# PERFORMANCE STUDY OF AUTOMATIC TRANSMIT POWER CONTROL (ATPC) IN POINT TO POINT MICROWAVE LINK FOR RAIN ATTENUATION PROBLEM IN MALAYSIA

MUHAMAD MOKHTAR BIN SAAD

A project report submitted in partial fulfillment of the
requirements for the award of the degree of
Masters of Engineering (Electrical – Electronics & Telecommunication)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

NOVEMBER 2006

## ACKNOWLEDGEMENTS

I would like to express my gratitude and appreciation to my supervisor, Prof. Dr. Tharek bin Abd Rahman, for his guidance in the execution of the project and for his kind understanding. I am especially grateful for all the help he provided and resources he made available without which the project would not have reached its current stage. I would also like to thank Dr Zaharuddin bin Mohamed, for being most efficient in coordinating the project. My acknowledgement also goes out to the project presentation assessors, Prof. Madya Dr. Jafri Din and Dr. Razali bin Ngah, who have given me much advice and guidance during the project presentation. Last but not least, I would like to thank my family especially my beloved wife Rodhiah Ismail and all my children Ashraf, Afif, Azim and Husna Maisarah for just being there, giving me the strength and much needed moral support.

## ABSTRACT

Point-to-point microwave system is the backbone link for mobile communication industry as well as for other applications. In tropical region particularly in Malaysia, rain attenuation is the major constraint for implementing microwave system above 10GHz. The extreme of propagation channel environment due to rain has brought to the research and development of an automatic transmit power control (ATPC) in microwave transceiver. ATPC varies the transmit power level in order to maintain the receive signal level (RSL) above the threshold for bit-error-rate (BER) desired. This research project will cover three main scope of study. First estimated calculation of rain attenuation on terrestrial point-to-point microwave link based on rain data captured. This will involve the understanding and computational of rain attenuation modeling equation by ITU-R recommendation using the Matlab software. Second is the basic concept and operational of ATPC applied in transceiver module of microwave link. Finally the experimental performance analysis of ATPC on actual microwave link install in Celcom microwave network. The performance will be measured on receive signal level on the actual system with ATPC option enable and disable for a certain period of time with realtime rain faded signal.

# ABSTRAK

Sistem perhubungan microwave titik ke titik merupakan talian hubungan utama bagi industri telekomunikasi mudah alih dan juga bagi aplikasi-aplikasi lain. Walaubagaimanapun bagi negara-negara tropika faktor hadangan hujan keatas perambatan gelombang microwave merupakan masalam utama bagi menggunakan kemudahan system perhungan titik ke titik ini terutamanya bagi perambatan gelombang microwave yang berfrekuensi melebihi 10GHz. Faktor hadangan hujan keatas perambatan gelombang microwave telah membangunkan system perambatan gelombang secara automatik (Automatic Transmit Power Control- ATPC). ATPC akan mengubah kekuatan nilai perambatan gelombang bergantung kepada hadangan hujan yang diterima oleh sistem. Projek penyelidikan ini akan merangkumi tiga bidang kajian. Pertama menentukan nilai hadangan hujan ke atas sistem hubungan microwave titik ke titik berdasarkan penerimaan jumlah hujan. Ini melibatkan pemahaman dan pengiraan hadangan hujan yang dicadangkan oleh ITU-R. Kedua mengkaji konsep pembinaan dan operasi ATPC didalam sistem hubungan microwave titik ke titik. Akhirnya ujian prestasi ATPC ke atas satu sistem hubungan microwave titik ke titik yang telah dipasang dalam rangkaian perhubungan Celcom. Prestasi ATPC akan dinilai keatas gelombang penerimaan sistem dengan optional ATPC dihidup dan dimatikan bagi satu tempoh masa yang ditetapkan.

