

INTERCELL INTERFERENCE STUDIES IN BROADBAND WIRELESS  
ACCESS NETWORKS

MOHAMMAD IBRAHIEM ABO-ZEED

A project report submitted in partial fulfillment of the  
requirements for the award of the degree of  
Master Engineering (Electrical-Electronics and Telecommunications)

Faculty of Electrical Engineering  
Universiti Teknologi Malaysia

MAY 2008

*To my Beloved Parents, The Great Father: DR. Ibrahim Abo-Zeed, The Brilliant Mother: Hakum Barguth, my brothers and my sister for their support and prayers throughout my study days.*

## ACKNOWLEDGEMENT

In the name of Allah, the Most gracious, the Most Merciful

First and foremost and forever my great deification, veneration, gratitude, and thanks to ALLAH , glorified and exalted be He, for all the things He blesses my life with, thanks to ALLAH for giving me the longanimity and the determination to pursue this study, thanks to Allah who made this possible for me.

I strongly would like to thank my direct supervisor PM Dr. Jafri Bin Din, During the past year I have known PM Dr. Jafri Bin Din as a sympathetic and principle-centered person. PM Dr. Jafri Bin Din gave me the confidence and support during my Master's program in International Relations. PM Dr. Jafri Bin Din thought me how to be challenger me to set my benchmark even higher and to look for solutions to problems rather than focus on the problem. I learned to believe in my future my work and myself. Thank you PM Dr. Jafri I am really grateful.

My thanks goes to my colleagues Zaid Ahmed Shamsan and Abdullah Saad Mohammed Al-Ahmadi for their advising and helping, during my study days.

Finally, I want to express my gratitude to my family, on whose constant encouragement and love I have relied throughout my time at Malaysia. I am grateful also to my example, my father, Dr. Ibrahim Abo-Zeed, my beloved mother Hakum Barguth, Their unflinching courage and conviction will always inspire me, and I hope to continue, in my own small way, the noble mission to which they gave their lives. It is to them that I dedicate this work.

I cannot end without thanking My brothers and my Sister, for supporting me in every step I do in my life.

Thank you all

## ABSTRACT

Capacity has become of primary importance in broadband wireless access (BWA) networks due to the ever-increasing demand for multimedia services and the possibility of providing wireless Internet, leading to their standardization by IEEE (802.16WirelessMAN) and ETSI (BRAN HIPERACCESS). The major factor limiting capacity in such systems is interference originating from co-channels and cells, namely intercell interference. This thesis presents a general analysis of intercell interference for a spectrally efficient BWA cellular configuration. It examines the statistical properties of the carrier-to-interference ratio in downstream channels. The focus is on the spatial inhomogeneity of rain attenuation over multiple paths, which is the dominant fading mechanism in the frequency range above 20 GHz, especially when two-layered [i.e., line-of-sight (LOS) and non-LOS] architectures are involved. Besides attenuation from precipitation, various architectural and propagation aspects of local multipoint distribution service systems are investigated through simulations, and worst-case interference scenarios are identified.

## ABSTRAK

Kapasiti telah menjadi kepentingan yang utama di dalam rangkaian BWA kerana permintaan yang semakin banyak dan kemungkinan membekalkan internet tanpa wayar, kearah standard oleh IEEE (802.16Tanpa wayarMAN) dan ETSI(BRAN HIPERACCESS). Faktor utama yang meyekat kapasiti dalam sistem tersebut adalah gangguan yang berasal dari co-saluran dan sel iaitu gangguan inter-sel. Thesis ini mempersembahkan analisis yang lazim dalam gangguan inter-sel untuk konfigurasi sellular BWA. Ia mengkaji sifat statistik pembawa kepada gangguan di dalam saluran ke bawah. Tumpuan adalah berkenaan ketidakseragaman pelemah hujan terhadap laluan yang pelbagai di mana ia adalah penyebab utama mekanisma pelemah di dalam lingkungan frekuensi 20Ghz ke atas terutamanyer apabila dua lapis [i.e., (LOS) and non-LOS] arkitektur terlibat. Selain pelemah yang cepat dan pantas, pelbagai aspek arkitektur dan penyebaran servis pelbagai titik tempatan telah di siasat melalui simulasi and senario kes yang paling teruk di kenalpasti.

