Chapter 1. Introduction
1.1 Overview

Over last two and half decades, the success of cellular system has revolutionized the wireless industry [1]. But the tremendous growth of wireless users [2] has put forth many challenges for wireless communications [3]-[4]. These challenges include accommodation of more users, needing for more spectrum, immunity to interferences from simultaneous users [5]-[8] etc. Engineers and researchers are putting many efforts to bridge these demand and supply gaps. Available spectrum is limited [9] which have posed growing pressure on wireless industry for efficient utilization [10] of available spectrum. Adding spectrum is not one of the enduring solutions to the above challenges. Therefore either new technology is to be evolved or existing technology to be modified for spectral efficiency. In this direction spread spectrum technique has emerged as one of the most popular tools to mitigate many issues [11] of wireless communications.

Since 1950, the spread spectrum systems have been developed, and initially, its applications were restricted for military to hide the data from enemy as an anti-jamming tactical communications [12]. In this technique the signal occupies the bandwidth [13]-[14], which is greater than the minimum necessary, for sending the information. Two methods, namely, (i) direct sequence spread spectrum (DSSS) [15] -[22] and (ii) frequency hopping spread spectrum (FHSS) [23] -[31] are used for spread spectrum communication. In the DSSS, fast pseudorandom sequence causes phase transitions in the carrier using different modulation techniques. In the FHSS system, pseudorandom sequences cause the carrier to hop from one frequency to another frequency.

To enhance system capacity/spectral efficiency, by accommodating a number of users on a single channel, different multiplexing techniques [32], namely, (i) time division multiplexing (TDM), (ii) frequency division multiplexing (FDM), (iii) code division multiplexing (CDM) and space division multiplexing (SDM) are used. In TDM, [33] successive intervals of time are assigned to the different uses. During these intervals the bits of information from all channels are transmitted in rotation. At the receiving terminal the pulses are sorted out according to their time of arrival, and
diverted to their respective channel. In FDM [34], the total available bandwidth is
divided into a series of non-overlapping sub bands, and each of them is dedicated to
each user. As compared to TDM, FDM occupies more bandwidth; therefore it is not a
bandwidth efficient system. CDM [35] is most bandwidth efficient technique and used
for commercial applications by allowing several users to communicate simultaneously
on common channel using pre-assigned code sequences. SDM [36]-[38] is more
recently evolved technique for higher speed requirement of 4th and 5th generation. It
utilizes the spatial separation of users. In these techniques all users are allowed to
simultaneously share the common medium.

Further, the advancement in VLSI technology and signal processing [39]-[40] has
played a dominating role to settle down some of the challenges of wireless
communication by improving the quality of service, reduced power consumption,
enhanced system capability and capacity [41]-[43]. Many signal processing techniques,
such as filtering [44]-[45], equalization [46] -[49], detection [50] -[51], pulse shaping
[52], demodulation [53] -[55], frequency to voltage converts (FVC) [56] -[58] etc., are
evolved to enhance the performances of the communication devices.

This work discusses the design of multi-channeling (multiplexing) scheme using
spread spectrum techniques for increasing channel capacity and performance evaluation
of designed system. The proposed BPSK demodulation for demodulating has been
studied for its performance. The sinusoidal FVC techniques have been studied for
improving the performance of wireless FHSS communication systems and for wide
band operation with very good linearity.

1.2 Multi-channel Communications
Since the origin of electronic communication there has been a requirement for providing
simultaneous transmission of many messages using single transmission media [33] -
[34]. Initially time division and frequency division multiplexing schemes were evolved
to increase the channel capacity [33]-[34]. The growth of users aggravated the capacity problem [59] and has caused an accelerating pressure on efficient use of bandwidth. The solution to the problem of efficient bandwidth utilization has emerged during 1950 and 1960, when researchers at Bell laboratories developed the cellular concept [60]. This concept exploits the fact that the power of transmitter signal fall off with distance therefore frequency reuse is possible at spatially separated location and hence more capacity. The founders of quality communication (QUALCOMM) developed CDMA technology for commercial cellular communications [1]-[61] to make even better use of the radio spectrum than other techniques for multiple accesses.

Code division multiple access (CDMA), is a spread spectrum technique in which each user is allocated signature code so that it can occupy same frequency spectrum simultaneously with the other users [15] -[16]. Therefore, CDMA systems can operate at much higher interference levels because of its interference resistance capability [61]. Along with this it provides multiple access capability with much higher capacity over other existing techniques like time division and frequency division multiplexing, high resistance to jamming, intentional interference therefore it is the most promising multiplexing technologies for current and future telecommunications services which has attracted it for future technology [35]-[36].

1.3 Open Issues in Multi-channel Wireless Communication
The resources those make wireless communications possible are limited. The one of the most important resource is bandwidth (spectrum). At the same time, the growth in the number of wireless users [2] has caused pressure on efficient use of available bandwidth [3]-[4]. The initially developed wireless systems for telephony have used 120 KHz of bandwidth and immediately the bandwidth was cut down to 60 KHz to accommodate more number of users by improving the technology [1]. It has doubled the channel capacity but there was a long waiting list of more users demanding to have wireless access capability. Seeing the growing number of users, in 1989 an additional
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spectrum of 10MHz was released to address these waiting users. With the advancement in very large scale integration (VLSI) and digital technology, in late 1991, the first US Digital Cellular (USDD) has supported 3 users in 30 KHz bandwidth and improved the channel capacity by three times. But this improvement in channel capacity was insufficient to cater all users. A better solution for capacity enhancement was proposed by QUALCOMM using spread spectrum based CDMA [61]. The rise in the number of wireless users will continue in future also due to population growth and technological advancement for more services. These factors are enhancing the pressure on existing technology. Further, the mounting pressure is not alone due to the exponential growth in the number of users; it is further accelerated by demand for high data rate, better quality of service, degradation due to interference, noises etc.