# TABLE OF CONTENT


| CHAPTER | TITLE | PAGE |
|---|---|---|
| | **DECLARATION** | ii |
| | **ACKNOWLEDGEMENTS** | iii |
| | **ABSTRACT** | iv |
| | **ABSTRAK** | v |
| | **TABLE OF CONTENTS** | vi |
| | **LIST OF TABLES** | viii |
| | **LIST OF FIGURES** | ix |
| | **LIST OF APPENDICES** | x |
| **1** | **INTRODUCTION** | 1 |
| | 1.1 Objectives of the project | 2 |
| | 1.2 Scope of the project | 3 |
| | 1.3 Problem Statement | 3 |
| | 1.4 Methodology and Report Structure | 4 |
| **2** | **DIGITAL MICROWAVE LINK AND PATH PROPAGATION ATTENUATION** | **6** |
| | 2.1 Transmission Lines | 6 |
| | 2.2 Radio Link System | 7 |
| | 2.3 Digital Point to Point Microwave Link | 7 |
| | 2.4 Introduction to Teresterial Link | 9 |
| | 2.5 Propagation Occurs Between Teresterial Link | 9 |
| | 2.5.1 Ground wave propagation | 10 |
| | 2.5.2 Space wave propagation | 10 |
| | 2.5.3 Sky wave propagation | 11 |

| | | |
|---|---|---|
| | 2.6 Path Propagation Attenuation | 11 |
| | 2.7 Effect of Atteneuation due to Hydrometeors | 11 |
| **3** | **RAIN ATTENUATION MODEL FOR USE IN PREDICTION METHOD** | 13 |
| | **3.1** ITU-R Rain attenuation prediction model | 13 |
| **4** | **ATPC DESIGN CONCEPT** | 18 |
| | 4.1 Block Diagram and Operation | 18 |
| | 4.2 Design Consideration | 20 |
| | 4.3 Feedback Loop ATPC | 21 |
| **5** | **RAIN ATTENUATION MODELLING BASED ON ITU-R RECOMMENDATION** | 24 |
| | 5.1 Design Flow Chart for Spesific Rain Attenuation Formula | 24 |
| **6** | **RESULTS AND DISCUSSION** | 28 |
| | 6.1 Calculation of estimated RSL on sample link | 28 |
| | 6.2 Calculated rain attenuation | 30 |
| | 6.3 Simulatin results on bench set up system | 31 |
| | 6.3.1 RSL response with ATPC enables | 31 |
| | 6.3.2 RSL response with ATPC disables | 32 |
| | 6.4 Results on the active system installed within Celcom network | 33 |
| | 6.5 Summary of Results | 34 |
| **7** | **CONCLUSIONS AND FURTHER WORK** | 35 |
| | 7.1 Positive Conclusion | 35 |
| | 7.2 Further improvement for this Project | 36 |
| | 7.3 Future research | 36 |
| | 7.4 A Final Note | 36 |
| **REFERENCES** | | 37 |
| **Appendices A – E** | | 39 - 63 |

# LIST OF TABLES


| TABLE NO. | TITLE | PAGE |
|---|---|---|
| 6.1 | Calculated RSL Report with Pathloss 4 | 29 |

# LIST OF FIGURES


| FIGURE NO. | TITLE | PAGE |
|---|---|---|
| 2.1 | Simplified block diagram of digital point to point microwave system | 8 |
| 2.2 | Teresterial Link | 9 |
| 2.3 | Line of Sight Propagation | 9 |
| 3.1 | k coefficient for horizontal polarization as a function of frequency | 15 |
| 3.2 | $\alpha$ coefficient for horizontal polarization as a function of frequency | 16 |
| 3.3 | k coefficient for vertical polarization as a function of frequency | 16 |
| 3.4 | $\alpha$ coefficient for vertical polarization as a function of frequency | 17 |
| 4.1 | Block diagram of microwave transmitter with ATPC | 19 |
| 4.2 | A functional block diagram of feedback loop ATPC | 21 |
| 6.1 | Path profile plot | 30 |
| 6.2 | Matlab GUI for rain attenuation | 31 |
| 6.3 | RSL response with ATPC enables | 32 |
| 6.4 | RSL response with ATPC disables | 33 |
| 6.5 | The RSL response on the sample link with ATPC enables | 34 |

