Rain Fading Mitigation in BWA Using Site Diversity

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Abstract-Local Multipoint Distribution Services (LMDS) is a terrestrial fixed radio technology for broadband communication applicable as point to multipoint wireless system operating at frequencies above 20 GHz. The most serious impairment at these frequencies is rain fading specially in the tropical areas. Many techniques could be used to overcome rain fading and applying Site Diversity as a possible solution to reduce the effect of rain. The rain attenuation in Malaysia was calculated and the effects of a moving rain cell over an LMDS system were analyzed. Different situations of interference according to the position of the rain over LMDS were elaborated. The site diversity was implemented and simulated based on the ITU-R to enhance LMDS using *C/I* ratio under rainy conditions with and without site diversity technique. Different cell sizes of LMDS with and without site diversity were considered

Keywords: BWA, rain fading, site diversity, interference

1. Introduction

There is a growing interest in providing broadband services through local access networks to individual users. Millimetric-wave radio solutions are considered as the optimal delivery systems to provide digital two-way voice, data, Internet, and video services or other digital services requiring high capacity traffic channels. They are termed as broad-band wireless access (BWA) systems or LMDS [1] which connect the users to the backbone network instead of broadband wired networks because of its cost efficiency, easy and fast installation, and re-configurability [2],broadband interactivity arrived with digitalization.

Interactive LMDS has a point-to-multipoint downlink and a point-to-point uplink [3] ; however due to the time and location variable channel conditions the system should apply fade mitigation techniques to reach the quality of service requirements. The overall performance of the LMDS system is measured by average C/I and since the intra- and intersystem interference and fading phenomena reduce the capacity of wireless systems so system planning should optimize the C/I conditions at each locations of the service area and efficient fade mitigation techniques should be comprised [2].

2. The Rain Fading

The demand for ultrawide bandwidths for high-speed, high quality, and multimedia transmission is driving the use of the higher radio frequency spectrum. However, attenuation and fading due to rain has long been recognized as a major limitation to reliable communication systems operating at higher frequencies.

Due to rain fading phenomenon and to the limited power that can be generated at low cost at millimeter-wave frequencies, the cell radius in LMDS networks is in the range of 2 to 5 km depending on the climatic zone, the available transmit power, and the required availability objectives [4].

The effects of rain can generally be neglected for wireless applications operating at frequencies less than 10GHz. However, attenuation due to rainfall is one of the principal factors affecting path loss at LMDS frequencies. The Exceedance is a performance metric of the radio link relative to rain attenuation. An Exceedance of 0.01% characterizes the link being unavailable for 0.01% of the time (52.56 minutes/year) and available for 99.99% of the time. The radio link must be designed to overcome the rain attenuation, therefore meeting the exceedance metric. The unit of the measured rain is in terms of mm/hr [5]. For LMDS frequencies, long periods of light rain effect the link availability much less than severe rainfall that lasts for 10-20 minutes.

The equation which is taken for calculating rain attenuation based on the International Telecommunications Union (ITU) model [5] is as follows:

$$A_{dB} = {}_k R^{\alpha} \quad (1)$$

The coefficients k and α are frequency and polarization dependent.

3. The LMDS System Architecture and Assumptions

As it is mentioned in the methodology, the service area of supposed LMDS was established by determination the cell size which it is 6 × 6 kms and the considered scenario according to [2]. The distance

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between the desired base station and terminal station which was putted at the left lower bottom corner of LMDS area or the path length of carrier (C) is 4.2426 kms. The three interference signals are coming from different adjacent base stations and different distances where I1 has a distance of 21.2132 kms and the others two interference signals (I2 and I3) have the same distance of 15.2970 kms. Also, a line-of-sight (LOS) was established between the BSs and TS. The architecture and distances are shown in Figure 1 and Table 1.

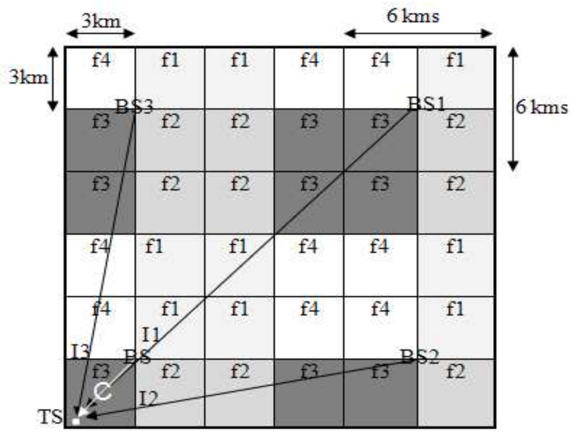

Figure 1: The supposed scenario of LMDS without site diversity

Table 1: The distance between terminal station and the effective base stations

The Base Station	*The Path Length (km)*
Desired signal (C)	4.2426
Interference signal (I1)	21.2132
Interference signal (I2)	15.2970
Interference signal (I3)	15.2970

Malaysian Communications and Multimedia Commission has regulated the frequency bands or LMDS 24.25 GHz to 27.00 GHz, 27.00 GHz to 29.50GHz and 31.00 GHz to 31.30 GHz for Local Multipoint Communication Systems (LMCS) or LMDS in Malaysia. In this work, 24 GHz was used. Indicating to [6] the LMDS parameters were considered to investigate this work, these parameters are included in the Table 2.

