CODE DIVISION SPREAD SPECTRUM TECHNIQUES FOR 900MHz, 2.4GHz WIRELESS TELEPHONE AND PABX APPLICATIONS

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Abstract

Before wireless local loop can reach the mass market, consumer cordless telephones will have to achieve similar performance levels to drive the scale economy on critical components. A new spread spectrum technique for consumer cordless telephones and PABX is described in this paper. It would offer the extended range, power tuning, voice quality and user density of the Code Division Multiple Access (CDMA) principle and at the same time achieve a cost level suitable for mass market production.

1. Introduction

Spread spectrum modulation technique as implemented in the Code Division Multiple Access (CDMA) principle offers many real advantages over existing time division or frequency division approaches. These advantages have been proven in military and aerospace applications in the past forty years. Because of this heritage, the overall complexity of the first generation CDMA systems tend to render themselves unsuitable for cost conscious consumer products, notably in cordless telephones and wireless PABX applications. This paper will describe an alternate implementation of the basic CDMA principle with user cost benefit tradeoff as the primary focal point.

The following approach, called Code Division Spread Spectrum (CD/SS), reduces system complexity by balancing the cost performance between the front end radio frequency (RF) circuit with the base band modem through digital compensation and mathematical coding techniques. The CDMA timing acquisition through global positioning (GPS) is replaced with a simple master slave synchronization scheme. The complexity of numerical DSP is replaced by a 1-bit analog to digital converter (ADC) to eliminate arithmetic elements in the base band processor. Since 1-bit quantization is used, high resolution automatic gain control (AGC) is no longer required in either the radio front end or in the digital signal processor, thereby further reducing cost and improving ease of manufacturing. The critical CDMA feature in employing long pseudo-random (PN) code to achieve high processing gain is however preserved and improved through the use of multiple symbol encoding method. Based on multiple symbol encoding, a high bit rate is achieved by using minimum shift keying (MSK) without resorting to the more complicated quadrature phase shift keying (QPSK) approach and reduces RF cost. Extensive forward error correction coding (FECC) and a simple space diversity antenna (SDIV) algorithm are also implemented due to their performance gain per transistor as measured by experimental test results. With these cost optimization, a second generation 900MHz digital cordless telephone handset can be implemented in less than $30 by early 1997. The architecture summary of CD/SS is compared to CDMA and direct sequence spread spectrum (DS/SS) in the table below.

	DS/SS	***CD/SS***	***CDMA***
Number of PN codes	1 set	Multiple sets	Multiple sets
PN assignment	Pre-determined	Pre-determined	Real-time assigned
Quantization	1-bit	1-bit	multiple level
Gain control	AGC not required	AGC not required	multiple AGC
Synchronization	various	Master-slave	GPS synchronization
Bit rate per symbol	low	high	high
Target applications	data	voice & data	voice & data

2. Implementation experience

Lanwave Technology has designed a CD/SS voice and data transmission system operating in the 900MHz unlicensed RF band based on the above principles. The cost performance tradeoff has been measured in subsequent laboratory and field trial results. This paper will focus on these results and the conclusions on the findings. The system block diagram below describes a typical wireless handset for a digital CD/SS cordless telephone or a wireless PABX key phone system.

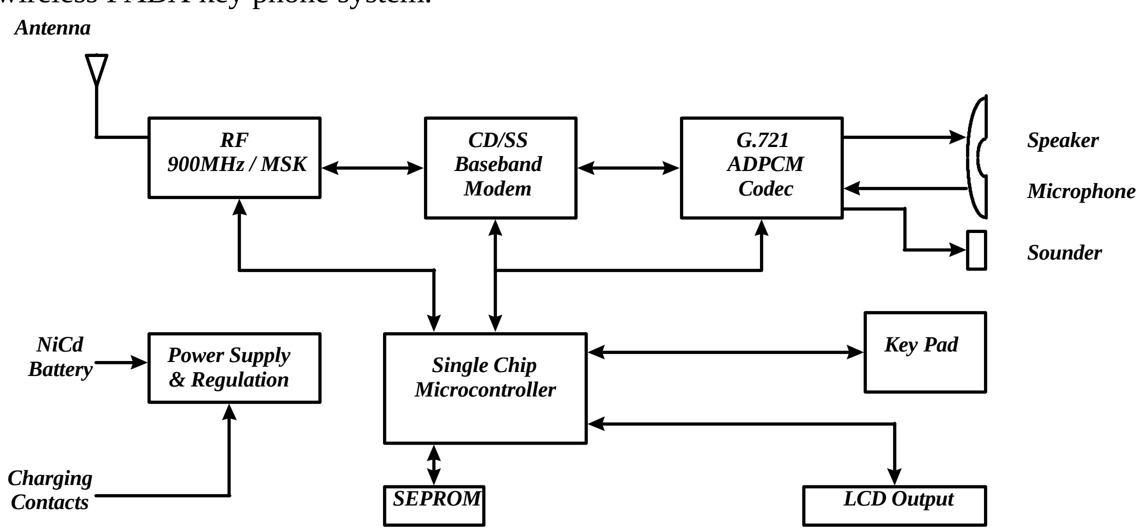

Figure 1. CD/SS handset architecture

2.1 RF sensitivity beyond the background noise brings diminishing return

Considerable cost savings can be gained by reducing unneeded RF receiver sensitivity. Receiver sensitivity, S, is expressed at ambient temperature by the following equation:

$$S(dBm) = -174(dB) + NF(dB) + 10\log(BW) - Gp + (Eb/No)$$

where

NF = receiver's noise figure.
BW = IF bandwidth = 2* (FSK deviation + PN code rate)
Gp = Processing gain = 10 log(PN code rate/ data rate)
Eb/No = bit energy to noise ratio, 11.2 dB for 10^-6 BER with differential coherent phase modulation.

In military designs, significant cost and energy is devoted to the improvement of the receiver's noise figure (NF). For consumer products, however, little can be gained if S is beyond the background noise level (other than the use of high processing gain coding.) Actual test data shows that this background noise ranges in between -80 to -100dbm in a residential neighborhood depending on the time of day and the environment. This provides a threshold for radio designers to optimize on RF component selection.

2.2 The cost of a QPSK modem is embedded in its phase recovery circuit

Coherent detection schemes like QPSK offers higher channel usage. But in a consumer product, where cost is a primary concern, channel usage can be compromised without affecting user benefit. By using non-coherent detection schemes like BPSK or MSK, RF circuit paths are simplified and thereby reduces cost. In addition, the elimination of the phase recovery circuit reduces manufacturing complexity and opens up more component options such as the newly available single-stage frequency converters.

2.3 1-bit DSP is feasible, when used in conjunction with long PN codes

CDMA base band processor use complex DSP techniques on high resolution quantized signals. In CD/SS, a 1-bit quantization approach is used to reduce demodulation circuits to a few match filters. This also eliminates the need for automatic gain control. To increase signal resolution, a longer PN chip length is employed in the time domain.

2.4 Multiple symbol encoding offers SNR benefits with little sacrificed data rate

In a sparse user environment, there is more room for a high jamming margin using orthogonal codes than to employ differential phase coding based on the same investment – if these codes are selected carefully. The cost factor is therefore shifted from the phase recovery circuit to mathematical coding. As the base band processor can typically control synchronization to within several chip periods, a significant number of codes can be found that satisfies these coding requirements.

2.5 Telephone hybrid imbalance is a real world reality

Acoustic echoes generated from telephone line or hybrid impedance mismatches are amplified by the buffering process after the voice codec. The amount of audible echo is related to the time division (TDD) frame size of the base band processor. A typical frame size of 5 to 10ms will produce audible echoes. Empirical data suggest that frame sizes of less than 3ms will lower echo to acceptable levels for human ears. This approach eliminates the need for costly digital echo cancellation currently employed by other telephone chip sets like in the DECT (Digital European Cordless Telephony) systems.

2.6 Simple forward error correction code will save 50% of transmission power

The need for data integrity is stem from the need to send command protocol error free between handset and the base unit (rather than for voice clarity). This will result in transmitting excess energy during the voice mode. A simple application of forward error correction code has resulted in a measurable improvement in battery life.

In addition to these findings, the experimental data has also verified the following:

- The most likely jamming source in the neighborhood is yourself
- Antenna diversity can be implemented in a low cost algorithm
- PN code is more secure when assigned off the air
- Master-slave synchronization is sufficient for the non-terrified, micro cell environment at home or in the office

3. Conclusion

By the extensive use of mathematical coding techniques and exercising careful cost benefit analysis in the design of RF and digital circuits, CD/SS has been able to apply the benefits of CDMA at an acceptable cost level to the consumer product manufacturer.

These techniques have been applied to a cordless telephone reference design and is being implemented in several telephone models.

References

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Mr. Kenneth Chan

Mr. Kenneth Chan is the President and CEO at Lanwave Technology, Inc.

Mr. Chan has 20 years of engineering and management experience in United States and Asia. From an R&D background in General Electric, Syracuse New York, and DSP modem design at startup Intertel, Inc. in Andover Massachusetts, he moved into semiconductor management in 1984. He holds a BSEE, MSEE and MBA degrees from Cornell University and was named Post Scholar for distinction. From 1987 to 1991 he was in charge of Asia PC marketing for Advanced Micro Devices stationing in Hong Kong, and from 1992 to 1995 was responsible for the high speed networking IC business at National Semiconductor in Sunnyvale, California.

He started Lanwave with private venture capital in 1996 to bring the digital wireless technology into the consumer semiconductor market.