# LIST OF APPENDICES


| APPENDIX | TITLE | PAGE |
|---|---|---|
| A | Timeline for Project 1 | 39 |
| B | Timeline for Project 2 | 40 |
| C | MATLAB Codes for Rain Attenuation Calculation | 41 |
| D | Frequency dependant coefficient for estimating specific attenuation | 53 |
| E | Sample of system RSL response captured from the system | 59 |

# CHAPTER 1

# INTRODUCTION

Moving forward to Third Generation Mobile Communication System (3G), point-to-point microwave link will continue to serve as the backhaul link for wireless systems. However, the heavy rain in tropical region country limits the full implementation of the system in terms of installation distance and frequency usage. As the frequency increasing, the rain attenuation will become worse [5-6]. The installation distance could be reduced in order to have lower rain attenuation; however the implementation cost will become higher since more microwave link is required. Furthermore, frequency spectrum congestion unavoidable will force the future system to operate in higher frequency band.

Numbers of researches have been conducted for measuring the rain attenuation at point-to-point microwave link. However, research for the method to overcome the problem is quite limited. Although power control system also integrated in some of the point-to-point microwave communication system, the discussions are limited to only the restrictions, applications and operations rather than system design and performance analysis [6-8]. The research reported in this paper therefore aims to give solution for rain attenuation problem at point-to-point microwave link by introducing adaptive transmit power control (ATPC) in the front-end of radio unit.

The response of ATPC to the receive signal level (RSL) decides how fast the system can compensate for the fading and prevent the system from outage. The design of radio system with ATPC needs to fulfill some regulations in the operating country in order to install the equipment. European fixed radio systems

recommendations are taken as reference for determining the effect of ATPC to transceiver system [7]. The ATPC is designed to provide sufficient power to overcome the propagation path loss, without introducing excessive distortion and spurious that will cause bit-error-rate (BER) performance degradation. Analysis of transceiver system involves with harmonics and inter modulation that could not be achieved with simple mathematical calculations. The system analysis will become more complex when digital modulated signal is processed.

For terrestrial microwave links operating at frequencies higher than **10** *GHz,* rain-induced degradations are significant. Major degradations caused by rain that affect the reliability and availability of terrestrial links are rain attenuation and rain fade. Besides attenuation, rain fade is another major factor affecting the performance of microwave links. Rain fade is the dynamic fluctuation of receive signal due to in homogeneities of the signal path, ranging from a few seconds to a few minutes. Rain fade provides additional information on understanding the characteristics of rain-induced degradations.

### 1.1 Objectives of the project

At the end of Project 1 and 2, I hope to achieve these 3 objectives:

* To calculate the estimation of rain attenuation on terrestrial point-to-point microwave link based on rain data captured.
* To study the basic concept and operational of an Automatic Transmit Power Control (ATPC) applied in point-to-point microwave link.
* To study the performance of ATPC to overcome rain attenuation for point-to-point microwave link in Malaysia

## 1.2 Scope of the project

This project will focus on three main scope of study.

1) The estimated calculation of rain attenuation on terrestrial point-to-point microwave link based on rain data captured. This will involve the understanding and computational of rain attenuation equation using the Matlab software.
2) Basic concept and operational of ATPC applied in transceiver module of microwave link.
3) Performance of ATPC on actual microwave link install in Celcom microwave network. The performance will be measured on receive signal level on the actual system with ATPC option enable and disable for a certain period of time.

