

Virtual sub carrier based Frequency and Phase Synchronization Algorithm for MC CDMA System

L.Nithyanandan, S.Thirunavukarasu and P. Dananjayan

Abstract— Fourth generation wireless communication system is expected to support high data rate multimedia services which is possible through Wideband Code Division Multiple Access (WCDMA) systems. Multi carrier CDMA system provides the advantage of frequency diversity and processing gain in CDMA system and thus reduces the bit error rate. Capacity of CDMA based systems can be increased by decreasing BER, which is possible through interference reduction and interference suppression. Error performance and capacity of OFDM based system can be improved through proper synchronization. In this paper, virtual sub carrier based frequency and phase synchronization algorithm is proposed which reduces the BER of MC CDMA systems indeed without any transmission overhead.

Index Terms - Synchronization, MC CDMA, OFDM, Bit error rate, Capacity.

I. INTRODUCTION

Cellular mobile communication has undergone tremendous development and enormous increase in the number of subscribers' right from the inception of first generation analog based voice only service. Presently mobile communication is heading towards 4G which is expected to provide wireless multimedia service to any one, any where and at any time. In order to achieve this goal, technology must have the capability to support multimedia and high data rate services like voice, audio, image, video and data which are possible through CDMA. In CDMA many users share the same bandwidth at the same time through unique code and hence provide higher capacity over TDMA and FDMA schemes. In the mean time, researchers have identified orthogonal frequency division multiplexing (OFDM), a multi carrier modulation scheme is highly suitable for high data rate service and is already in use for DAB, DVB-T and WLAN. Since mobile community is not interested in losing the advantage gained out of CDMA suitability of combination of CDMA and OFDM is explored for high data rate mobile services. In 1993 three types of new multiple access schemes [1,2] such as multi carrier CDMA (MC CDMA), multi carrier DS-SS (MC-SS CDMA) and multi tone CDMA (MT CDMA) were proposed based on combination of CDMA and OFDM. Since FFT is incorporated, it is possible to realize transmitter and receiver without much complexities for the above three schemes.

These schemes have high spectral efficiency due to minimally densely sub carrier spacing. Comparing these three schemes MC CDMA will be the probable access choice for beyond 3G services due to its ability to overcome the frequency selective fading. However the performance of the MC CDMA system highly depends on the frequency offset and phase noise due to the imperfect carrier recovery. The carrier frequency offset and phase deviations results in a false symbol timing and phase recovery and in turn introduce inter carrier interference (ICI) due to the loss of orthogonality among sub carriers.

In this paper a bandwidth efficient virtual sub carrier based carrier frequency and phase synchronization algorithm is proposed for an MC CDMA system. A prototype network is simulated and the error rate is obtained through simulation for a MC CDMA system with and without the proposed frequency and phase synchronization technique.

II. CARRIER FREQUENCY SYNCHRONIZATION IN MC CDMA

Even though MC CDMA system provides remarkable resilience to multipath fading and impulsive noise, to operate perfectly MC CDMA receiver should accurately compensate for the carrier frequency offset in the input signal. At the front-end of the receiver MC CDMA signals are subject to synchronization errors due to impairments of oscillator and sample clock differences. The demodulation of the received radio signal involves oscillators whose frequencies normally will not be perfectly aligned with the transmitter frequencies and in turn results in a carrier frequency offset which leads to loss of orthogonality between the sub carriers resulting in ICI. The characteristics of this ICI are similar to white Gaussian noise and lead to a degradation of the SNR. For both AWGN and fading channels, this degradation increases with the square of the number of sub carriers. Like frequency offsets, phase noise and sample clock offsets cause ICI and thus further degrades the SNR. In order to improve the performance of MC CDMA system carrier synchronization techniques are employed. Since MC CDMA is a blend of OFDM and CDMA techniques, a detailed survey regarding the carrier synchronization schemes used for OFDM system is made. Frequency synchronization for OFDM system includes [3–6], [11–13] Phase locked loop algorithm, Frequency offset estimation algorithm and Guard interval based frequency offset estimation algorithm [7,8].

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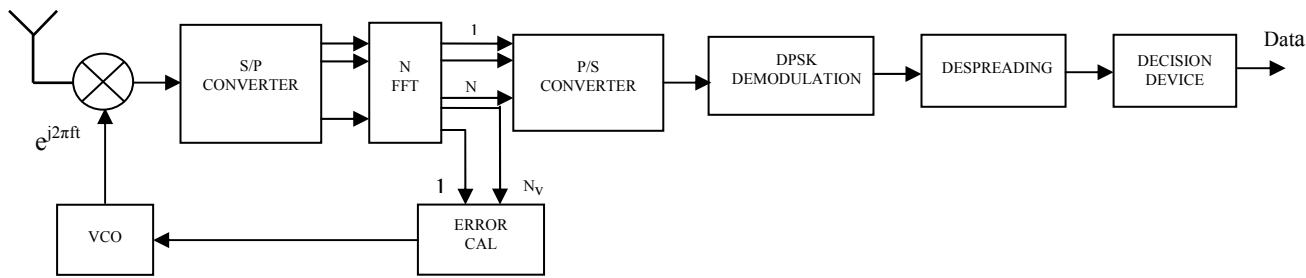


Fig. 1 MC CDMA receiver with synchronization algorithm

A. Virtual Sub Carrier based Frequency Synchronization Algorithm

Virtual sub carrier (VSC) based frequency synchronization algorithm capitalizes on the fact that the system is not fully loaded, i.e., not all available subcarriers are used for transmitting symbols. The proposed method exploits these null, or virtual, subcarriers to enforce time and frequency synchronization conversely, the method herein, guarantees unambiguous carrier offset estimates with performance independent of the channel zeros location. Moreover, it is specifically devised for multi user systems and is simpler to implement than the algorithms explained earlier because it does not require any eigen-decomposition of the received signals. Even though the presence of virtual sub carriers can be seen as the transmission of known (null) symbols, there is a basic practical difference as the transmission of null symbols does not imply any waste of power. Furthermore, null sub carriers are intrinsically present in any non fully loaded MC system (a situation which occurs most of the time).

