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A Propagation Study of Ka-Band Digital Modulation LMDS System in Taiwan

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Abstract: In this paper, a study on three year collections on rain rate and drop size distributions of Taiwan is presented and used to assess the performance of the LMDS system with QAM modulation in terms of its signal-to-interference ratio (S/I), bit error rate, and channel capacity. The seasonal rain effects and drop size distributions typical for the Taipei region of Taiwan will be emphasized in particular. The availability of the 4, 16, 64 QAM modulation schemes were considered.

1. Introduction

The demand of ultra-wide bandwidth for high-speed, high quality and multimedia transmission is pushing the use toward the higher radio frequency spectrum. However, attenuation and fading due to rain has long been recognized as a major limitation to reliable communication operating at higher frequencies [1]. The Local Multipoint Distribution System (LMDS) [2] is a line of sight (LOS), point-to-multipoint wireless access system operating at the Ka-band microwave frequency. LMDS provides wireless broadband access and employs cellular-like design and reuse. The bandwidth of above 1GHz, allocated by FCC, envisions throughputs for LMDS as fast as 1.5 Gbps downstream, with upstream rates as high as 200 Mbps. In fact, fading due to rain restricts the path length of radio communication systems, limits the use of higher frequencies for line-of-sight microwave links and affects the performance of wireless communication especially with QAM modulation [1]. This study is aimed at analyzing rain fading and system performance of LMDS under rainfall conditions in Taiwan [9] for which raindrop size distributions were measured.

In past studies, observations and theoretical analyses indicate that fading due to rain is highly dependent on rain rate and drop size distribution. Research on this subject is continuing for developing improved rain attenuation prediction models. Because of the different climate regions and geo-locations different rainfall conditions result, parameters obtained by measurement in local areas differ, and it is important to optimize these regional models [3-6]. In a subtropical region, like Taiwan, for which rain rate distribution or attenuation are excessive, generalized models for the Asia Pacific climate regions lead to model inaccuracy [3-5]. In this paper, long term statistics of raindrop size distribution and rain attenuation were obtained from our multi-year contiguous measurements collected in northern Taiwan to estimate the Ka-band LMDS performance using QAM modulation in terms of signal-to-interference ratio (S/I), channel capacity, and bit error rate for the seasonal Taiwan rain fading environment[7-8].

2. System description

The measurement system includes Ka band CW up-down converters, optical rain gauge, and

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distrometer to analyze the rain attenuation in Taiwan. Figure 1 shows the block diagram of our measurement system. The system we designed possesses +20dBm power output. Two 34dBi vertical polarization cassegrain antennas were employed. The receiver has a 200MHz IF signal output measured with a spectrum analyzer and recording automatically the power level on a desk-top computer through a GPIB interface at 5 seconds interval. For rain measurements, the optical rain gauge (ORG-815) which has 0.001mm sensitivity. A 2D-video distrometer was used to collect the raindrop information like rain-rate, raindrop size, ellipticity…etc. The transmitter was placed on the rooftop of the 4th Science Building at NCU and the receiver was located on the rooftop of the NCU CSRSR building with a 0.57 km LOS distance.

In the LMDS parameter analysis at 28.35 GHz, a system made by New Bridge Networks Corporation, including base station wireless equipment (BTS) and customer premises equipment (CPE), was used to perform the system analysis. Figure 2 shows the diagram of the analysis procedure. First, in the cell planning procedure, the LMDS cell type, system and geography parameters were used to analyze the performance of LMDS in single and multi-cellular environments. Second, according to well established theory, the rain attenuation, which was extracted form measured raindrop size distributions, is integrated with the resulting cell planning procedure. Finally, using integrated prediction procedures, the signal to interference ratio, channel capacity and bit error rate performance were obtained. These results made possible for the LMDS provider to evaluate the feasibility effectively. In this paper, two kinds of cell networks, with 2 and 4 frequencies and with 2 polarizations (2F2P, 4F2P), are used to analyze LMDS system performance for QAM modulation.

3. Results of raindrop size distribution

The raindrop size distribution (DSD) is one of the major sources of error in any rain prediction model mainly because of its variability in both space and time. We used the raindrop size distribution to calculate the rain attenuation in Chung-Li, Taiwan, and compared it with the experimental results in order to compare it with other model. The distrometer measurement data are used to establish a Gamma rain drop size distribution for Chung-Li, Taiwan, and in another experiment we carried out the rain attenuation at Ka band (28GHz). The specific attenuation A (dB/km) due to rain is calculated by summation over all of the rain drops as:

$$A = 4.343 \cdot \sum N(D) \cdot Q(D, l, m) \qquad (dB/km)$$

where Q is the extinction cross section being a function of the drop diameter *D*, the wavelength *?*, the complex refractive index of the water drop *m* being a function of the frequency and the temperature, and N(D) is the rain drop size distribution. The extinction cross section Q is defined by applying the classical scattering method of the Mie series expansion for a plane wave impinging upon a spherical particle. Figure 3 shows a comparison of theoretical results from prediction of rain drop size distributions? according to ITU-R 838 and applying the Crane model in the northern Taiwan area. The calculation result for the proposed rain drop size distribution model result in minimum RMS errors for the rain attenuation measurement data of the "Ka band (28GHz) terrestrial link propagation system" which are comparable to the ITU-R 838 and Crane models. In other words, we find a raindrop size distribution model suitable for use in the northern Taiwan region, from which we can predict the rain attenuation more directly and accurately.

