A Propagation Study of the 28 GHz LMDS System Performance under Rain Fading

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Abstract

In this paper, rain statistics of 10 years record in Taiwan area was used to investigate the transmission performance of the Ka-band LMDS system with QAM modulation. Emphasis was placed to investigate the effects of rain fading under M-QAM modulation schemes. It is found that for LMDS cellular network, M-QAM modulation is difficult to provide an effective and reliable high speed transmission for the case of 6 km radius of cell coverage unless the frequency and polarization diversities are applied; otherwise, the cell coverage of service should be reduced.

1. Rain Distribution Statistics

Taiwan is an island located around 24°N, 120°E covering the boundary of tropical and subtropical zones. Fig.1 shows yearly rain statistics for 4 large cities from north to south for 12 years from 1989-2000 records. For rain measurement, two kinds of rain gauge were used to record and compared to each other: the tipping bucket rain gauge with 0.1mm sensitivity and optical rain gauge with 0.001mm sensitivity sampling at every 5 seconds. It is well known that rain rate in hourly basis from annual observation is not suitable for fading margin estimation of telecommunication system [7-8]. It is necessary at this point to convert a long-term hourly data to short-term minutely measurements. To do so, we follow the procedure proposed in [9] by introducing a conversion factor (CF)

$$CF = \frac{R\,(mm/\,min)}{R\,(mm/\,hr)} \qquad (1)$$

where R(mm/min) and R(mm/hr) represent the rain rate cumulative distribution on minutely and hourly basis, respectively. By regress fitting, we obtain a CF for Taiwan area: $CF = 0.69(R^{0.12})\exp[1.51R^{0.02}]$.

Accordingly, the Crane model [4] for attenuation was modified as

$$A(R,D) = \begin{cases} aR^b\left[\dfrac{e^{ubd}-1}{ub}\right], (0 \le D \le d) \\ aR^b\left[\dfrac{e^{ubd}-1}{ub} - \dfrac{B^b e^{cbd}}{cb} + \dfrac{B^b e^{cbD}}{cb}\right], (d < D \le 22.5km) \end{cases} \qquad (2)$$

where *A* is rain attenuation in dB as function of rain rate R and operating distance D, and all the coefficients are given below.

$$\begin{aligned} &u = \ln\left[Be^{cd}\right]/d \\ &B = 2.3R^{-0.17} \\ &c = 0.026 - 0.03\ln(R) \\ &d = 3.8 - 0.6\ln(R) \quad km \end{aligned} \qquad (3)$$

In (2) the parameters *a* and *b* are locally tuned to fit the measurements as *a*=0.048, *b*=1.192.

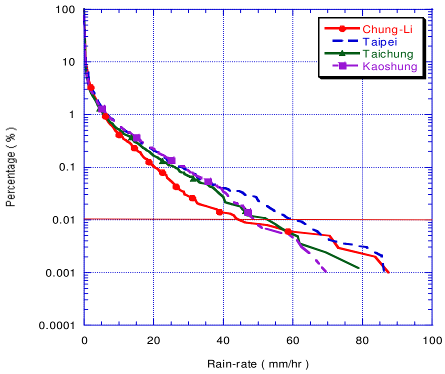


Fig. 1 Comparison of time exceeded cumulative rainrate of 12 years hourly integration in 4 cities from north to south in Taiwan.

2. Performance Analysis of LMDS under Rain Fading

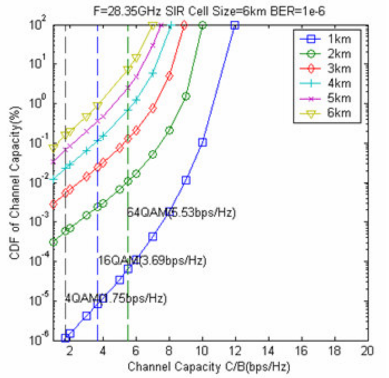
A. *two Frequency - dual polarization(2F2P)*

