.T.U.R	Recommendation of International Telecommunication Union
P.L.H	Horizontal Polarization
P.L.V	Vertical Polarization
P.L.C	Circular polarization
C.N.R	Signal to Noise Ratio
B.E.R	Bits Error Rate
B.P.S.K	Binary Phase –Shift Keying
Q.P.S.K	Quadrature Phase –Shift Keying
8.P.S.K	Eight Phase –Shift Keying
L,C,KA,KU& V.BAND	Operating frequency Ranges in the Radio Spectrum
R.M.S	Root Mean Square
L.O.S	Line Of Sight
V.S.A.T	Very Small Aperture Terminal
H.F	High Frequency
E.I.R.P	Effective Isolation Radiated Power
I.N.T.A.L.S.A.T	International Telecommunications Satellite Organisation
P.I.M.T.S	Propagation Impairements Mitigation Techniques
L.E	Length Effective
E. L(θ)	Elevation angle
C.O.S.E.C	One over Cosines (Co-secant)
R.F	Radio Frequency

Q,O.S	Quality of service
L.S	Slant Length
R.E	Effective Radius of the earth
H.S	Height of Antenna from the ground to slant path
L.G	Horizontal projection of the slant path
L. P	Loss Path

LIST OF SYMBOLS

$5G$	Fifth wireless generation
f	Frequency
$D, E \& F$	Different layer (region) of isosphere
Θ	Canting Angle (Fig.2.3)
T_r	Noise Temperature in sky due to rain
A_r	Rain Attenuation
K	Unit to measure Temperature in Kelvin
T_θ	Cloud temperature for elevation angle θ
T_z	Zenith angle cloud temperature
$A \& X$	Non-thermal sources Cassiopeia A, Cygnus A and X
Hr	Rain Height
h_0	Height above mean sea level
$X(Lo)$	Longitude
$Y(La)$	Latitude
Km	Unit to Measure the distance
$R_{0.01\%}(R_p)$	Rainfall Rate at outage of 0.01%
mm/hr	Millimeter per hour (unit to measure rain intensity)
Yr	Specific Rain attenuation
$K \& \alpha$	Dependent Coefficient of frequency
$k_H \& \alpha_H$	Dependent Coefficient of frequency for pL-H

k_v & α_v	Dependent Coefficient of frequency for pL-v
k_c & α_c	Dependent Coefficient of frequency for pL-c
τ	Angle dependent of coefficient frequency (45°)
$r_{0.01\%}$	Horizontal reduction factor
$V_{0.01\%}$	Vertical Adjustment
ƺ	Depth angle
LR	Reduction length
Ψ	Phi angle
X& B	Dependent angle of Phi angle respectively
$A_{0.01\%}$	Predict Attenuation exceeded 0.01% of an average
P	Percentage
$A(R_p, D)$	Crane Model Attenuation
u, b, c, d	Empirical coefficient
H	The 0°C isotherm height for high values of R_p
$P(e)$	Probability
D	Dependent distance of H in terms of P(e) and EL (θ)
Q-band	Very high frequency band
Db	Log conversion
$P_{r(ca)}$	Receiver power in clear air
G_r	Gain Receiver
L_{ant}	Transponder output back off
L_m	Loss gained from mixer in RF receiver of antenna
T_{in}	Equivalent noise source at the input (TA))
T_{RF}	Noise Temperature of RF Low Noise Amplifier
T_m	Noise Temperature of Mixer

T_{IF}	IF Temperature
G_{RF}	Gain of RF
G_m	Gain of Mixer
G_{IF}	Gain of IF
K	Boltzmann's constant (1.38 X 10^{-23})
B_n	Noise Bandwidth
T_R	System noise temperature of receiver
T_{Aca}	Antenna temperature in clear air
η	Constant coupling
T_{scA}	Sky temperature in Clear Air
T_0	Ambient Temperature in clear air(290˚k) and during rain (270˚k)
P_t	Power transmitter
G_t	Gain Transmitter
dia	Diameter of antenna
λ	Wavelength
c	Speed of light (3.10^8 m^{-s})
d	Distance from the satellite to slant path of the earth's base station
G	Atmospheric absorption in clear air (Abs.att)
G'	Atmospheric absorption during rain (Abs.att+rain attenuation)
N	Receiver Noise
P_r	Power Receiver
M	The number of arrays based on the types of modulation
ΔN_{rain}	Increase Noise Power
T_{Srain}	Sky Temperature during Rain
T_{Arain}	Antenna temperature during Rain

