SITE DIVERSITY AGAINST RAIN FADING IN LMDS SYSTEMS

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To my beloved parents, to my beloved wife, to our sons Osamah and Mohammad, and to our daughters Sumaih and Shadha.

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ABSTRACT

Local Multipoint Distribution Service (LMDS) is a new terrestrial fixed radio technology for broadband communication applicable that can be used to provide digital two-way voice, data, Internet, and video services or other digital services requiring high capacity traffic channels. LMDS is a point to multipoint wireless system operating at frequencies above 20 GHz, the most serious impairment at these frequencies is rain fading. In the system point of view a moving rain cell over the LMDS service area will not only attenuate the desired signal but also the interferer. Many techniques could be used to overcome rain fading. Applying Site Diversity as a possible solution to reduce the effect of rain is necessary, because a rain-cell degrades the system performance at a part of the service area but the rain can improve the carrier signal conditions elsewhere depending on the locations of the Base Station, Terminal Station and the rain-cell. The rain attenuation of different locations in Malaysia region in a given LMDS is calculated and the effects of a moving rain cell over an LMDS system are analyzed, different situations of interference according to the position of the rain-cell over the service area of LMDS are elaborated. The site diversity is implemented based on the ITU-R Recommendations to enhancement LMDS. The location dependent C/I in the LMDS service area under rainy conditions with and without site diversity technique is calculated and simulated. Different cell sizes of LMDS with and without site diversity are considered in this project for significant analyses and discussions. It is found that site diversity has high ability to improve the performance level of all LMDS service area specially under rainy conditions.

ABSTRAK

Local Multipoint Distribution Service (LMDS) adalah suatu teknologi baru daripada radio bumi yang ditetapkan untuk komunikasi jalur lebar yang dapat digunakan untuk menyediakan jalur digital suara dua hala, data, Internet, dan perkhidmatan video atau perkhidmatan digital lainnya yang memerlukan saluran trafik berpasitas tinggi. LMDS adalah suatu sistem titik ke banyak titik dari media tanpa wayar yang beroperasi pada frekuensi di atas 20 GHz, kebanyakan pelemahan rangkaian pada frekuensi ini adalah pemudaran oleh hujan. Jika dilihat dari prespektif system LMDS, sel hujan yang bergerak melepasi kawasan perkhidmatan LMDS bukan sahaja melemahkan isyarat yang diterima, tetapi turut mengganggunya. Banyak cara dapat digunakan untuk mengatasi masalah pemudaran hujan. Teknik kepelbagaian lawan dapat digunakan sebagai kemungkinan mengurangi kesan hujan. Sel hujan akan melemahkan prestasi perkhidmatan pada sebahagian kawasan liputan tetapi akan meningkatkan prestasi perkhidmatan bergantung kepada kedudukan stesen tapak, stesen terminal dan sel hujan. Pelemahan hujan pada beberapa lokasi LDMS di Malaysia telah ditentukan dengan mengambilkira kesan pergerakan sel hujan melepasi kawasan LDMS. Perbezaan situasi gangguan disebabkan oleh perbezaan kedudukan sel hujan telah dilaporkan. Prestasi LDMS dinilai berdasarkan pengalaman perlaksanaan perkhidmatan LDMS. Teknik kepelbagaian laluan dilaksanakan berdasarkan rekomendasi ITU-R. Lokasi bersandar C/I dalam perkhidmatan LDMS ketika hujan dengan dan tanpa teknik kepelbagaian lawan dihitung dan disimulasikan. Perbezaan saiz sel LMDS diambilkira dalam perbincangan dan analisa kajian. Ini didapati bahawa teknik kepelbagaian lawan mempunyai keupayaan yang tinggi bagi mempertingkatkan tahap prestasi semua kawasan perkhidmatan LMDS terutamanya pada waktu hujan.