## TABLE OF CONTENTS

<b>CHAPTER</b>	<b>TITLE</b>	<b>PAGE</b>
	<b>DECLARATION</b>	ii
	<b>DEDICATION</b>	iii
	<b>ACKNOWLEDGEMENTS</b>	iv
	<b>ABSTRACT</b>	v
	<b>ABSTRAK</b>	vi
	<b>TABLE OF CONTENTS</b>	vii
	<b>LIST OF TABLES</b>	xi
	<b>LIST OF FIGURES</b>	xii
	<b>LIST OF ABBREVIATIONS</b>	xiv
	<b>LIST OF SYMBOLS</b>	xvi
	<b>LIST OF APPENDICES</b>	xvii
<b>1</b>	<b>INTRODUCTION</b>	1
	1.1 Background	1
	1.2 Objective of the Project	3
	1.3 Scope of the Project	3
	1.4 Methodology of the Project	4
	1.5 Thesis Outline	4
<b>2</b>	<b>BROADBAND WIRELESS ACCESS NETWORKS AND LOCAL MULTIPOINT DISTRIBUTION SERVICE</b>	6
	2.1 Introduction	6

2.1.1	Why Broadband Wireless Access?	7
2.1.2	Why Broadband?	8
2.1.3	Why Wireless?	9
2.1.4	Local Multipoint Distribution Services	11
2.1.5	What is LMDS?	11
2.1.6	How does LMDS work?	12
2.2	Basic Concepts	14
2.2.1	Advantages/Disadvantages of LMDS	16
2.2.2	Applications and Service Performance	19
2.2.3	Frequency Band and Spectrum Allocation	20
2.2.4	Network Architecture	22
2.2.5	System Equipment Segments	22
2.2.6	Standards	24
2.3	Architectural Options	24
2.4	Wireless Links and Access Options	25
2.4.1	TDMA or FDMA Selection	29
2.5	Modulation	29
2.6	System Capacity	30
2.6.1	Data-Rate Capacity—FDMA Access	30
2.6.2	Maximum Number of Customer- Premises Sites—FDMA Access	32
2.6.3	Data-Rate Capacity—TDMA Access	32
2.6.4	Maximum Number of Customer- Premises Sites—TDMA Access	32
2.7	Microwave Propagation Issues	33
2.8	Network Planning	35
2.8.1	Cell Design	35
2.8.2	Frequency Reuse Optimization	37
2.9	Link Budget Calculation	40
2.10	C/I and Inter-Cellular Interference	41

<b>3</b>	<b>THE RAIN FADING</b>	47
3.1	Rain Effects	50
3.2	Rain Attenuation Equation based ITU-R Model	51
3.3	Rain-Cell over LMDS System	53
3.4	Effects of Rain Fading on the Efficiency of the Ka-Band LMDS System	54
3.5	Interference Analysis of the Boundary Subscriber	54
3.6	Channel Capacity in Rain Fading	55
3.7	Bit Error Rate ( BER)	57
3.8	Cell Coverage Effect	57
<b>4</b>	<b>PROJECT METHODOLOGY</b>	59
4.1	Introduction	59
4.2	Establishing of LMDS Network	60
4.3	Calculation of Rain Attenuation	62
4.3.1	Specific Rain Attenuation	63
4.3.2	Effective Path Length	63
4.3.3	Rain Attenuation	64
4.4	Rain Cell Movement within LMDS	64
<b>5</b>	<b>RESULTS AND ANALYSIS</b>	66
5.1	Introduction	66
5.2	LMDS Configuration	67
5.3	LMDS Frequencies and Parameters	68
5.4	Rain Attenuation Data and Calculations	69
5.4.1	Specific Rain Attenuation Calculation	69
5.4.2	Effective Path Length Calculation	69
5.4.3	Rain Attenuation Calculation	70
5.4.3.1	Rain Attenuation at 26 GHz	70
5.5	Terminal Station Situation Possibilities	71