4. Implementation and Results

Rain attenuation was calculated for each rain rate at R 0.01, Jelebu (96 mm/h), Johor Bahru (125 mm/h) and Taiping (145 mm/h), the results are drawn in Figure 2.

Table 2: Parameters and formulas for LMDS at 24 GHz

Parameter	*Units*	*Formula*	*Value*
Transmit Power into antenna	dBW	Ptx : Transmit power per carrier	2.0
Transmit Antenna Gain	dBi	Gt = Gant	18.0
Receiver Antenna Gain	dBi	Gr = Gant	38.0
Frequency	GHz	f : Transmit Frequency	24.0
Path Length	km	d : from base station to terminal station	4.2426
Field Margin	dB	Lfm : Antenna Mis-Alignment	1.0
Free-Space Loss	dB	Lfs = 92.45 + 20 * log(f) + 20 * log(d)	132.6
Atmospheric Loss	dB	Latm = d * 0.1 dB/km	0.42426

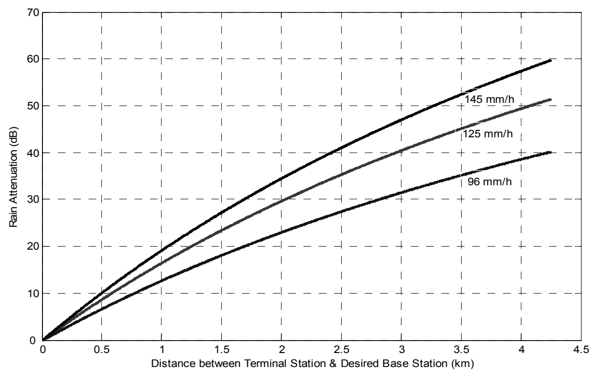

Figure 2: Rain attenuation vs. rain rates at 24 GHz and horizontal polarization

4.1 Terminal Station Situation Possibilities

According to the assumed LMDS system and indicating to Figure 1, there are six cases and scenarios can be occurred of terminal station at any time. These scenarios can be listed them down into two scenarios:

The first four cases, the effective signals have different situations in relation to rain movement over LMDS service area as follow:

Case1: desired signal (C) & Interference signal (I1) are in rain while (I2 & I3) are without rain *(the worst case).*
Case2: desired signal (C) & Interference signals (I1& I2) are in rain while I3 is without rain.
Case3: desired signal (C) & Interference signal (I1) are without rain while (I2 & I3) are in rain.
Case4: desired signal (C) & Interference signals (I1& I2) are without rain while (I3) is in rain.

However, in the other two cases the effective signals has uniform situation in relation to rain, these two cases can be listed as follow:
Case5: all LMDS service area is with rain and
Case6: all LMDS service area is without rain.

According to [2] and [7] the overall performance of the LMDS system is measured by average C/I. Average C/I (the threshold C/I=11dB) was calculated for all rain rates (96, 125 & 145 mm/h) at 24 GHz for all scenarios which may happen in LMDS service area the scenarios have been simulated by Matlab program; the results are shown in the Figure 3 and 4 only for rain rate of 125 mm/h.

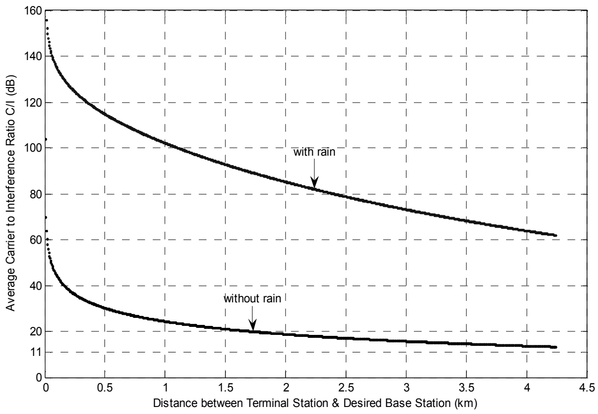

Figure 3: All LMDS with rain (case5) and without rain (case6) at 24 GHz and 125 mm/h

