CHAPTER 1

INTRODUCTION

1.1 Overview

Historically, parallel or multicarrier radio modems have been the first high frequency modem to provide high datarate wireless communications. In particular in the 1960's, this technique was used in several HF military systems viz., Kineplex [Doelz, 1957] and Kathryn [Bello, 1965]. High datarate serial radio modem appeared as soon as it was possible to implement adaptive algorithms that are required for equalization. Nevertheless, the equalization algorithm became more and more complex when higher datarate needed to be transmitted over the HF band and hence a parallel or multicarrier solution was called for.

A multicarrier modem system is a technique that transmit data by dividing it into several interleaved bit streams and using these to modulate several subcarriers in turn. It has been shown to be an effective technique to combat multipath fading in wireless communication systems. It has been successfully used for military HF radio applications and is also the standard for digital audio broadcasting and digital terrestrial TV broadcasting in Europe and high-speed wireless local area networks.

This thesis will evaluate the performance and perform a throughput analysis of a multicarrier radio modem employing Differential Quaternary Phase Shift Keying or DQPSK in a Rayleigh fading radio channel affected by additive white Gaussian noise or AWGN. The majority of multicarrier modems in the market uses coherent modulation as the digital modulation methods. This project thesis concerns about the use of DQPSK since it is not very sensitive to phase error (as in the case of a coherent system) and also comparatively simpler and cheaper to implement.

1.2 Objectives

This research work investigates the performances of a multicarrier radio modem system using DQPSK with 2-bit encoding as the digital modulation method in the presence of AWGN environment only as well as AWGN with Rayleigh fading channel. It will also compare the performances with binary DPSK modulation which uses single bits to encode sequences of binary data. A throughput analysis of the system will also be presented for the multicarrier DQPSK case.

In the past several years, there have been many studies being carried out concerning multicarrier systems for use in a wide variety of wireless communications applications mainly using coherent PSK and QAM as the digital modulation methods. The great interest is due to their bandwidth-efficient property and good error performances in a challenging radio environment. But these are complex coherent systems that require the use of expensive receivers with equalization for carrier phase recovery in order to prevent phase ambiguities in the detection process at the receiver.

For the purpose of this research work, the candidate will attempt to investigate the use of DQPSK modulation with 2-bit differential encoding. In this technique, the information is encoded in the phase transitions rather than in the actual phase value. The process of differential encoding, phase shift keying, detection and differential decoding is immune to any phase ambiguity and allows suboptimum differential detection to be carried out. In this case, a carrier phase recovery circuit is not needed since the relative phases of the consecutive received symbols is what is important. And this suboptimum detection strategy is an attractive proposition in wireless applications where phase changes are difficult to track without expensive hardware.

The multicarrier HF radio modem system for this project also uses the (inverse) Fast Fourier Transform technique to orthogonally multiplex many narrow subchannels, each signalling at a relatively low rate, into one high datarate channel. With each subchannel signalling at a low rate, the multicarrier technique can provide added protection against delay spread. To enhance the behaviour of the system in a heavily frequency-selective HF environment, bit-interleaving of the symbol data will also be performed in order to randomize the data for better detection process at the DQPSK receiver. This is achieved by differentially encoding the input data stream between frames across the time axis making up the multicarrier signal.

1.3 Scope

There are generally two classes of HF radio modems in use today, viz. the singletone or serial (ie. singlecarrier) system and the multitone or parallel (ie. multicarrier) system. This project thesis is a comparison study on the bit error rate performances between multicarrier DPSK systems with a multicarrier DQPSK system in an HF channel corrupted with AWGN noise only as well as one which is corrupted with AWGN noise and at the same time affected by slow (Rayleigh) fading. A throughput analysis of the multicarrier DQPSK system will also be carried out in order to determine the parameters involved which affects the performance of the radio modem. As a start, error rate performance comparisons will be made between singlecarrier QPSK and singlecarrier DQPSK in order to show that coherent systems have better error rate performances compared to differential systems. Subsequent to that, comparisons between DPSK and DQPSK multicarrier systems will be made. The Rayleigh fading radio channel has been chosen as it closely resembles the actual channel characteristics of current HF radio channels in which the great majority of signal transmission and reception are non line-of-sight with multipath condition. Measurements confirm that the short-term statistics of the resultant signal envelope approximate a Rayleigh distribution.