	5.5.1	All LMDS Service Area with and without Rain	72
	5.6	The result comparison	73
<b>6</b>		<b>CONCLUSION AND FUTURE WORK</b>	88
	6.1	Summary	88
	6.2	Conclusion	89
	6.3	Future Work	90
		<b>REFERENCES</b>	91
		Appendices A - C	94-115

## LIST O TABLES

<b>TABLE NO.</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Capacity comparison of available access technologies	17
2.2	LMDS Advantages/Disadvantages	19
2.3	TDMA and FDMA System Issues	28
2.4	FDMA Access Modulation Methods	30
2.5	Spectral Efficiencies	31
2.6	Parameters and formulas for LMDS:	40
3.1	An example of calculation of rain attenuation	52
3.2	Relationship between reversed distance dR, rain rate RR and cell size	55
4.1	The sell size, sector size, and coverage area by LMDS network	61
5.1	Parameters, formulas for LMDS (26 GHz).	68
5.2	Specific rain attenuation	69

## LIST OF FIGURES

<b>FIGURE NO.</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Broadband Wireless Access network.	8
2.2	LMDS System Illustration of an LMDS network	14
2.3	The operation of LMDS for broadcast.	15
2.4	Multipath propagation and LMDS systems	16
2.5:	LMDS band allocation in USA	21
2.6	Co-Sited Base Station	24
2.7	Analog Fiber Architecture	25
2.8	FDMA Access	26
2.9	TDMA Access	26
2.10	Horizontal and Vertical Polarization Reuse	38
2.11	Configuration of the BWA network	39
2.12	Co-Channel Interference	42
2.13	Dual frequency and polarization reuse plan for LMDS.	44
2.14	CIR sector distribution under clear sky conditions	45
4.1	LMDS area structure	60
4.2	The supposed scenario of LMDS	62
4.3	The radius of the equivalent coverage area under rain conditions	65
5.1	Configuration of the BWA network	67
5.2	Rain attenuation vs. path length at 26 GHz and 125 mm/h (Johor Bahru)	71

5.3	All LMDS with and without rain at 26 GHz and 125 mm/h	72
5.4	2D = 2 km, L=0.5, The rain over I1 or I2 or I3.	73
5.5	2D = 2 km, L=1, The rain over I1 or I2 or I3.	74
5.6	2D = 2 km, L=2, The rain over I1 or I2 or I3.	74
5.7	2D = 2 km, L=3, The rain over I1 or I2 or I3.	75
5.8	2D = 2 km, L=4, The rain over I1 or I2 or I3.	75
5.9	2D = 2 km, L=0.5, The rain over I1, I2 and I3.	76
5.10	2D = 2 km, L=1, The rain over I1, I2 and I3.	76
5.11	2D = 2 km, L=2, The rain over I1, I2 and I3.	77
5.12	2D = 2 km, L=3, The rain over I1, I2 and I3.	77
5.13	2D = 2 km, L=4, The rain over I1, I2 and I3.	78
5.14	2D = 2 km, L=0.5, The rain over the desired path C.	78
5.15	2D = 2 km, L=1, The rain over the desired path C.	79
5.16	2D = 2 km, L=2, The rain over the desired path C.	79
5.17	2D = 2 km, L=3, The rain over the desired path C.	80
5.18	2D = 3 km, L=0.5, The rain over I1 or I2 or I3.	80
5.19	2D = 3 km, L=2, The rain over I1 or I2 or I3.	81
5.20	2D = 3 km, L=4, The rain over I1 or I2 or I3.	81
5.20	2D = 3 km, L=0.5, , The rain over I1, I2 and I3.	82
5.21	2D = 3 km, L=2, , The rain over I1, I2 and I3.	82
5.22	2D = 3 km, L=4, , The rain over I1, I2 and I3.	83
5.23	2D = 3 km, L=0.5, The rain over the desired path C.	83
5.24	2D = 3 km, L=1 The rain over the desired path C.	84
5.25	2D = 4 km, L=1, The rain over I1 or I2 or I3.	85
5.26	2D = 4 km, L=4, The rain over I1 or I2 or I3.	85
5.27	2D = 4 km, L=1, The rain over I1, I2 and I3.	86
5.28	2D = 4 km, L=4, The rain over I1, I2 and I3.	86
5.29	2D = 4 km, L=0.5, The rain over the desired path C.	87
5.30	2D = 4 km, L=1, The rain over the desired path C.	87