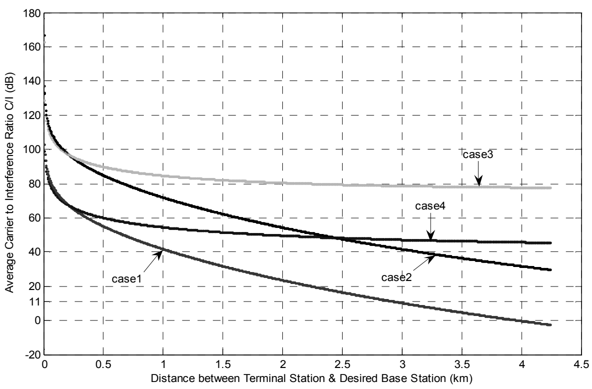

Figure 4: The cases(1-4) under 24 GHz and 125 mm/h conditions

4.2 Maximum Coverage and Different Sector Size

As a result of worst case it needs to be overcome and because of the calculations which were already calculated for 6×6 kms have shown no coverage at cell corner at the different rain rates and frequencies. Different sector sizes were considered for every 0.5 km step starting from 0.5×0.5 km, 1×1km, 1.5×1.5 kms until 3×3 kms. The result was graphed in Figure 5 which shows average C/I of worst case for different sector sizes of LMDS at 125 mm/h. This explains the maximum distance of every sector size equals (sector size ×√ 2) and the average C/I value at each point on this distance. For example, sector size of 3×3 kms has maximum path length (the point at corner of sector) of 3×√2 = 4.2426 kms and the average C/I value is negative dB value which means there is no coverage at the corner point as the graph shows but the average can be available at distance lower than 3 kms from the desired base station (at the zero point on the horizontal axis).

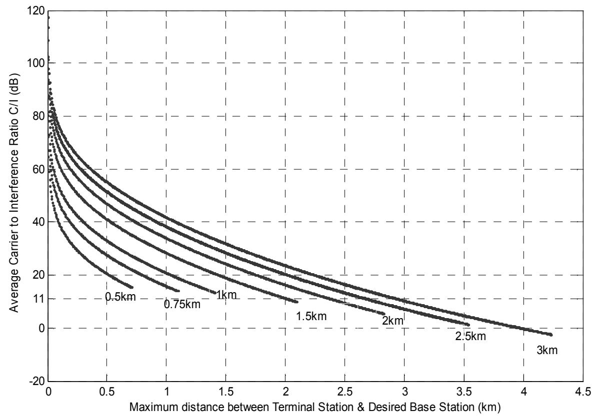

Figure 5: Maximum coverage vs. different sector size of worst case at 24 GHz and 125 mm/h

Table 2 shows that the maximum distance between the base station and terminal station of Malaysia region is slightly more than 1 km for rain rates of 125 and 145 mm/h and 2 kms for rain rate of 96 mm/h.

Table 2: Maximum coverage can be get during worst case without site diversity

Maximum coverage (100 %) without Site Diversity for 24 GHz C/I = 11dB		
Rain Rate (R0.01)	Maximum Sector Size (km) to avoid worst case	Maximum distance between TS & BS
96 mm/h (Jelebu)	1.5×1.5	2.12 km
125 mm/h (Johor Bahru)	1×1	1.41 km
145 mm/h (Taiping)	1×1	1.41 km

4.3. Site Diversity Implementation and Calculations

Site diversity was applied when the C/I reaches the critical value caused by rain, this is done by making a switch-over to one of the nearest “rain free” neighbor SDBS. As it is noted from the Figure 6, when the LMDS area suffer from rain specially the worst case (case1) the average C/I reaches the critical value, therefore the connection to terminal station or the

desired signal (C) from BS will reload to the available SDBS1 or SDBS2 or that one provides greater C/I whereas BS will be switched off. The distance from the SDBS1 and SDBS2 are equal as it is drawn in dashed lines in Figure 6 and the interference signals still effect on the terminal station.

According to the Figure 6 the distance of new desired base station or site diversity base station (SDBS1 or SDBS2) to terminal station TS has changed to become 9.4868 kms while all interference signals distance did not change. The power received from SDBS was calculated depending on the new distance without rain attenuation and C/I for every link also calculated to obtain average C/I value at terminal station for every rain rate.

The overall average C/I values in dB of LMDS with rain and without rain before and after using site diversity were calculated in worst case at corner point (4.2456 kms) and a distance of 2 kms from the original desired station. These values can be summarized in the Table 3 and 4.

