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Performance Analysis of Multicarrier DS-CDMA System Using BPSK Modulation

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Abstract: ***In this paper we apply a multicarrier signalling technique to a direct-sequence CDMA system, where a data sequence multiplied by a spreading sequence modulates multiple carriers, rather than a single carrier. The receiver provides a correlator for each carrier, and the outputs of the correlators are combined with a maximal-ratio combiner. This type of signalling has the desirable properties of exhibiting a narrowband interference suppression effect, along with robustness to fading, without requiring the use of either an explicit RAKE structure or an interference suppression filter. We use band limited spreading waveforms to prevent self-interference, and we evaluate system performance over a frequency selective Rayleigh channel in the presence of partial band interference. There is no interference from the CDMA signals to the existing microwave systems. Thus, there is no need for either a narrowband suppression filter at the receiver or a notch filter at the transmitter. This paper specially analyses the BER performance under Rayleigh fading channel conditions of multicarrier DS-CDMA in presence of AWGN (Additive White Gaussian Noise) using BPSK modulation for different number of subcarrier, different number of users using MATLAB program***

Keywords: CDMA, multicarrier-CDMA, AWGN, BER, Rayleigh fading channel

I. INTRODUCTION

Direct sequence spread spectrum (DS-SS) techniques to multiple access communications [1]. This is partly due to its multiple access capability, robustness against fading, and anti-interference capability.

In direct sequence spread spectrum, the stream of information to be transmitted is divided into small pieces, each of which is allocated across to a frequency channel across the spectrum. A data signal at the point of transmission is combined with a higher data-rate bit sequence (also known as a chipping code) that divides the data according to a spreading ratio. The redundant chipping code helps the signal resist interference and also enables the original data to be recovered if data bits are damaged during transmission.

A. Multicarrier DS-CDMA

In this paper, we propose a multicarrier DS SS system [2] [3] in which a data sequence multiplied by a spreading sequence modulates M carriers, rather than a single carrier. The receiver provides a correlator for each carrier, and the outputs of the correlators are combined with a maximal-ratio combiner. This type of system has the following advantages: First, a multicarrier DS SS system is robust to multipath fading, second, a multicarrier system has a narrowband interference suppression effect and finally, a lower chip rate is required, since, in a multicarrier DS system with M carriers, the entire bandwidth of the system is divided into M (not necessarily contiguous) equi-width frequency bands, and thus each carrier frequency is modulated by a spreading sequence with a chip duration which is M times as long as that of a single-carrier system. In other words, a multicarrier system requires a lower speed, parallel-type of signal processing, in contrast to a fast, serial-type of signal processing in a single carrier RAKE receiver [6]. This, in turn, might be helpful for use with a low power consumption device.

In fact, multicarrier DS systems have already been proposed, and these proposed techniques can be categorized into two types, a combination of orthogonal frequency division multiplexing (OFDM) and CDMA or a parallel transmission scheme[8] of narrowband DS waveforms in the frequency domain. In the former system, a spreading sequence is serial-to-parallel converted, and each chip modulates a different carrier frequency. This implies that the number of carriers should be equal to the processing gain, and each carrier conveys a narrowband waveform, rather than a DS waveform. In other words, the resulting signal has a PN coded structure in the frequency domain. In the latter system, the available frequency spectrum is divided into M equi-width frequency bands, where M is the number of carriers, typically much less than the processing gain, and each frequency band is used to transmit a narrowband DS waveform. In fact, both systems show a similar fading mitigation effect over a frequency selective channel. However, the latter system requires only M adaptive gain amplifiers in the maximal ratio combiner, which may simplify the receiver. The system described in this paper belongs to the second group.

In a multicarrier system [9], carrier frequencies are usually chosen to be orthogonal to each other, i.e., carrier frequencies satisfy the following condition:

$$\int_0^{T_c} \cos(\omega_i t + \phi_i) \cdot \cos(\omega_j t + \phi_j) dt = 0, \text{ for } i \neq j. \quad (1)$$

Where T_c is the chip duration, ω_i and ω_j are, respectively, the i thand j th carrier frequencies, and ϕ_i and ϕ_j are arbitrary carrier phases, respectively. This is done so that a signal in the j th frequency band does not cause interference in the correlation receiver for the i th frequency band. However, in an asynchronous CDMA system [5], signals from other users are no longer orthogonal to the desired signal, even if (1) is satisfied. In addition, orthogonality might be lost because of multipath propagation or Doppler frequency shift even for a synchronous system. This implies that co-channel interference [4] in one frequency band causes interference not only at the output of the correlator for that frequency band, but also in the signals out of all the other correlators. In this paper, we use band limited multicarrier DS waveforms to minimize such unnecessary self-interference, and so orthogonality among carriers is not required. Also, this signaling scheme prevents narrowband waveforms from causing interference to all frequency bands

II. SYSTEM MODEL

In recent years, several wideband CDMA systems have been proposed either to realize an overlay system [5], where DS CDMA waveforms are overlaid onto existing narrowband signals to enhance the overall capacity, or to combat multipath. A multicarrier system can be considered as one realization of such a wideband DS system.