Therefore, these issues were developed since the origin of communication system because of a gap in demand and supply. The technological advancement is continuously trying to fill the gap by advanced signal processing techniques and will continue in future also. The main issues of multichannel wireless communications are bandwidth efficiency, better channel capacity and improvement in signal to noise ratio.

1.4 Objectives

The main objectives of this dissertation are as follows:

- To design and simulate the proposed Code phase shift keying (CPSK) based DSSS transceiver for a multi-channel using Sallen-Key filter.
- To design and simulate the proposed CPSK based DSSS receiver for a multi-channel using a proposed demodulator for improvement of BER performance under noise and jamming in comparison to the CPSK based DSSS transceiver using Sallen-Key filter
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- To design and simulate code M-ary frequency shift keying (CMFSK) based FHSS transceiver for multi-channel using BPF.
- To design and simulate the CMFSK based FHSS receiver for multi-channel using proposed sinusoidal FVC for improvement of BER performance under noise and jamming

1.5 Contributions

The conclusions of this research work along with key contributions are summarized as below:

1. Design and implementation of CPSK based DSSS transceiver for accommodating 4 users has been made. It has been found that without an increasing frequency band, numbers of users are increased by the same DSSS system and at the same time BER is less.
2. The proposed BPSK demodulator has been studied for DSSS system in order to reduce the BER further for DSSS.
3. Design and implementation of M-ary FSK based FHSS transceiver for accommodating 4 users has been studied and design along with performance evaluation.
4. R-C based FVC has been proposed for simplification of the FHSS circuit as the design of narrow band pass filter is critical requiring more order of the filter. It was also found that the proposed FVC provides linear frequency to voltage conversion over a wide range of frequency.

As a future prospect, one can try to implement the transceiver with the increase number of users (more than four) using CPSK based DSSS and M-ary FSK based FHSS systems. It is also seen that although a DSSS system requires less number frequency than that of FHSS system, the BER performance for later system is better than that for former system. So it is required to propose and develop a FHSS system with less
number of frequencies without degradation of BER performance. Another issue to be looked at the future is signal safety or security.

1.6 Thesis organization:

The structure of this thesis is as follows:

**Chapter-2: Overview of Spread Spectrum Signaling for Wireless Communications**  – This chapter reviews the PN sequences with properties and types. The basic theory of single user DSSS, CPSK based DSSS, FHSS, M-ary FHSS, Slow and fast FHSS are presented here. Previous work in multiplexing, M-ary keying and multiple accesses techniques along with AWGN and intentional noise (Jamming), are discussed briefly.

**Chapter-3: Review of Multiplexing and Multiple Access Techniques and their Evaluation for Wireless Communications**  – In this chapter a literature review is presented that describes existing multiuser/multiplexing system for accommodating more number of users. Brief history of multiplexing techniques such as, TDMA, FDMA CDMA AND SDMA is discussed. We have also surveyed sinusoidal frequency to voltage converter (FVC) for wider band of frequencies and existing binary phase demodulator.

**Chapter-4: Design and Simulation of CPSK based Multi-Channel Direct Sequence Spread Spectrum System**  – This chapter presents architecture and working principle of CPSK based transceiver for accommodating K-users. Further this chapter concentrates on the design and performance test of the proposed system for accommodation of four users to show the concept of using CPSK technique for bandwidth efficiency. The proposed technique for BPSK demodulation, using BPSK to ASK converter and peak to peak detector has been explained here.

**Chapter-5: Performance Evaluation of CPSK based DSSS System**  – In this chapter the performance analysis of CPSK based DSSS transceiver is presented. Performance is
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discussed under AWGN, jamming and due to phase mismatch. Performance analysis of
designed system is carried out with the simulation setup using Microsim software.

Chapter-6: Design and Simulation of Multi-Channel Frequency Hopping Spread
Spectrum Spread Spectrum Communication System using coded M-ary Frequency Shift
Keying – It describes the architecture of transceivers for K-users using the CMFSK
based FHSS technique. Further, this chapter describes the design and simulation of the
system for accommodating 4-users. P-Spice simulated circuit using band pass filters
(BPF) for transceiver has been presented the Chapter. Proposed wide band FVC has
been discussed along with its performance for response time, linearity, and ripple
calculation

Chapter-7: Performance Evaluation of CMFSK based FHSS System – This Chapter
high lights analytical evaluation of symbol error rate (SER) and bit error rate (BER) s
performance of the designed FHSS system under AWGN. Jamming and BER
performance has been investigated with simulations. Chapter also presents the
performance of designed device with proposed frequency to voltage converter (FVC)
using P-Spice simulation model. Section Eye diagram analysis for noise margin and
distortion also discussed. Finally, the experimental traces obtained from experimental
measurement are presented.

Chapter-8: Conclusion and future scope – This chapter summarized the thesis
conclusion with the future scope of this PhD research work.

References
Wireless Communications and Networking Conference Workshops (WCNCW’12),
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