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EVALUATED FREQUENCY MODULATED SPREAD-SPECTRUM ANALYSIS

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ABSTRACT

Analog frequency modulated (FM) systems offer advantages of reliable speech quality and simplicity, whereas code division multiple access (CDMA) system promise high capacity, resistance to multipath fading, and simplified frequency planning. In this thesis, we investigate the performance of a wireless local loop (WLL) system that uses the frequency modulation with the CDMA technique. The performance of the FM CDMA system is affected by the choice of the frequency demodulation method. Performance of different state-of-art DSP based FM demodulators is evaluated. Design improvements with threshold extension, pre-deemphasis, and voice company ding techniques are explored, and the limitations of the DSP based FM demodulation methods are identified. The transmitter, the channel, and the receiver of the FM CDMA system are simulated for particular values of FM bandwidth and spread-spectrum processing gain. The capacity supported by the FM CDMA system is estimated with different levels of orthogonal as well as non- orthognal multiple access interference. The performance of the FM CDMA system in AWGN, multipath fading, Doppler spread, and nonlinear signal processing effects is predicted. A power control algorithm for the FM CDMA system is proposed, and its effect on the system performance is studied.

Keywords: Wireless Local Loop, Code Division Multiple Access.

I INTRODUCTION

Wireless local loop (WLL) enables a fixable connection of fixed subscribers to the network operations, and has become an economical tool for implementing subscriber loops in low density, rural, or third world areas. Driven by a strong customer need for the tether less access to telephone network, many organizations are spending time, money, and effort at research and development in the wireless local loop services [Cox91]. As economical advantages of wireless access to subscriber fuel the ambitions of service providers, rapid advances in RF semiconductor devices, digital signal processing technology, and VLSI methods continue to sustain the technological demands of wireless local loop implementations.

This paper investigates an analog frequency modulated code division multiple access (FM CDMA) scheme aimed at providing wireless access to the telephone net-work. The primary goal of the research is to estimate the capacity of such a

system in a variety of channel distortions. The thesis also compares different DSP implementations of the FM receiver, and identifies possible approaches for achieving capacity improvement over the FM CDMA technique as shown in fig:1