MATLAB will be used in this project to calculate the estimated rain attenuation based on rain rate data captured. I choose to use MATLAB as the computer language to design the PSK based communications systems because it is one of the most popular computer simulation languages in the world

## 1.3 Problem statement

Attenuation due to rainfall can severely degrade the radio wave propagation at centimeter or millimeter wavelengths. It restricts the path length of radio communication systems and limits the use of higher frequencies for line-of-sight microwave links and satellite communications. The attenuation will pose a greater problem to communication as the frequency of occurrence of heavy rain increases. In a tropical region, like Malaysia, where excessive rainfall is a common phenomenon throughout the year, the knowledge of the rain attenuation at the frequency of operation is extremely required for the design of a reliable terrestrial and earth space communication link at a particular location.

### 1.4 Methodology and Report Structure

This is a simulation project as well as life data captured from the system. To achieve its objectives the following methodology are followed.

1) Select the experimental point to point microwave link for case study
2) Calculate the estimated RSL based on the path profile; transmit power and gain of the system.
3) Calculate the estimated rain attenuation based on the planning path profile and ITU-R recommendation.
4) Set up one experimental point to point microwave link at bench to simulate the ATPC performance by capturing the RSL with ATPC enable and disable using the results calculated on the above. Plot the graph RSL vs time and compare the results.
5) Capture the RSL on the experimental link with ATPC enable and compare the result with the link without ATPC.

Prior to the actual modeling and simulation of ATPC performance of the systems, objectives, scope, motivations and problem statements are identified. This is documented in Chapter 1 together with the overview of the project. The timelines for Project 1 and Project 2 are attached in Appendix A and B.

The second chapter delves deeper into the subject matter which is digital point to point microwave link and propagation attenuation due to rain. Extensive research is carried out on the existing point to point microwave communications system and its underlying siganal propoagation restrictions.

The third chapter outlines the modeling and calculation of rain attenuation prediction based on ITU-R recommendations. This chapter illustrates the mathematical models used to in writing the MATLAB codes

Subsequently, the next chapter, Chapter 4, writes about the ATPC design concept. Two type of design consideration is introduced and basic operation of ATPC module loopback type was clearly explained.

The fifth chapter puts together all the flow chart in writing the MATLAB script to calculate the rain attenuation predictions.

The final section of this report gives all the results obtained throughout the project. Discussions and analysis on the results are included in this section.

## REFERENCES


1. International Telecommunication Union Recommendation P.530-11 Propagation Data and Perediction Methods Required for the Design of Teresterial Line of Sight System; 2005.

2. Inter national Telecommunication Union Recommendation P.838-3 Spesific Attenuation Model for Rain for Use In Prediction Methods; 2005.

3. Prof Dr Tharek Rahman, Lecture Notes Wireless Communication, UTM; 2005.

4. N.Nagatomo, NEC Pasolink+ Technical Reference Manual, NEC Tokyo, 2003.

5. Robert K. Crane, Prediction of Attenuation by Rain, IEEE Transactions on Communications, Vol. Com-28, No 29, September 1980. 1717 – 1733.

6. Rafiqul M.I & Tharek A.R, One Year Measurement of Rain Attenuation of Microwave Signal at 23GHz and 38 GHz in Malaysia, The 4th CDMA International Conference (CIC'99), Seoul, Korea, September 8-11, 1999.

7. Hsuan-Jung Su and Geraniotis, Adaptive Closed Loop Power Control with Quantized Feedback and Looping Filtering. Wireless Communications, IEEE Transaction on, Volume: 1 Issue 1. 2002; 76-86.

8. Mohd Nizam Asari, Basic Micowave Transmission, Celcom Academy, Kuala Lumpur, 1998

9. Proakis, J.G. Digital Communications, 3rd ed., NY: Mcgraw-Hill, 1995.

10. http://www.mathworks.com

11. Sampei, S., Applications of Digital Wireless Technologies to Global Wireless Communications, Upper Saddle River, NJ: Prentice Hall, 1997

12. Prasad, J. G., Digital Communications, 3rd Edition., New York: McGraw Hill, 1995

13. Jakes, W.C., Microwave Mobile Communications, NewYork:IEEE Press, 1994