4. Analysis of system performance

According to our modified rain model, we calculated the channel signal to noise and co-channel interference ratio of the LMDS system using 2 cell planning methods (2F2P, 4F2P) for the Taiwan rain environment. Figure 4 shows the SIR result of 2F2P and 4F2P with 6km cell size of the terminal site at rainy days (worst case). As to be expected, the 4F2P is better. The availability of the 4, 16, 64 QAM modulation schemes were considered. When there is rain fading without cellular interference, the BTS service boundary shrinks to BER = 10^{-6} in a 5 km cell. When cellular interference is present under 2F2P cell planning, it was found that the effective BTS service boundary shrinks less than 2 km using 16 QAM and 64 QAM under BER = 10^{-6}. In the same case, the 16 QAM and 64 QAM LMDS service radius should be less than 1 km according to the channel capacity in rain fading with cellular interference in the 6 km cell coverage area. In order to solve the interference problem, we expanded the cell planning to 4F2P. Then, the performance of LMDS using *M*-QAM in the 4 frequency network is better than the 2 frequency network. Figures 5 and 6 depict the channel capacity analysis for the2 cell planning.

5. Conclusions

In summary, it may be concluded from this study that under Taiwan's seasonal rain pattern, the LMDS at 28 GHz cellular network using M-QAM modulation is less effective, to some extent, for providing effective and reliable high speed transmission for a 6 km cell coverage radius unless we expand the frequency channels. By means of frequency reuse and taking the advantage of CPE's beam width, the main interference sources could be avoided effectively and the effective service range of the system can be increased by 1km - 2km for the same rain conditions.

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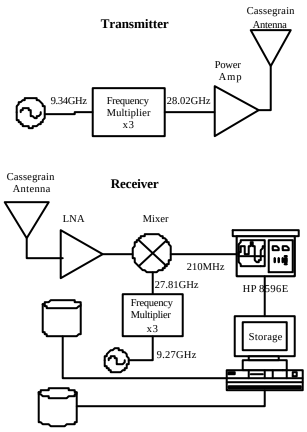

Figure 1 Block Diagram of a 28GHz Measure System

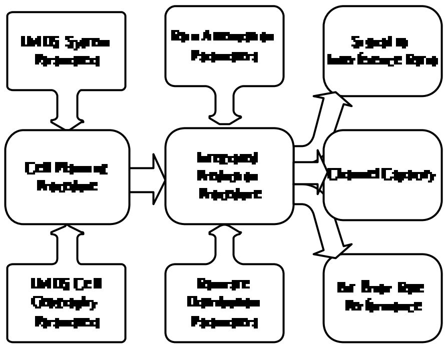

Figure 2 Block diagram of analysis procedu re

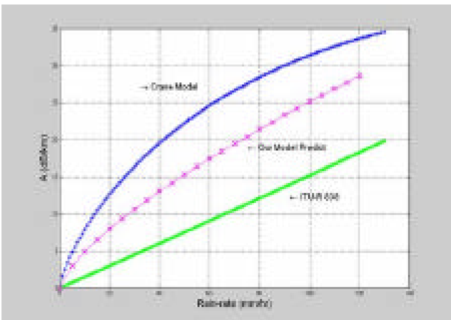

Figure 3 comparison of DSD prediction? ITU-R and Crane mode

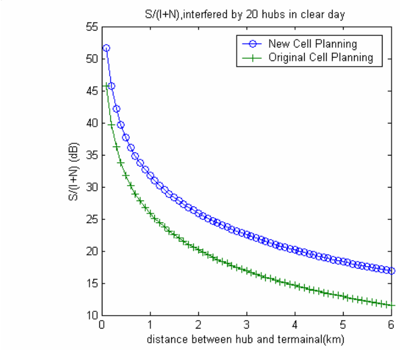

Figure 4 the SIR of 2F2P and 4F2P

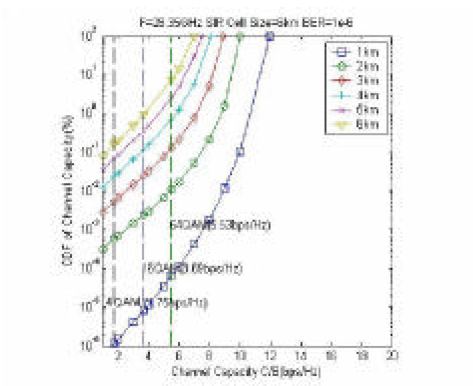

Figure 5 CDF of channel capacity in 4F2P

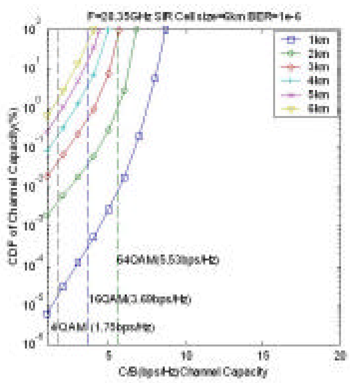

Figure 6 CDF of channel capacity in 2F2P