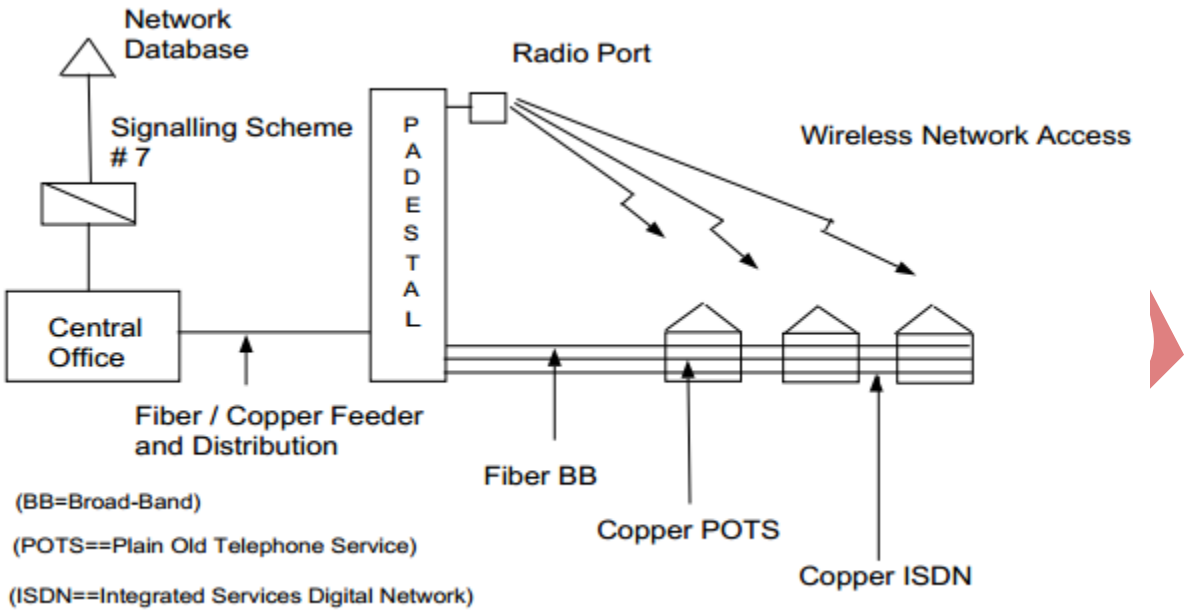

Figure1: Bellcore's Digital Radio Scheme

1.1Status of Wireless Local Loop Services

Wireless local loop design and development has attracted attention of many organizations, including Bellcore, Inter digital Corp., BNR, Qualcomm, and Analog Devices. Figure 1 shows a low power digital radio scheme developed by Bellcore. The system includes a copper feeder for providing private branch exchange (PBX) connection to several radio ports located in a central area. The digital radio system provides several wireless lines from the distributed radio ports, and coexists with the wire line services. Depending on the status of the local loop in a service area, and the level of network control sophistication, the digital radio service can be merged to a set of Personal Communication Services (PCS) .D.L.Schilling, in an article on broadband CDMA, describes a WLL service developed by Inter digital, first implemented for commercial purposes by GTE in Quitaque,Texas. The Inter digital WLL product, Ultraphone, is based on a 16 PSK TDMA system and supports four time division multiplexed channels per 25 KHz band allocation.

1.2 An Overview of Code Division Multiple Access

An ideal communication system would maximize the output signal to noise ratio (SNR) while minimizing the spectrum usage. Information theory, in agreement with our intuitive and philosophical senses, denies achieving both the goals in a system. Shannon's theorem sets a direct relationship between the performance of communication systems, in terms of output SNR, and the cost of the communication systems, in terms of bandwidth requirements. Where, E_b/N_o is signal to noise ratio (SNR) per bit, R is the data-rate in bits per second, and W is the channel bandwidth in Hertz. Accordingly, it is possible to achieve very high SNR values by increasing the transmission bandwidth W. Frequency modulation is one

practical method in which better SNR values are obtained for wideband FM signals. Another practical method is the spread spectrum technique which uses a very high frequency spreading signal to modulate the transmitted signal. United States' digital cellular standard, IS-95, is based on spread-spectrum principle.

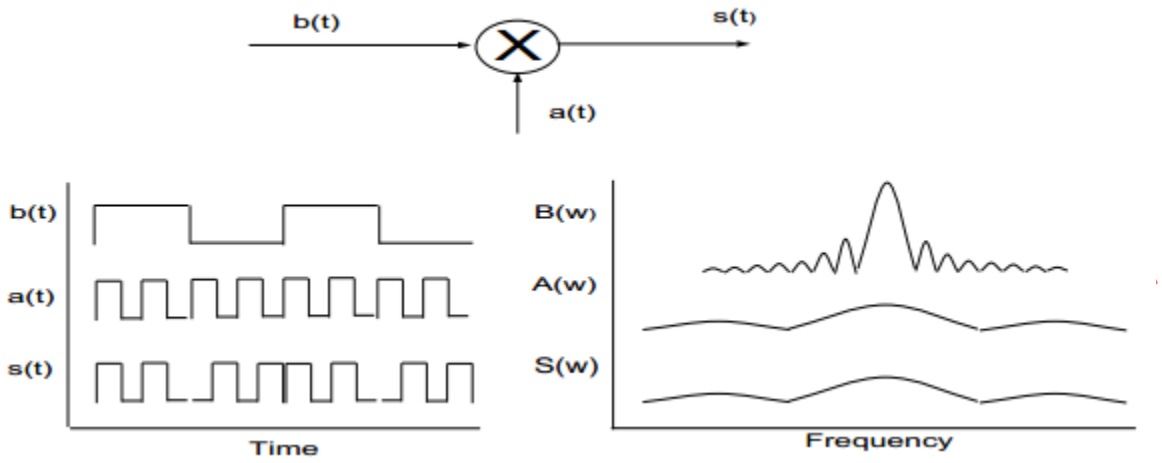

Figure 2: An Example of Spread-Spectrum Signal Generation

$$\frac{E_b}{N_o} = \frac{2^{R/W} - 1}{R/W}$$

1.3 Motivation behind the Design Choices

Frequency Modulation offers two-fold advantage over other analog modulation techniques, including Amplitude Modulation. One advantage for FM systems is realized due to the constant envelope nature of FM signal. Since all the information is contained in the phase of the FM signal, it does not suffer from amplitude fading and non-linearity effects, unlike AM signals whose performance deteriorates in such conditions. FM systems also offer an inherent way of increasing the SNR by trading band occupancy, whereas AM systems do not offer such an exchange between SNR and bandwidth.

II PURPOSE OF RESEARCH

Advantages of digital CDMA systems are now widely accepted, and are on the verge of practical realization. However, the advantages of analog CDMA systems are less understood. The purpose of the this research is to evaluate the performance, and the capacity of such systems by simulating the FM CDMA system.