1.4 Problem Statement

Current multicarrier modulation systems employing coherent PSK and QAM have several disadvantages – they have good error performance quality but require complex and expensive filter banks as well as channel equalizers at the receiver. However the luxury of an expensively-designed multicarrier systems mentioned above could be economically-justified by telecommunications and broadcasting operators worldwide due to the high returns involved.

But if cost is a factor as in the provision of rural telecommunication services or in military applications where long-distance repeaterless communication is a necessity without third party involvement (like the use of an intermediate satellite link that can be open to sabotage and enemy transgression), then alternative but cheaper designs which can be more secure will have to be considered (The ionosphere, over which HF communications takes place, unlike satellites, cannot be destroyed). One possible approach is to use some form of differential modulation and demodulation technique for transmission and detection. Singlecarrier DQPSK by itself does not produce very good error performances compared to coherent PSK and QAM systems. But it could be implemented in systems requiring simpler designs with cost-effective receivers. Therefore if it is to be implemented in conjunction with a multicarrier system with the inherent advantages that it can offer like reduction of multipath effects and intersymbol interferences, it will definitely help improve the error performance statistics apart from being comparatively simpler and cheaper to design since now the requirements of channel filtering and carrier recovery circuits as well as equalization can be done away with.

1.5 Research Methodology

Literature reviews on the topics related to HF multicarrier implementations are necessary in order to have a clear understanding on the research areas currently undertaken or that which have already been carried out by researchers worldwide. It is also crucial to understand the assumptions made and the aspects which have been taken into considerations that contribute to the development of HF multicarrier systems. For this purpose, on-line publications from IEE and IEEE are of great help.

From the reviews that have been done by the candidate up to this point in time, it was discovered that the vast majority of HF multicarrier systems are being implemented using coherent modulation methods which are either PSK-based or QAM. These methods require the use of expensive filtering and equalization techniques in order to transmit signals in a bandlimited and challenging channel environment apart from having to mitigate the effects of a non-uniform (ie. variable) and fading channel. However, there must be good reasons to support these trends which might be due to the very good error performances attained by those modulations.

But it must also be pointed out that this is true for commercial communication systems like wireline assymetric digital subscriber line or ADSL for fast internet access, digital line-of-sight microwave transmissions, terrestrial digital radio and television broadcasting systems, data transmission over mobile cellular channels as well as in wireless LANs where there exist large subscriber bases in addition to their usage being already well established. This is unlike the case for long-distance and repeaterless wireless military applications as well as for rural telecommunications.

In order to generate the data signal, encode it, modulate, transmit and thereafter affected by AWGN with multipath fading on the channel, an analysis on the error performances of the multicarrier system at the receiver after demodulation and detection process could be done with programs written and simulations carried out. For this purpose, Matlab 6 will be used as the computer programming and analysis tool that will help in the simulation work. This requires then that the candidate be proficient in programming using Matlab. Books and references that deal with programming communication systems using Matlab will have to be consulted. Subjects that have been taken by the candidate during the course of this masters programme have become invaluable. These include Advanced DSP and Advanced Digital Communication Systems which have been previously taught by this candidate's supervisor.

At the end of this research work, comparisons on the error performances between multicarrier DPSK with multicarrier DQPSK system in a Rayleigh fading radio channel will be carried out and results compiled, tabled and graphed.

Throughput analysis concerning the performance of multicarrier DQPSK radio modems will also be performed in order to determine the parameters that may further affect its performance.

It is predicted that it will lead to the following conclusions:

(a) The error rate performance of QPSK will be better than DQPSK for the case of singlecarrier HF modems.

(b) The error rate performance of multicarrier DPSK will be better than multicarrier DQPSK with the exception that multicarrier DQPSK is more spectrally-efficient than the former. Therefore if higher SNR is available, then DQPSK is more attractive due to its higher capacity.

(c) Lowering the transmission rate through the HF radio channel will improve the bit error rate and throughput performance for a given SNR for a multicarrier DQPSK modem.

(d) Increasing the block or packet length through the HF radio channel with data transmission rate constant will improve the throughput performance of the DQPSK multicarrier modem.