## LIST OF ABBREVIATIONS

ACI	-	Adjacent Channel Interference
ADSL/VDSL	-	Asynchronous/Very High– Rate Digital Subscriber Line
ATM	-	Asynchronous transfer mode
BER	-	Bit Error Rate
BS	-	Base Station
BWA	-	Broadband wireless access
C/B	-	Channel Capacity
CCI	-	Co-Channel Interference
CDF	-	Cumulative Distribution Function.
C/I	-	Carrier to Interference ratio
CPE	-	Customer Premise Equipment
FCC	-	Federal Communications Commission
FDMA	-	Frequency Division Multiple Access.
FEC	-	Forward error correction
HS	-	Hub Station
HS	-	Inter-symbol Interference
ITU	-	International Telecommunication Union Radio- Broadcasting
LMCS	-	Local Multipoint Communication Systems
LMDS	-	Local Multipoint Distribution Services.
LOS	-	Line of sight.
MCMC	-	Malaysian Communications and Multimedia Commission
MSS	-	Mobile Satellite Service
NOC	-	Network Operations Center
PDF	-	Probability Density Function

PONs	-	Passive Optical Networks
PSTN	-	Public Switch Telephone Networks
QAM	-	Quadrature Amplitude Modulation
QPSK	-	Quadrature Phase Shift Keying
S/I	-	Signal-to-Interference Ratio.
SNR	-	Signal to noise ratio
SRSP	-	Standard Radio System Plan
TDMA	-	Time Division Multiple Access.
TS	-	Terminal Station

**LIST OF SYMBOLS**

$A$	-	Attenuation
$A_{0.01}$	-	Attenuation at 0.01% of time
dB	-	Decibel unite
$f$	-	Frequency
GHz	-	Giga Hertz
$k, \alpha$	-	Regression coefficients
km	-	Kilometer
$L_{eff}$	-	Effective Path length
L	-	Rain cell diameter
mm	-	Millimeter
P (%)	-	Percentage in time of the year
$R_{(i)}$	-	Rain rate at percentage in time of the year
$R_{0.01}$	-	Rain rate at 0.01% of time of the year
$\gamma_R$	-	Specific attenuation

**LIST OF APPENDIX**

<b>APPENDIX</b>	<b>TITLE</b>	<b>PAGE</b>
Appendix A	Frequency-dependent coefficients for estimating specific rain attenuation	94
Appendix B	Matlap simulation Program	98
Appendix C		102
Appendix D	Frequency Bands allocated for LMCS or (LMDS)	115



## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Background**

The growing demand for high-speed data connection to serve a variety of business and personal uses has driven an explosive growth in telecommunications technologies of all sorts including optical fiber, coaxial cable, twisted-pair telephone cable, and wireless.

Nowadays wireless recognized as one of the most important technology in order to have comfortable type of communication.

Broadband wireless access is the most challenging segment of the wireless revolution due to the dire need of Gigabit data transport and processing technologies.