For higher BER, the lower order modulation has slight change of excedence probability. Relaxation of BER to lower values would also lower the excedence probability and the system gained better transmission performance accordingly. It is thus reasonably expected that for higher BER tolerant (e.g., 10-3 for voice) system, it should have higher availability than, say, data transmission (BER=10-6) system. We also see that among these path length changes, the 64 QAM gets the worst results for the case under consideration. It is almost out of bounds right away when D>2 km. Now, the long-term statistical analysis of channel capacity is in order. Because the channel is subject to fading, its capacity varies with the changes in the propagation medium. One could say that the channel capacity inherits in one way stochastic properties of fading process. For the same link length, with increase of the cell size, the capacity is apparently increased. Two more pronounced phenomena were observed. First, for higher order modulation, the capacity was rapidly reduced. Secondly, the link length poses significant impact on the capacity. One also sees that the curves of CDF of capacity were quite parallelized for various link lengths, no quick drop-off, and all closed to quasi-linear. One may reach that even for small cell size it seems hardly to avoid the interference.

At this point, we show that when M-QAM modulation scheme is used, all the service distances (D=1~6 km) for downstream are hardly to link well with 6km cell size using this cell plan, namely, two-frequency-dual-polarization configuration. In the following, we shall perform similar analysis but using four-frequency, dual-polarization cell plan.

B. four Frequency - dual polarization(4F2P)

As presented above, the poor BER performance of M-QAM is due to the short path of the interference source. In order to improve the performance, we extend the distance between the BTS and interference sources. The new cell structure now uses 4 frequencies and 2 polarizations, where the main interference sources have four cells, instead of three sites in the configuration of two-frequency and dual polarization, with only one site closer to CPE than the others. Because the distance of the other three sites was now doubled, the S/I of downstream were increased. Comparing the signal-to-(noise + interference) between the two cell plans, i.e., 2F2P and 4F2P, it shows that about 5 dB gain can be obtained from this new cell plan. It may be mentioned at this point that this study is not intent to pursue exhaustive examination of every possible cell plans. Because of the shorter distance of interference source and narrow antenna beam width of CPE, the S/I is higher than that of 2F2P. Based on this cell plan, we analyzed the bit error rate (BER) performance and channel capacity of LMDS under the rain and cell interference environments. Fig. 2 shows the channel capacity in comparison with the 2F2P cell plan at 6km cell coverage. It is obvious that the capacity is now substantially increased. For example, for CDF smaller than 10-2, the channel capacity increases from about 6 to10 bps/Hz at link length of 1 km.



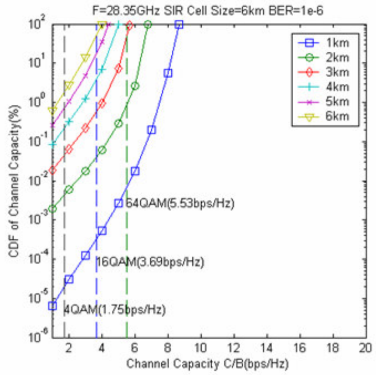


Fig. 2 Comparison of channel capacity between two cell plans (left: 4F2P, right:2F2P) at various of distance with cell size of 6 km and BER=10-6.

3. Conclusion

In this study, we used 12-year rain measurements data if Taiwan to conduct the long-term statistical channel performance of LMDS system operated at 28 GHz. Results indicated that the LMDS with M-QAM digital modulation, the service radius for data transmission should be less than 1 km with cellular interference in the 6 km cell coverage area under the rain fading. According to the performance analysis, it is suggested that the LMDS cellular network with M-QAM modulation was found to be hard to provide an effective and reliable high speed data transmission in 6 km large cell coverage radius in Taiwan's rain environment. To improve the performance, the cell plan may be configured by frequency and polarization diversity. It was found that the capacity of the LMDS using M-QAM was enhanced due to larger inter-cell interference link path. Even with this improvement, we may conclude that for M-QAM modulation, the service range is quite limited considering the rain fading and inter-cell interference in terms of cost-effect..

References

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