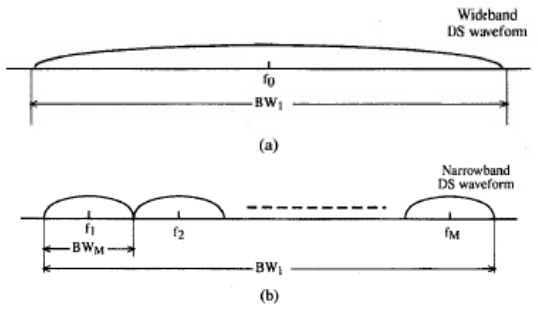


Fig 1. (a) PSD of Single Carrier (b) PSD of Multicarrier DS waveform

Fig 1. (a) Shows a band limited single-carrier wideband DS waveform in the frequency domain, where the bandwidth, *BW1*, is given by

$$BW_1 = (1+\alpha)\frac{1}{T_c} \quad \text{.....(2)}$$

In (2), $0 < \alpha \leq 1$, and T, is the chip duration of the single carrier system. In a multicarrier system, we divide BW1 into M equi-width frequency bands as shown in Fig. l(b), where all bands are disjoint.

Then the bandwidth of each frequency band, BWM, is given by

$$BW_M = \frac{BW_1}{M} = (1+\alpha)\frac{1}{MT_C} \quad \text{.....(3)}$$

A. Transmitter

The transmitter has input a random binary sequence representing data, and pseudo-random spreading signature sequences are given to multiplier. We assume that there are N chips per symbol, and that each user has a different signature sequence. The sequence modulates an impulse train, where the energy per chip is E,. After passing through a chip wave-shaping filter, the

signal out of the filter modulates the multiple carrier signals and is transmitted. Note that the transmitter and receiver block diagrams for the proposed multicarrier system can be effectively implemented by using a DFT technique

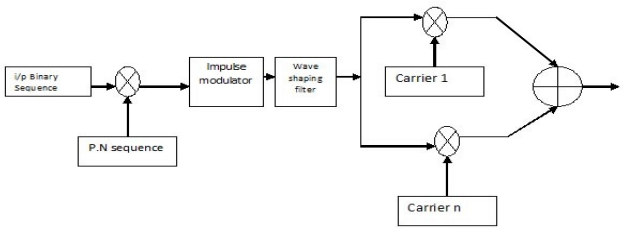


Fig 2. Block Diagram of transmitter

B. Pseudo-Noise Sequences

PN sequences are periodic sequences that have a noise like behaviour. They are generated using shift registers, modulo-2 adders (XOR gates) and feedback loops.

So far we haven't discussed what properties we would want the spreading signal to have. This depends on the type of system we want to implement. Let's first consider a system where we want to use spread spectrum to avoid jamming or narrow band interference.

If we want the signal to overcome narrow band interference, the spreading function needs to behave like noise. Random binary sequences are such functions. They have the following important properties:

- Balanced: they have an equal number of 1's and 0's
- Single Peak auto-correlation function

In fact, the auto-correlation function of a random binary sequence is a triangular waveform as in the following figure, where T_C is the period of one chip:

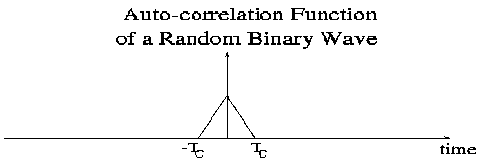


Fig 3. Auto Correlation function

Hence the spectral density of such a waveform is a since function squared, with first zeros at $\pm 1/T_C$

PN sequences are periodic sequences that have a noise like behavior. They are generated using shift registers, modulo-2 adders (XOR gates) and feedback loops. The following diagram illustrates this:

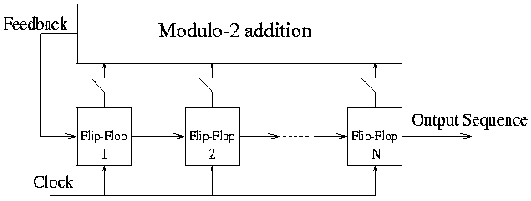


Fig 4. Generation of PN sequence

The maximum length of a PN sequence is determined by the length of the register and the configuration of the feedback network. An N bits register can take up to 2^N different combinations of zeros and ones. Since the feedback network performs

linear operations, if all the inputs (i.e. the content of the flip-flops) are zero, the output of the feedback network will also be zero. Therefore, the all zero combination will always give zero output for all subsequent clock cycles, so we do not include it in the sequence. Thus, the maximum length of any PN sequence is 2^N-1 and sequences of that length are called *Maximum-Length Sequences* or *m-sequences*.