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LIST OF ABBREVIATIONS

ADSL/VDSL	-	Asynchronous/Very High– Rate Digital Subscriber Line
ATM	-	Asynchronous transfer mode
BER	-	Bit Error Rate
BS	-	Base Station
BSC	-	Base Station Controller
BTS	-	Base Station Transceiver
BWA	-	Broadband wireless access
C/B	-	Channel Capacity
CDF	-	Cumulative Distribution Function.
CDMA	-	Code Division Multiple Access.
C/I	-	Carrier to Interference ratio
CPE	-	Customer Premise Equipment
DBA	-	Dynamic Bandwidth Allocation
FCC	-	Federal Communications Commission
FDMA	-	Frequency Division Multiple Access.
FEC	-	Forward error correction
FTTH	-	Fiber-to-the-home.
HFC	-	Hybrid Fiber Coax
HS	-	Hub Station
ISI	-	Inter-symbol Interference
ITU-R	-	International Telecommunication Union Radio-Broadcasting
LAN	-	Local Area Network
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
SD	-	Site Diversity
SDBS	-	Site Diversity Base Station
S/I	-	Signal-to-Interference Ratio.
SNR	-	Signal to noise ratio
SRSP	-	Standard Radio System Plan
TDMA	-	Time Division Multiple Access.
TS	-	Terminal Station
WAN	-	Wide Area Network

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CHAPTER 1

INTRODUCTION

1.1 Background

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. (Panagopoulos *et al*., 2002).

The new broadband networks and services are developed continuously to serve the different demands, e.g., Internet, mobile Internet, broadcasting, telephony, e-commerce, Video on Demand, etc. 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. (Sinka and Bito, 2003).

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. (Panagopoulos *et al*., 2002).

To combat rain attenuation, several fade mitigation techniques have been developed such as diversity protection schemes, power control and adaptive processing techniques. Among these techniques, the most efficient is site diversity (SD). SD takes advantage of the spatial characteristics of the rainfall medium by using two earth stations to exploit the fact that the probability of attenuation due to rain occurring simultaneously on the alternative Earth-space paths is significantly less than the relevant probability occurring on either individual path. (Panagopoulos *et al*., 2002).

Though the cost effectiveness of SD remains questionable, the interest on SD has been renewed, due to the significant reduction of ground terminal antennas and other hardware sizes. Nowadays, terminals can be installed in customers' premises and the use of public terrestrial networks to carry out signaling seems possible. (Panagopoulos *et al.,* 2002).

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. (Sinka *et al*., 2002).

From the pervious paragraphs, it is clarified that the problem statement of this project indicates that the high availability of LMDS can not be obtained under rain effects, so site diversity should be suggested as one effective means to overcome rain fading.

1.1 Objective of the Project:

The main objective of this project is to study the effects of site diversity in LMDS under rainy conditions in Malaysia.

1.2 Scope of the Project

The scope of this project includes:

- To analyze the effects of a moving rain cell over an LMDS system
- This study includes calculation of Rain Attenuation in a given LMDS system.

1.3 Methodology of The Project

To carry out this project, the following methodology is designed as the following steps:

- Establishing of LMDS Network:

  By determining

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

- 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).

- 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.

- Site Diversity Implementation, this step is done according to the previous studies related to LMDS system.

1.5 Thesis Outline

The layout of this report is as follows, chapter one includes a brief general background of LMDS system and rain attenuation. The objective of this project is clearly stated. The research scope and methodology are presented.

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 shows the concept of Site Diversity system and expressions which are used to describe the performance of the site diversity. This chapter explains brief details about how to implement site diversity in LMDS system during rainy conditions and some parameters to express site diversity.

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 and site diversity implementation are presented.

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 with and without site diversity. Comparisons and simulations of these results are also presented.

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

REFERENCES

Agne Nordbotten, Telenor R&D (2000). *LMDS Systems and their Application*. IEEE Communications Magazine June 2000.

Arapoglou, P. D. M., Kartsakli, E., Chatzarakis, G. E. and Cottis, P. G. (2004). *Cell-Site Diversity Performance of LMDS Systems Operating in Heavy Rain Climatic Regions*. International Journal of Infrared and Millimeter Waves, 2004 – Springer.

Arapoglou, P. D. M., Panagopoulos, A. D., Kanellopoulos, J.D. and Cottis, P.G. (2005). *Intercell radio interference studies in CDMA based LMDS network*. IEEE Trans. Antennas Propag. vol. 53, no. 8, Aug. 2005.