Pe	Percentage (p %)
P_o	Polarization

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND STUDY

In general, microwave link system for the earth –to -a satellite is designed to be operated at high frequency approximately 10 GHz and above. To operate up to 10 GHz (Freeman, 2006;Islam, Rahman, Hossain & Azad, 2008), it suffers from high rain rate attenuation which may affect the signal transmission due to heavy rain in the tropical countries. It is highly affected by propagation impairments by this heavy rain especially those operating at higher frequencies. This effect is the main problem of microwave link faces when operating in such countries. Comoros is one of the tropical countries and therefore the microwave link operated is entirely influenced by the high rain intensity especially during the period of heavy rainfall. Therefore, to evaluate this effect on the signal and the performance of the microwave link operating in Comoros, the in-depth analyses have been done to evaluate the range of availability and unavailability of this link at all frequency bands such as L-band (2 GHz), C-band (4 GHz), Ku-band (12 GHz), Ka-band (20 GHz) and V-band (40 GHz) in three polarizations such as horizontal (PL_h), vertical (PL_v) and circular (PL_c).

The prediction attenuation was derived from ITU-R Recommendation of rain attenuation and the ones obtained from simulation have been analysed to identify the overall availability and the outage time of the proposed link operated under the rain effects at all microwave's frequency bands with their respective polarizations. Also, this study intends to analyse the performance of the microwave link budget to transmit high data rate of the signal with a minimum loss.Moreover, the modulations technique (B-

PSK, Q-PSK and 8-PSK) were used to estimate the carrier to noise ratio (CNR) under two environment conditions such as in clear air and during rain with their respective bits errors rate (BER) at outage of year percentage (0.01%). The evaluations will determine the required frequency band for backup from optical link with 100 Gbps capacity (5G wireless) to the proposed microwave link without failure of signal and much loss. Hence, the achievement of these evaluations is the goal of this study. The prediction attenuation model based on the ITU-R of rain attenuation (ITU-R P.618-12/13) (Series, 2015)included with other model such as (ITU_R P.839-3/4&/837-7/838-3),(Sector, 2001; Series, 2012; Union, 2005) have been used by other researchers in the same field of study and therefore this study proposed to use the same model.

1.2 PROBLEM STATEMENT

Microwave link used in communication system is the beam of radio waves based on microwave frequency band to send high data rate signal between transmitter and receiver. This quality of service introduces a lot of activities in Telecom Company of Comoros in such way many Telecom operators use this link for many purposes; for providing their client with high-speed internet access without using cable, use telephone calls between switching center of microwave link to ensure proper communication between severs and users. Although the earth -to satellite transmission link brings a lot of benefits from their companies and users, but during rainfall, the microwave spectrum is mostly unavailable for them to exchange data especially when this link is operating at higher frequency. Therefore, the signal is affected which causes the serious failure of signal in some of frequency bands at some polarization. At outage, the performance of the link is getting worst and worst in such way there is degradation of transmission signal in based station system. Since, there is another alternative of transmission signal such as fiber optic, the transmission signal is wisely transmitted without losing data. However, the problem is when the fiber is faulty, it is needed to do backup from optical link with 100 Gbps (5G wireless), there is a big loss in such way it affects the quality of the services; the outcomes of the service is also bad. So, they are the main problems that have been highlighted to find the solution in this particular link to make it more reliable.

1.3 RESEARCH OBJECTIVES

The study aimed to achieve the following objectives:

1- To analyse the rain fades for the earth to satellite microwave link operating in Comoros at different frequency bands in three polarizations (vertical, horizontal and circular).

2- To design earth-to-satellite microwave links operating at L, C, Ku, Ka and V-bands.

3- To evaluate the link performance in clear air as well as due to rain at all five bands.

1.4 RESEARCH METHODOLOGY

1- Comprehensive literature review has been done in these two following areas; rain effects and performance of the microwave link where most of the researchers applied robust studies on microwave transmission at high frequencies because of the failure of the signal due to heavy rainfall depending on their geographical area.

2- Analyze these rain effects as well the performance of their proposed link using the ITU-R recommendation of rain attenuation including with another modeling (modulation techniques such as BPSK, QPSK and 8-PSK). EXCEL software has been used to drive all quantitative data of these effects (APPENDIX A-C) which is used in MATLAB for the simulation result shown in section 3.6 and 3.7.

3- The mathematical model used based on the previous researchers (Freeman, 2006; Mandeep & Zali, 2011).

Figure 1.1 shows the flow of the project used as the methodology to achieve the objectives.