Impulse Modulator: It is used to modulate the impulse train coming from the multiplier, where the energy per chip is E.

Wave shaping filter: This filter is used to modify the shape of the waveform i.e., it is used to adjust the energy levels of the waveform before the sequence modulates the multiple carriers.

III. CHANNEL MODEL

A. Rayleigh Channel Model

Rayleigh fading is a statistical model [9] for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium will vary randomly, or fade, according to a Rayleigh distribution the radial component of the sum of two uncorrelated Gaussian random variables. Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver Rayleigh fading is a reasonable model when there are many objects in the environment that scatter the radio signal before it arrives at the receiver, if there is sufficiently much scatter, the channel impulse response will be well modeled as a Gaussian process irrespective of the

distribution of the individual components. If there is no dominant component to the scatter, then such a process will have zero mean and phase evenly distributed between 0 and 2π radians. The envelope of the channel response will therefore be Rayleigh distributed.

B. AWGN Channel Model

Additive White Gaussian Noise channel model [9] as the name indicate Gaussian noise get directly added with the signal and information signal get converted into the noise in this model scattering and fading of the information is not considered. Additive white Gaussian noise (AWGN) is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude. The model does not account for fading, frequency selectivity, interference etc. However, it produces simple and tractable mathematical models which are useful for gaining insight into the underlying behaviour of a system before these other phenomena are considered.

C. Receiver

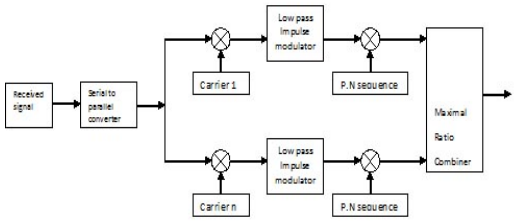


Fig 5. Block Diagram of Receiver

1) Serial to parallel converter: At the transmitter end N bits are sent simultaneously over N sub-carriers. Each sub-carrier transmit different symbol with spreading code in time-domain. In order toseparate different symbol of each subscriber we use this converter.

2) Maximal ratio combiner: Maximal Ratio Combining is defined as all paths co-phased and summed with optimal weighting to maximize combiner output SNR MRC is the optimum linear combining technique for coherent reception with independent fading. Its main advantage is the reduction of the probability of deep fades

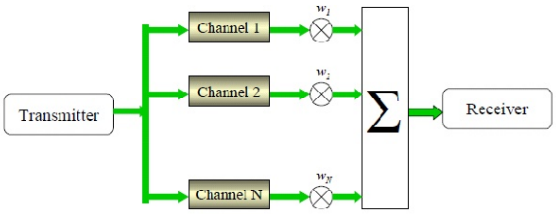


Fig 6. Maximum ratio combiner

$$f^{-1}\left|H(f)\right|^2 \equiv x(t)$$

$$\int_{-\infty}^{\infty}\left|H(f)\right|^2 df \equiv 1 \quad \text{..... (4)}$$

Also, we assume that $\left|H(f)\right|^2$ is band limited to W', where W' is

$$W' \le BW_M / 2 = (f_{i+1} - f_i)/2 \quad \text{.....(6)}$$

and f_i is the i th carrier frequency. This implies that the DS waveforms do not overlap.

IV. SIMULATION RESULTS

Bit error rate (BER) of a communication system is defined as the ratio of number of error bits and total number of bits transmitted during a specific period. It is the likelihood that a single error bit will occur within received bits, independent of rate of transmission. There are many ways of reducing BER. In our case, we have considered the most commonly used channel: the Additive White Gaussian Noise (AWGN) channel where the noise gets spread over the whole spectrum of frequencies.

BER has been measured by comparing the transmitted signal with the received signal and computing the error count over the total number of bits. For any given BPSK modulation, the BER is normally expressed in terms of signal to noise ratio (SNR).

