Telephony Solution for Local Multi-Point Distribution Service

Derek Lam
Computer Systems Laboratory
Aly F. Elrefaie, Lynn Plouse, Yee-Hsiang Chang
Video Communications Division
HPL-97-165
December, 1997

E-mail: derek@hpl.hp.com

telephony, LMDS, wireless local loop (WLL), Personal Communications Services (PCS)

This paper presents a telephony solution for Local Multi-point Distribution Service (LMDS) using technology for Personal Communications Services (PCS). An actual system based on Digital Enhanced Cordless Telecommunications (DECT) has been implemented. The system architecture of the DECT-based LMDS telephony system is discussed. Performance measurement results show that a DECT-based system does not have stringent frequency stability requirement and therefore can allow low-cost implementation.

Internal Accession Date Only

© Copyright Hewlett-Packard Company 1997

1. Introduction

Local Multi-point Distribution Service (LMDS) is a broadband wireless distribution technology at the millimeter-wave (mm-wave) frequency band. The U.S. Federal Communications Commission (FCC) has approved over 1,000 MHz of spectrum [1] for LMDS near 28 GHz. Approximately 850 MHz of the spectrum is assigned for downstream communications (i.e., from network to customers) and about 150 MHz of the spectrum is dedicated for upstream communications (i.e., from customers to network). With the large available bandwidth, LMDS is capable of providing two-way broadband network access to the home. It can support integrated applications, such as telephony, high-speed data, and video services.

The deregulation of the telecommunications industry, through the 1996 Telecommunications Act, has opened up opportunities for Competitive Local Exchange Carriers (CLECs) to enter the local telephony service market. In the highly competitive telecommunications world, time-to-market and cost of deployment are critical factors when it comes to choosing the appropriate infrastructure technology for any service. LMDS is an attractive communications technology that can be used to deploy telephony service to the home. Because of its wireless nature, LMDS can offer fast and low cost deployment by avoiding the need and the cost of installing underground cables or fibers, and their associated ``right-of-way'' problems. Another advantage of LMDS is that it is a broadband infrastructure. Therefore, even with an initial deployment of only telephony service over LMDS, any service provider can expand to provide other broadband services with minimal additional infrastructure cost. Much of the LMDS equipment at the network side and the customer side can be re-used.

In this paper, we present our approach[1] to support telephony over LMDS using existing technology for Personal Communications Services (PCS). A product was developed based on the Digital Enhanced Cordless Telecommunications (DECT) standard. We have demonstrated our DECT-based system at SUPERCOM'97. The rest of this paper is organized as follow. In Section 2, we describe our design approach and the system architecture for our telephony solution. Section 3 reports measured BER performance results for a DECT-based LMDS system. Particularly, we found that the overall system does not have stringent frequency stability requirement and therefore can allow low-cost implementation of the LMDS mm-wave equipment. Finally, we conclude the paper in Section 4.

[1] Patent pending (filed).