Athanasios, D. Panagopoulos, Pantelis-Daniel M. Arapoglou, John D. Kanellopoulos, and Panayotis G. Cottis. (2005). *Long-Term Rain Attenuation Probability and Site Diversity Gain Prediction Formulas*. IEEE Transactions on Antennas and Propagation, vol. 53, no. 7, July 2005.

Blake, R. (2001). *Wireless Communication Technology*. Wadsworth Inc.

Chu, C. and Chen, K. S. (2005). *Effects of Rain Fading on the Efficiency of the Ka-Band LMDS System in the Taiwan Area*. IEEE Transactions on Vehicular Technology, Vol. 54, NO. 1, January 2005.

Douglas A. Gary (1997). *A Broadband Wireless Access System at 28 GHz.* IEEE, Wireless Communications Conference, Aug11-13, pp.1-7.

Enjamio, C., Vilar, E. and Fontán, F. P. (2002). *Spatial Distribution of Rainfall Rate: Benefits of the Site Diversity as a Dynamic Fade Mitigation Technique*. COST 280 PM3009 1st International Workshop 2002.

Falconer, D. D. and DeCruyenaere, J. P. (2003). *Coverage Enhancement Methods for LMDS.* IEEE Communications Magazine, vol. 41, no. 7, pp. 86-92, July.

Heder, B., Singliar, R., and Bito, J. (2005). *Site Diversity Examination based on Rain Attenuation Measurement*. 47th International Symposium ELMAR, 08-10 June 2005, Zadar, Croatia.

Hendrantoro, G., Bultitude, R. J. C. and Falconer, D. D. (2002). *Use of Cell-Site Diversity in Millimeter-Wave Fixed Cellular Systems to Combat the Effects of Rain Attenuation.* IEEE JSAC, vol. 20, no. 3, Apr. 2002, pp. 602-14.

Hikmet Sari. (2000). "*Trends and Challenges in Broadband Wireless Access*. 0-7803-6684, IEEE, 2000.

ITU-R Recommendations (2005). *Propagation data and prediction methods required for the design of terrestrial line-of-sight systems*. P.530-11.

ITU-R Recommendations (2005). *Specific attenuation model for rain for use in prediction methods*. P.838-3.

Lee, C., Chung, B. and Lee, S. (1998). *Dynamic Modulation Scheme In Consideration of Cell Interference for LMDS*. International Conference on Communication Technology, ICCT'98 October 22-24, Beijing China, 1998.

Michael D. Lei. (2001). *Factors Affecting Deployment Strategies for an LMDS System in a Rural Commercial Environment*. M.Eng. Thesis, Faculty of the Virginia Polytechnic Institute and State University.

Panagopoulos, A. D. and Kanellopoulos, J. D. (2002). *Cell-site diversity performance of millimeter-wave fixed cellular systems operating at frequencies above 20 GHz*. IEEE Antennas Wirel. Propag. Lett., vol. 1, pp. 183-185.

Panagopoulos, A. D, Liolis, K. P. and Cottis, P. G. (2006). *Cell-Site Diversity Against Co-Channel Interference in LMDS Networks.* Wireless Personal Communications 39: 183–198, Springer.

Salem Salamah (2000). *Transmit power control in fixed broadband wireless systems*", M.Eng. Thesis, Carleton University Aug. 2000.

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.

Sinka, C., Lakatos, B., Bitó, J. (2002). *The Effects of Moving Rain Cell Over LMDS Systems.* COST Action 280, PM3027, 1st International Workshop July 2002.

Standard Radio System Plan. (2003). *Requirements for Local Multipoint Communications Service (LMCS) Operating in the Frequency Bands From 24.25 GHz to 27.0 GHz, 27.0 GHz to 29.5 GHz and 31.00 GHz to 31.3 GHz.* Malaysia Communications and Multimedia Commission (MCMC SRSP)-509, Issue 3.

The International Engineering Consortium (IEC). (2005). *Local Multipoint Distribution Service (LMDS).* web proforum tutorials, (www.iec.org.14/9/2006).

Zvanovec S., Pechac P. (2004). *Site Diversity Time-Space Simulations for LMDS*. 0-7803-8521-7/04 IEEE.