The figure shows simulated graph between BER and SNR for 2 user system under Rayleigh fading channel conditions of multicarrier DS-CDMA in presence of AWGN (Additive White Gaussian Noise) using BPSK modulation

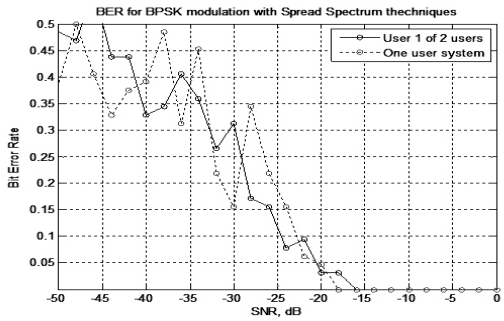


Fig 7. BER for 2 users system and single user system

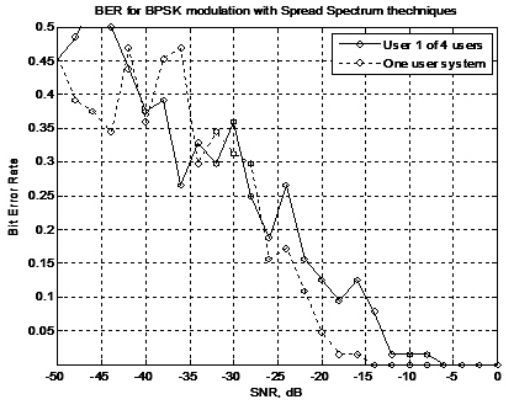


Fig 8. BER for 4 user system and user 2 system

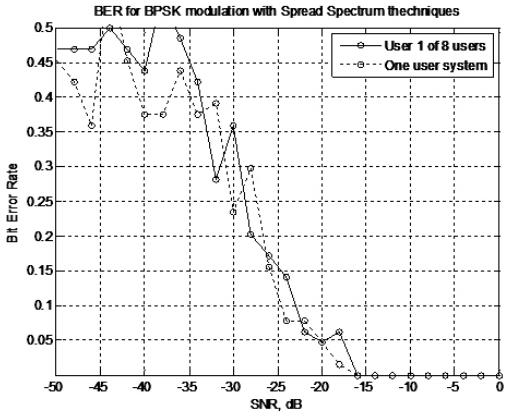


Fig 9. BER for 8 user system and 6 user system

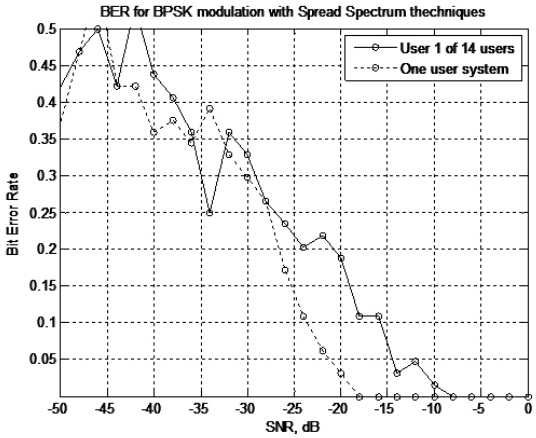


Fig 10. BER for 12 user system and 10 user System

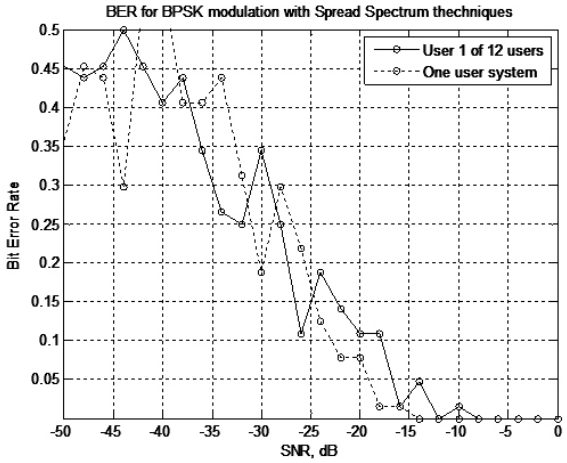


Fig 11. BER for 14 user system and 3 user system

Computer simulations are done to simulate SNR vs. BER performance of Multicarrier DS-CDMA for different channel noise conditions

V. CONCLUSION

In this paper the performance of Multicarrier DS-CDMA in AWGN channel and Rayleigh channel Using BPSK modulation technique is considered. As from graph it is evident that as E_b/N_0 increases the BER decreases. BER vs. SNR graphs for different number of users under Rayleigh Fading channel in presence AWGN is plotted and analysed successfully by using MATLAB programming.