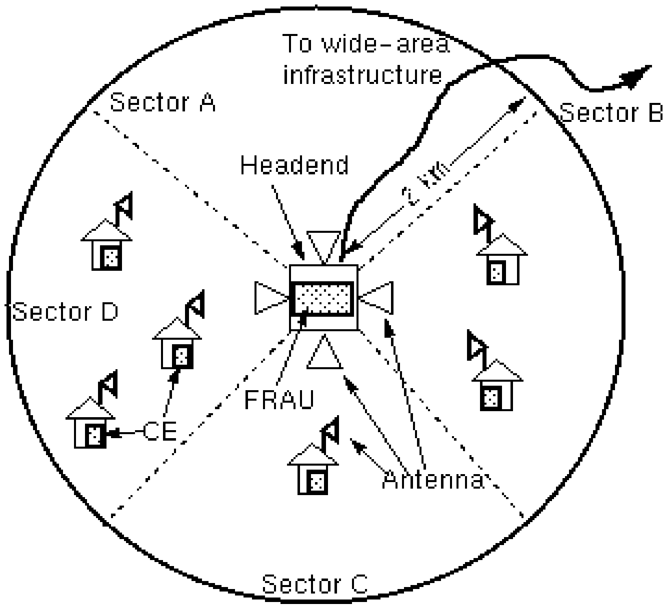

Figure 1. LMDS System Architecture

2. Design Approach and System Architecture

Figure 1 shows the architecture of our telephony system over LMDS. LMDS uses a cellular architecture with a typical cell size of about 2-km in radius [2]. Due to antenna and other system design tradeoffs, each cell can be divided into different sectors. At each headend location, an antenna is used to transmit/receive signals to/from the customers within its sector. Correspondingly, each customer has antenna to transmit/receive signals to/from the headend. We see in Figure 1 that each cell is divided into 4 sectors. At the headend, equipment can be connected to the wide-area communications infrastructure via fiber links [3]. The downstream path (i.e., headend-to-customers) is a broadcast channel in which the headend broadcasts information to the customers within the cell. This feature distinguishes LMDS from the traditional point-to-point microwave technology. In upstream direction (i.e., customer-to-headend), each customer communicates with the headend using a point-to-point link.

We use a wireless local loop (WLL) [4] architecture to deliver voice services to the customers. Comparing to other approaches, the advantage of using LMDS to build WLL's is that other services, such as video and high-speed data, can easily be integrated into the same broadband LMDS infrastructure. In this WLL architecture, Fixed Radio Access Units (FRAU's) are placed at headend locations and a Customer Equipment (CE) is placed at each customer location. Figure 2 further illustrates the WLL architecture. The FRAU has interface to the existing wire-line telecommunications infrastructure. It also executes the protocol to coordinate customer access to the wire-line network. In the downstream path, it delivers a properly conditioned IF signal (i.e., after modulation and frequency conversion) to the LMDS mm-wave/RF radio equipment. The LMDS radio equipment then frequency converts the IF signal to the LMDS band for transmission. At the customer end, the LMDS equipment receives and down-converts the received signal to a lower IF signal before delivering to the CE. The CE then performs the demodulation and later produces the original transmitted base-band signal. The upstream process is similar. The CE delivers a modulated IF signal to the LMDS mm-wave/RF equipment at the customer side. The LMDS equipment then up-converts the signal to the LMDS band for transmission. After receiving the signal at the headend, the headend LMDS equipment down-converts it to a lower IF before delivering to the FRAU for demodulation.

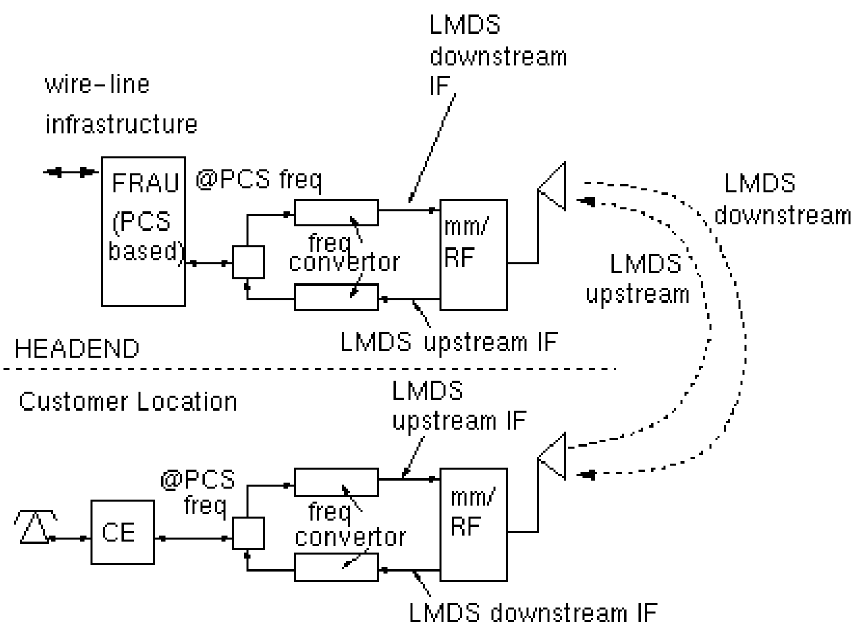

Figure 2. LMDS/PCS WLL Block Diagram

Recently, there has been strong interest in various WLL applications. Particularly, many communications techniques, ranging from analog FM to digital mobile radio, have been considered for WLL deployment. These technologies have their own characteristics. We would like to choose an appropriate technology that can achieve the following in our LMDS telephony solution.