There is a growing interest in providing broad-band services through local access networks to individual users. Millimetric-wave radio solutions are considered as the optimal delivery systems for these services. They are termed as broad-band wireless access (BWA) systems or local multipoint distributed services LMDS. [15]

The new broadband networks and services are developed continuously to serve the different demands, Internet, mobile Internet, broadcasting, telephony, e-commerce, and Video on Demand. Point-to-multipoint wireless system could be a promising solution to connect the users to the backbone network instead of broadband wired networks because of its cost efficiency, easy and fast installation, and re-configurability; however due to the time and location variable channel conditions the system should apply fade mitigation techniques to reach the quality of service requirements.[17]

Capacity has become of primary importance in broadband wireless access (BWA) networks due to the everincreasing demand for multimedia services and the possibility of providing wireless Internet, leading to their standardization by IEEE (802.16WirelessMAN) and ETSI (BRAN HIPERACCESS). [15]

The focus is on the spatial inhomogeneity of rain attenuation over multiple paths, which is the dominant fading mechanism in the frequency range above 20 GHz, especially when two-layered [i.e., line-of-sight (LOS) and non-LOS] architectures are involved. [15]

The Ka (20/30 GHz) and V (40/50 GHz) frequency bands are becoming increasingly attractive for user oriented future commercial satellite services, due to their large available bandwidths. However, they suffer more from rain fades in comparison to the almost congested Ku (12/14 GHz) band. Therefore, prediction models for annual rain attenuation, such as the ones developed by several research groups over the past three decades are required to provide guidance in the course of balancing availability requirements and cost.[15]

A rain-cell degrades the system performance at a part of the service area but the rain can improve the carrier-to-interference ratio  $C/I$  conditions elsewhere depending on the locations of the base station, terminal station and the rain-cell. Interference fluctuation is a very important thing in LMDS network planning procedures, which needs countermeasure techniques to avoid degradation of the quality of service. [17]

The comprehension from the previous paragraphs, it is clarified that the problem statement of this project that the high quality of LMDS cannot be obtained under rain effects, so there is need to have such study on the intercell interference in BWA.

## **1.2 Objective of the Project:**

- i. To examine the Intercell interference in LMDS networks over clear sky and rainy condition.
- ii. To determine the statistical properties of the carrier-to-interference ratio in downstream channel.

## **1.3 Scope of the Project**

The scope of this project includes:

- i. Calculation of Rain Attenuation in a given BWA network for multidistances.
- ii. To analyze the intercell interference in LMDS network under heavy multilocation rains ( in the downstream channel) .

## **1.4 Methodology of the Project**

To consummate this project, the following methodology has been designed as the following steps:

First Step, establishing of LMDS Network by determining

- i. Frequency used and sectorisation
- ii. Structure of system (BS & TS)
- iii. Distance or cell size

Second Step, calculation of Rain Attenuation based ITU-R Model by using Rainfall rate of different locations over Malaysia in order to cover all Malaysia region weather and therefore the study can be generalized to include the regions that have the same climate (tropical climate weather).

Third Step, analyzing of Rain cell Movement within LMDS, this is done by taking all possibilities or terminal station situations over LMDS area and effect of Interference signals.

## **1.5 Thesis Outline**

The layout of this report is as follows:

Chapter one embodies an introduction about BWA, LMDS system and rain attenuation. Furthermore it includes the objective of this project, research scope, methodology of the work, and the outlines of this thesis.

Chapter two is the first chapter of the literature review, presents the Local Multipoint Distribution Service Systems and its specifications and components as

will as rain fading and its effects on the signal, also this chapter includes steps to calculate rain attenuation.

Chapter three is the brief about the rain fading mechanism and effects of rain fading on the efficiency of the Ka-Band LMDS System and how to calculate rain attenuation, based ITU-R Model.

Chapter four represents the methodology of this project, including the details of how to establish LMDS, rain attenuation calculation, effects of rain over LMDS area.

Chapter five presents the whole results of this work and discussions of these results as well as some of analyses. The results include specific rain attenuation, rain attenuation and different LMDS cell sizes.

Chapter six contains summary, conclusion and the recommendations or future works which are presented based on the obtained results.