The first task of the research is identification of an optimum FM demodulator based on digital signal processing techniques. Improvement in output SNR for FM demodulators by means of pre-deemphasis (PDE), and companding techniques are estimated. A lower limit, or threshold, on the operation of FM demodulators is determined, and an estimate of the extent of threshold extension possible due to the receiver operating above the threshold is evaluated. Various

objective voice quality measures, such as mean squared error (MSE) and SNR at the output, segmented SNR, and distribution functions of segmented SNR values are used, apart from the subjective voice quality evaluations.

III SYSTEM DESCRIPTION

WLL system development encompasses a broad range of design and implementation challenges. This chapter provides an introductory treatment of various FM CDMA WLL engineering issues such as cell and frequency planning, air and wire line interface protocols, and system evolution strategies. The base-station and user phone architectures of the FM CDMA WLL system are described, and a framework for the remainder of the thesis is built.

3.1 FM CDMA WLL Engineering Issues

The main components of the WLL system are shown in Figure 3. The system provides tetherless connection between the base-station and the user phone. The system does not support hand-o, and roaming user identification typically associated with cellular mobile radio networks.

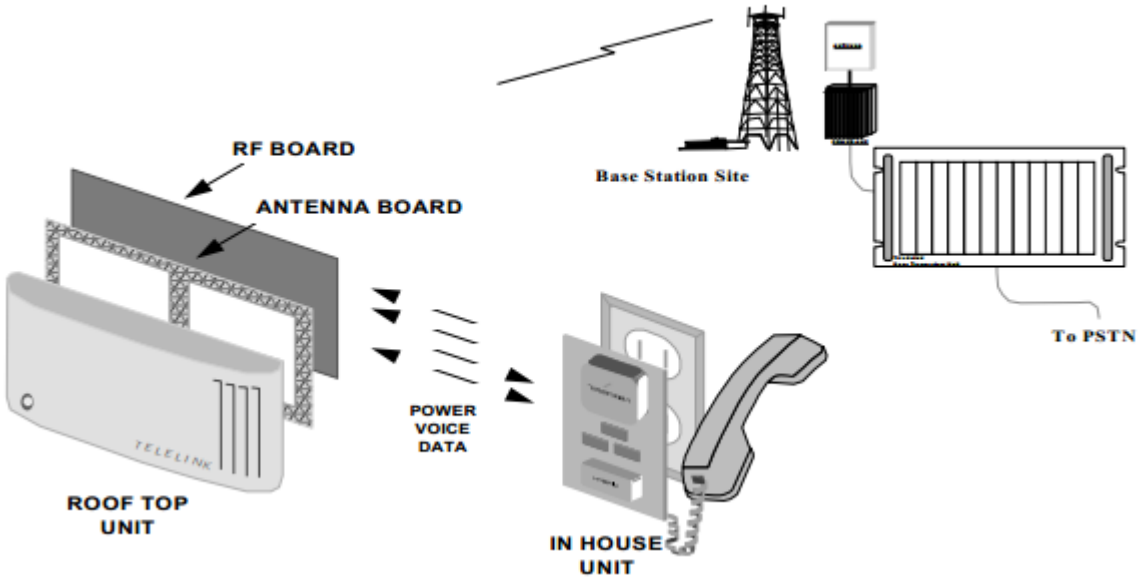

Figure 3: Elements of Wireless Local Loop System

IV CONCLUSIONS

Exploring the performance and the dynamic ranges of various DSP algorithms for the FM demodulation is the major task of the research. The results pertaining to the di erential FM detection, the quadrature FM detection, and the arctangent FM detection are presented in the third chapter. More advanced FM demodulation algorithms, such as the PLL based FM detection and the zero crossing detection, are also developed and their output SNR characteristics are compared with the three basic FM receiver structures. We observe that the differential and the quadrature method are simple and robust FM demodulation techniques, the arctangent method is a more elegent DSP technique (since it does not require an explicit

phase extraction), and the PLL and the zero-crossing detectors have a greater complexity, but they also over the potential of the threshold extension.

Even though, the work on the FM CDMA system evaluations encompasses the major study aspects, there are many limitations on the scope of the research. This research focused on the physical link of the FM CDMA system. An equally challenging task is to develop and optimize the network layer issues associated with the WLL systems. Investigations pertaining to the transponder algorithms at the base-station or at the system switch, the call set-up and termination procedures, and the interface of the WLL system with existing digital telephone network are the examples of important practical work that may be very helpful at the time of the system deployment.

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