Voice Quality: As mentioned in the introduction, it is envisioned that LMDS can be used to deploy telephone service to the home. As a result, the voice quality of the telephony solution must be comparable to that of existing wired service.

Time-To-Market/Costs: We would like our telephony solution to be based on proven technology to reduce development cost.

Tolerance to Frequency Drifts: LMDS operates at mm-wave frequency band near 28 GHz. At such high frequency, current mm-wave component technology cannot provide stable frequency source at low cost. In order to avoid expensive mm-wave equipment, particularly for customer equipment, the LMDS telephony solution must be able to tolerate frequency drifts without incurring severe impairment to voice quality.

Because of the time-to-market/cost considerations, we have found that existing wireless mobile telephony technology to be most suitable for our WLL application in LMDS. Existing wireless mobile telephony technology can be classified into two categories [5]: high-tier cellular systems and low-tier Personal Communications Services (PCS) systems. Unfortunately, all existing high-tier cellular technologies, such as analog FM, IS-54 and GSM, employ narrow frequency channels (channel bandwidth less than a couple hundred kHz). The narrow frequency channels mean that these technologies require strict frequency stability, which is hard is achieve at low cost in the LMDS frequency band. Furthermore, the digital cellular technologies, such as IS-54, IS-95, and GSM, employ speech coding to reduce their bandwidth requirements. Their voice quality is generally inferior to that of wire-line voice because their speech rates are usually more than 4 times slower than the wire-line 64 kbit/sec. As a result, high-tier cellular technologies are not applicable for integration to LMDS.

Table 1. DECT System Parameters

Frequency (MHz)	1880-1900
Multiple Access	TDMA/TDD (10 carriers)
Modulation	GMSK
Raw Bit Rate (Mbit/sec)	1.152/carrier
Speech Coding	ADPCM

Our approach is to base our LMDS WLL application using the low-tier PCS technology that is available in the market today. Due to the PCS design philosophy, all these systems support wire-line speech quality using 32 kbit/sec ADPCM speech coding. Currently, there are three different low-tier PCS systems: Digital Enhanced Cordless Telecommunications (DECT), Personal Access Communications System (PACS), and Japanese Personal Handiphone System (PHS). DECT is an European standard; while PACS and PHS are U.S. and Japanese standards, respectively. Integrating to the LMDS system can be accomplished by building frequency converters to translate their respective operating frequency to the LMDS IF frequency (Figure 2). Other system components, such as network interface and multiple access protocol, are already supported by the hardware developed for these systems. While these PCS technologies have been proposed to support WLL by themselves, the drawback of these systems comes from the fact that they are originally designed for low-power operations with long battery life. Consequently, they have only a limited practical coverage range of several hundred meters. The main advantage of our LMDS/PCS WLL approach is that we can extend coverage to about 2 km for each antenna tower, thus saving the infrastructure cost to provide service for a certain area.

As mentioned already, the LMDS/PCS WLL approach is satisfactory in terms of voice quality and development cost considerations. The remaining issue is whether these PCS technologies can tolerate frequency drifts expected in our LMDS radio equipment. We have proven our approach by developing a telephony solution based on DECT. DECT was chosen because it has the highest channel bandwidth (more than 1.5 MHz) among all the PCS candidates. As a result, it is expected to have the best frequency tolerance. Table 1 shows the system parameters for DECT. We have successfully implemented our DECT-based LMDS product. It was demonstrated in SUPERCOM'97. In the next section, we present measurement results showing the BER and frequency tolerance performance of a DECT-based LMDS telephony system.

4. Performance

In this section, we present actual measurement results showing the performance of DECT when combined with LMDS radio equipment. The goal of the experiment is to study the actual BER performance and the frequency tolerance of the integrated system. We have performed experiments using the DECT modulator and demodulator from Philips (Philips SA639). Figure 3 shows the setup for the reference experiments, which consists of connecting the DECT modulator and demodulator back-to-back without going through the LMDS system. The Bit-Error-Rate (BER) analyzer generates pseudo-random data. The data from the BER analyzer are modulated and then subsequently demodulated by the DECT demodulator. The demodulated data are then fed back to the BER analyzer. Figure 4 shows BER versus frequency offset over selected received power levels. As expected, it can be seen that frequency offset tolerance is higher for higher received power level. For voice applications, we are interested in BER of better than 10^{-3}. From the figure, we have found that frequency tolerance ranges from 30 kHz at received power of –69.3 dBm to approximately 100 kHz at received power of –57.3 dBm. This result indicates that expensive frequency drift compensation circuit is not needed.