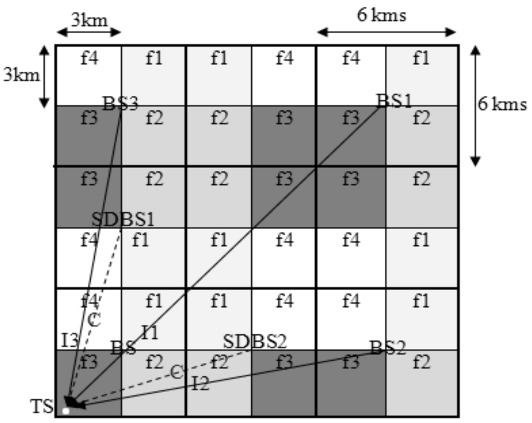

Figure 6: Implementation of site diversity

Using of site diversity as a technique to combat rain fading and prevent an outage on the feeder link has proved a high performance and high stability. Where as it is shown in the previous figures which were obtained LMDS without site diversity has a low values of average C/I of 1.6509 dB for 96 mm/h and go under zero (negative values) during 125 and 145 mm/h rain rates of -2.4417 dB and -5.0021 dB respectively at the corner of cell.
However, by using site diversity as depicted in Figure 7, the average C/I were obtained have stable and high values of 34.3435 dB, 41.4604 dB and 47.2160 dB at every point on the link for 96, 125 and 145 mm/h respectively. Also it can be seen that as rain rate is high the C/I is high during site diversity exploiting.

Table 3: Average C/I (dB) of LMDS service area at (24 GHz) and d= 4.2456 kms

Average C/I (dB) of the LMDS Service Area in *WORST CASE* (Downlink) (f =24 GHz) at the corner(d= 4.2456 kms)				
Rain Rate ($R_{0.01}$)	Without Rain	With rain		Gain Improve-ment
		without Site Diversity	with Site Diversity	
96 mm/h (Jelebu)	13.3887	1.6509	34.3435	32.6926
125 mm/h (Johor Bahru)	13.3887	-2.4417	41.4604	43.9021
145 mm/h (Taiping)	13.3887	-5.0021	47.2160	52.2181

Table 4: Average C/I (dB) of LMDS service area at (24GHz) and d= 2 kms

Average C/I (dB) of the LMDS Service Area in *WORST CASE* (Downlink) (f =24 GHz) at the corner(d= 2 kms)				
Rain Rate ($R_{0.01}$)	Without Rain	With rain		Gain Improve-ment
		without Site Diversity	with Site Diversity	
96 mm/h (Jelebu)	18.8977	23.3677	34.3605	10.9928
125 mm/h (Johor Bahru)	18.8977	23.3677	41.2957	17.6883
145 mm/h (Taiping)	18.8977	24.3691	46.8739	22.5048

Different cell sizes were considered to observe the site diversity effects and its relation with cell size, it is found than site diversity is not suitable of small cell size because the rain cell may cover these links at all furthermore average C/I by using site diversity has higher value for large cell size than that of small cell size as the Figure 8 below.

5. Conclusion

Preventing the highest degradation of performance level in the LMDS area can be applied by using site diversity technique. The TS can make a switch over to the nearest SDBS without rain when the C/I value reaches the critical threshold caused by rain. Site diversity is capable to improve the performance level even at LMDS corner area or worst case.

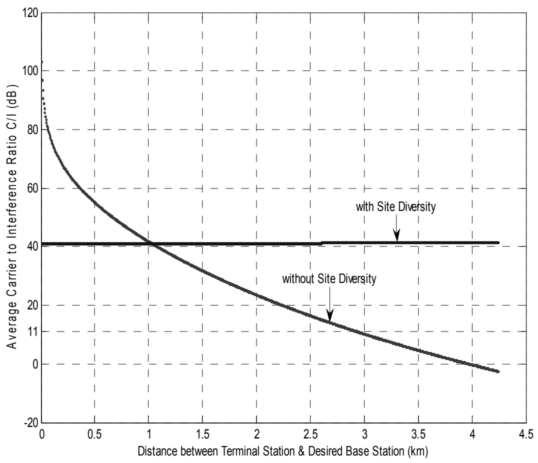

Figure 7: LMDS with and without site diversity at 24 GHz and 125 mm/h

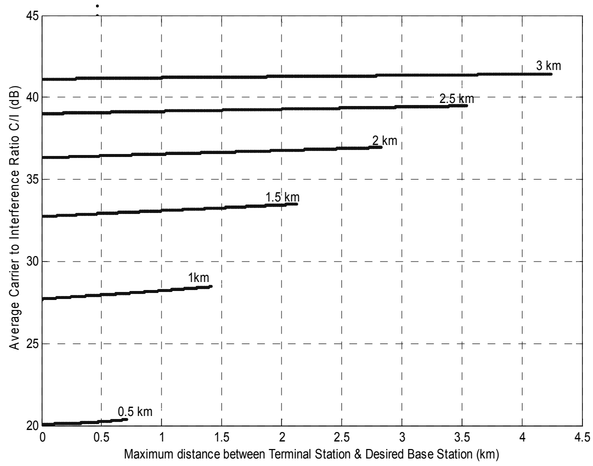

Figure 8: Site diversity vs. different sector sizes of worst case at 24 GHz and 125 mm/h

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