## REFERENCES

- [1] A. D. Panagopoulos and J. D. Kanellopoulos, "Cell-site diversity performance of millimeter-wave fixed cellular systems operating at frequencies above 20 GHz," *IEEE Antennas Wireless Propag. Lett.*, vol. 1, pp. 183–185, 2002.
- [2] Sinka and János Bitó, "Site Diversity Against Rain Fading in LMDS Systems" VOL. 13, NO. 8, AUGUST 2003
- [3] Athanasios D. Panagopoulos "Intercell Radio Interference Studies in Broadband Wireless Access Networks" VOL. 56, NO. 1, JANUARY 2007
- [4] Broadband Wireless Access over two-layer LMDS with an IEEE 802.16 future Petri M?h?nen (petri.mahonen@vtt.fi), Zach Shelby (zach.shelby@vtt.fi) VTT Research, Wireless Internet Laboratory Finland
- [5] Wirelessman The IEEE 802.16 Working Group on Broadband Wireless Access Standards. wirelessman.org
- [6] The international Engineering Consortiumium [IEC]
- [7] Agne Nordbotten, Telenor R&D. LMDS Systems and their Application. *IEEE Communications Magazine* June 2000.
- [8] Blake, R. *Wireless Communication Technology*. Wadsworth Inc. (2001).
- [9] Agne Nordbotten, Telenor R&D. LMDS Systems and their Application. *IEEE Communications Magazine* June 2000.
- [10] Salem Salamah (2000). "Transmit power control in fixed broadband wireless systems", M.Eng. Thesis, Carleton University Aug. 2000.

- [11] Douglas A. Gary (1997). A Broadband Wireless Access System at 28 GHz. IEEE, Wireless Communications Conference, Aug11-13, pp.1-7.
- [12] Federal Communications Commission
- [13] Hikmet Sari Trends and Challenges in Broadband Wireless Access, 2000 IEEE
- [14] ACTS Project 215, Cellular Radio Access for Broadband Services (CRABS), Feb. 1999.
- [15] Chang-Hoon Lee Dynamic Modulation Scheme Consideration of Cell Interference for LMDS International Conference on Communication Technology ICCT'98 October 22-24, 1998 Beijing, China.
- [16] Georg Bauer, and Rolf Jakoby, "Two-Dimensional Line of Sight Interference Analysis of LMDS Networks for the Downlink and Uplink" IEEE, VOL. 52, NO. 9, SEPTEMBER 2004
- [17] Ranjan Bose, Andreas Hayn, and Rolf Jakoby, "Intra- and inter-cell interference investigations for broadband radio access systems above 10 GHz" Journal of Telecommunications and Information Technology 2/2001
- [18] Peter B. Papaeian "Study of the Local Multipoint Distribution Service Radio Channel" IEEE transactions on broadcasting, vol. 43, no 2, June 1997
- [19] Chih-Yuan Chu and K. S. Chen "Effects of Rain Fading on the Efficiency of the Ka-Band LMDS System in the Taiwan Area" VOL. 54, NO. 1, JANUARY 2005
- [20] RECOMMENDATION ITU-R P.1410-4 Propagation data and prediction methods required for the design of terrestrial broadband radio access systems operating in a frequency range from 3 to 60 GHz (1999-2001-2003-2005-2007)
- [21] Site diversity against rain fading in lmds systems, Zaid Ahmed Shamsan Abdo, Master thesis, UTM Malaysia, MAY 2007

- [22] Panagopoulos, A. D, Liolis, K. P. and Cottis, P. G. “*Cell-Site Diversity Against Co-Channel Interference in LMDS Networks*” *Wireless Personal Communications* 39: 183–198, Springer. 2006
- [23] Sinka, C., Bito, J. (2003). *Site diversity against rain fading in LMDS systems*. *IEEE Microw. Wireless Comp. Lett.*, vol 13, no. 8, pp. 317-319, August 2003.