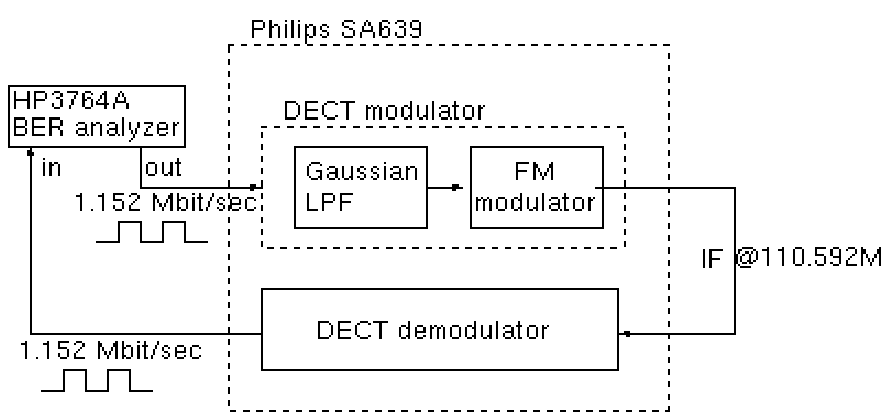

Figure 3. Reference Experiment Block Diagram

In addition to the frequency tolerance measurements, we would also like to verify the performance of DECT after it has been integrated into the LMDS system. Particularly, we would like to verify that indeed special frequency drift compensation circuit is not needed. Figure 5 shows the block diagrams for the downstream and the upstream paths for the integrated system, respectively. These block diagrams are simply the reference block diagrams (Figure 2) added with the appropriate frequency translators for downstream and upstream operations. The LMDS mm/RF system employs a free-running DRO with no phase lock loop to covert signal to/from LMDS frequency band. Figure 6 shows the BER performance of the integrated system for various values of E_b/N_o. The reference curves are obtained using the reference setup in Figure 2. It was found that the performance degradation is acceptable. There were 3 dB and 4.25 dB of degradation at BER of 10^{-6} for the downstream and upstream paths, respectively.