VI. FUTURE SCOPE

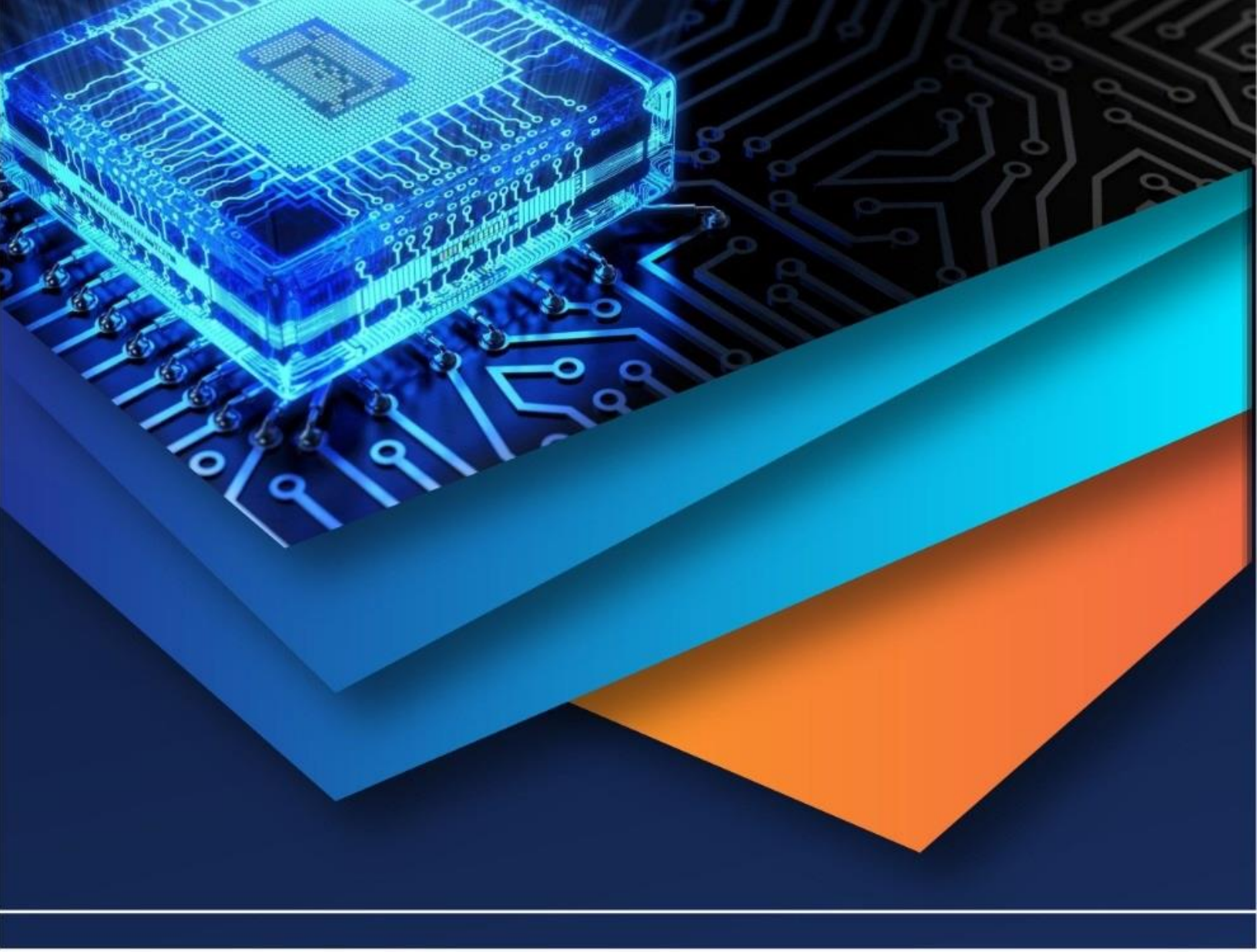
Multicarrier DS-CDMA technology is more useful for 3G and 4G mobile generations. There is a very wide scope for future scholars to explore this area of research in the field of Multicarrier DS-CDMA.

Further works can be carried out

1. To evaluate the effect of timing jitter in a MC DS CDMA system in the presence of fading.
2. To evaluate the performance of MC DS CDMA system with Rake receiver to overcome the effect of fading.
3. To find the performance limitations due to non-orthogonality among the subcarriers (due to imperfect carrier synchronization).
4. To evaluate the performance improvement with forward error correction coding like convolution coding and Turbo coding etc.

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