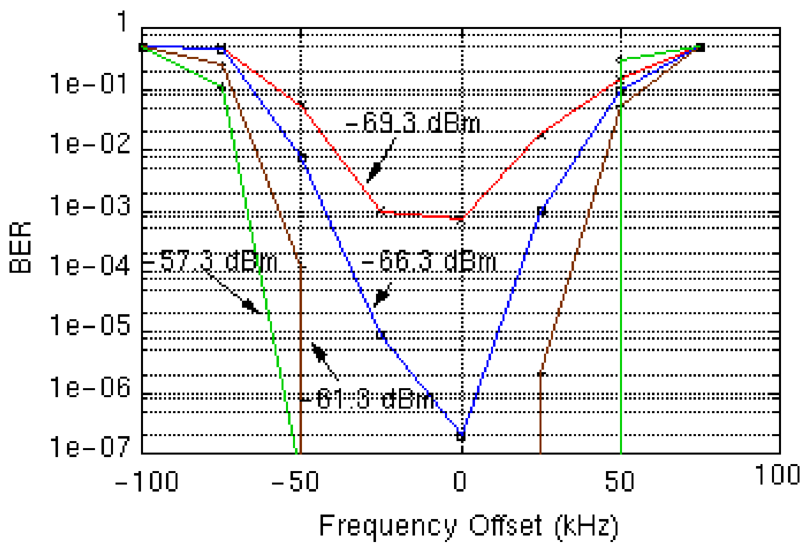

Figure 4. BER vs. Frequency Offset for Various Received Power Levels

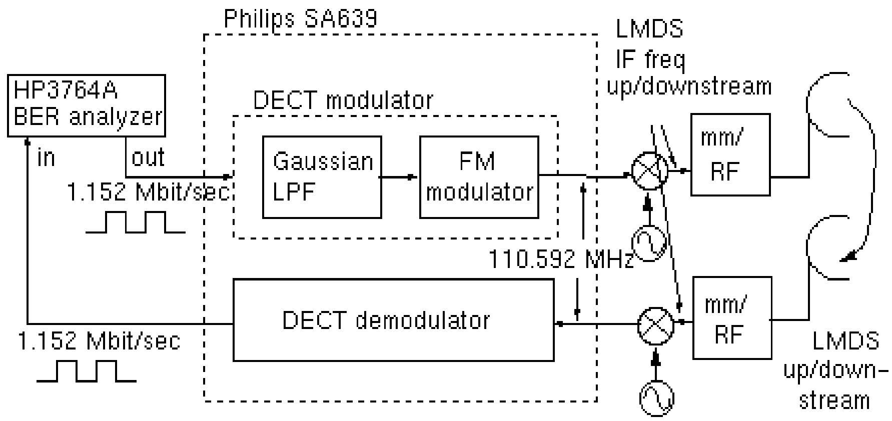

Figure 5. Block Diagram Up/Downstream Experiments

4. Conclusion

An approach to provide telephony over LMDS is presented in this paper. The telephony solution is designed using current PCS technology. A product based on the European DECT standard was developed and demonstrated at SUPERCOM'97. The advantage of the proposed telephony solution is that by using DECT or other existing PCS technology, the cost of product development and time-to-market can be reduced. Also, the LMDS architecture can effectively extend the range of existing PCS systems while integrating them to a broadband infrastructure. A service provider can therefore potentially reduce infrastructure cost by using only one tall antenna tower at the headend to deliver integrated services (i.e., telephony, high-speed data, and video) to customers within a 2 km radius at the LMDS frequency band, as opposed to deliver only voice services at the PCS band using several other antenna towers. We have also reported measurement results showing the BER performance and frequency tolerance of DECT over LMDS.

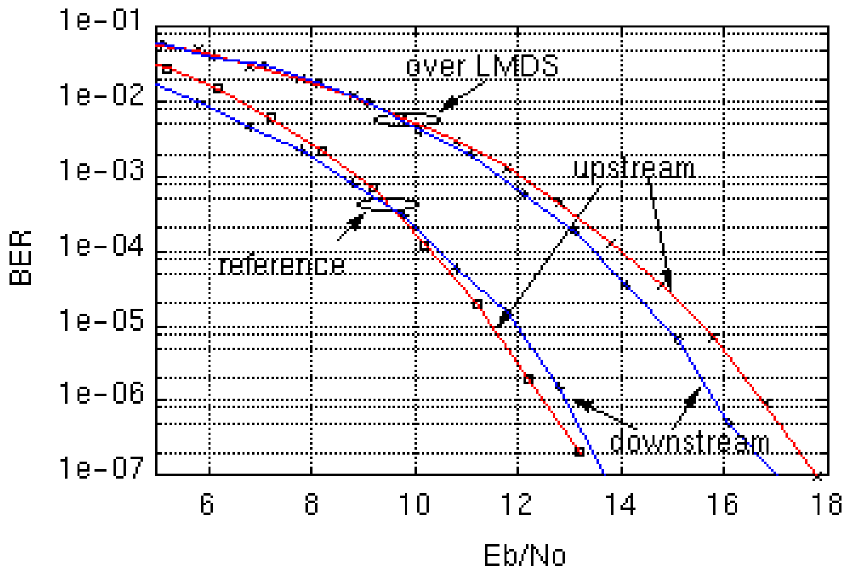

Figure 6. Performance over LMDS

5. References

[1] Public Notice DA 97-2081, Federal Communications Commission, September 1997.

[2] Gray, D. A., "Broadband wireless access systems at 28 GHz: Lower infrastructure costs, faster time to market", CED, vol. 22, no. 8, pages 46-8, 52, 54-6, Chilton Publications, July 1996.

[3] Park, J., Elrefaie, A. F., and Lau, K., "1550-nm Transmission of Digitally Modulated 28 GHz Subcarriers Over 77 km of Nondispersion Shifted Fiber", IEEE Photonic Technology Letters, vol. 8, no. 2, pages 256-258, February, 1997.

[4] Cox, D. C., "Wireless Local Loops: What Are They?", International Journal of Wireless Information Networks (JWIN), vol. 3, issue 3, 1996.

[5] Cox, D. C., "Wireless Personal Communications: What Is It?", IEEE Personal Communications Magazine, vol. 2, no. 4, pages 20-35, April 1995.