The novelty lies in the algorithm for estimating and compensating both time and frequency offsets. The basic idea for synchronization is fairly simple. The average energy falling across the virtual sub carriers is measured and the oscillator frequency is updated until a minimum of the measured energy is reached. In case of perfect synchronization and no noise situation, null energy is observed. When some energy is detected, the receiver oscillator is updated in order to minimize such energy. Correspondingly, the synchronization algorithm is rather simple. An iterative search is run which yields the frequency offset that minimizes the energy falling in the band corresponding to the virtual sub carriers. Perfect synchronization leads to zero MUI/ISI among MC CDMA symbols and null energy in the band not occupied by information symbols. Conversely, non perfect synchronization is revealed by the presence of MUI/ISI and of a non null energy in correspondence with the null sub carriers.

Figure 1 depicts a typical MC CDMA reception system with proposed synchronization algorithm. In the transmitter side the generated data is spreaded using a sequence of length 16/32/64. Then the spreaded data is OFDM modulated and transmitted through the Rayleigh fading channel in AWGN floor. The received signal is first OFDM demodulated and the energy, J from the virtual sub carriers is computed. This energy from the virtual carriers is used as the measure of error. The change in energy with respect to the velocity, dJ/dv is also calculated and is used to update the oscillator frequency.

This process is repeated until a minimum of measured error energy is reached. Data from the other sub carriers are despreaded and are retrieved back using the decision device.

B. Simulation Results and Discussion

The MC CDMA transceiver model has been developed and simulated in MATLAB. The input data for transmission is randomly generated and the bits are spreaded using the spreading sequence and the code length of the sequence is chosen as 16, 32 or 64. The spreaded data is modulated using DPSK modulation technique and the data is grouped for OFDM Modulation. If there are 64 sub carriers, the modulated data is grouped into symbols of 64 and the input data is OFDM modulated where each data is superimposed on the orthogonal sub carriers. The required number of virtual sub carriers is identified before modulation and those null carriers are also modulated. The number of virtual sub carriers may be 2 or 4 and the output of the OFDM system is again parallel to serial converted for pass band modulation. The OFDM signal is sampled and up-converted to the desired frequency. The transmitted signal is passed through the channel to introduce the required errors into the signal. In mobile communication environment multipath fading is an important factor and hence the transmitted signal is analyzed in the presence of Rayleigh fading channel in AWGN floor. The received signal is then down converted and the sampled instants are retrieved back and they are averaged to give the digital form of signal. Finally the data is serial to parallel converted and the virtual carriers are separated from the data and the energy of those carriers is obtained and used as the measure of error.

Figure 2 shows the performance of the MC CDMA system with and without frequency synchronization for 16 sub carriers out of which 2 are virtual sub carriers. The result implies that the system performs better with the proposed synchronization algorithm. Figure 3 gives the performance of the system with 16 sub carriers including 4 virtual carriers which clearly indicates the performance of the system with 4 virtual carriers is better than the 2 virtual carriers. This is due to the fact that average error from the 4 VC can be used effectively for frequency correction than from 2 VC. Figures 4, 5, 6 and 7 depict the performance of the system with 32/2, 32/4, 64/2 and 64/4 SC/VC respectively. These figures indicate the performance improvement due to the increase in processing gain and the number of virtual subcarriers.

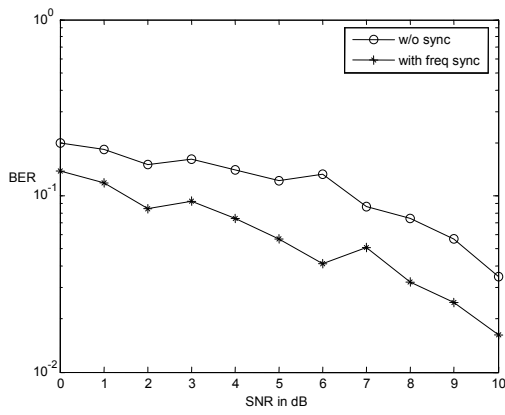


Fig. 2 Frequency synchronization (16 SC/ 2 VC)

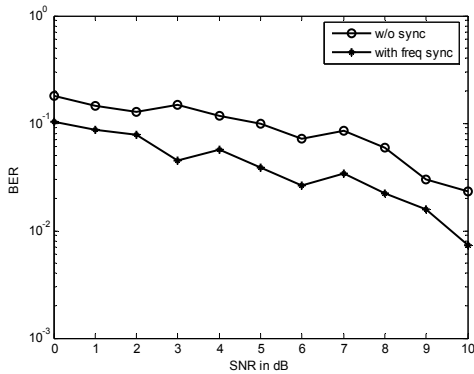


Fig. 3 Frequency synchronization (16 SC/ 4 VC)

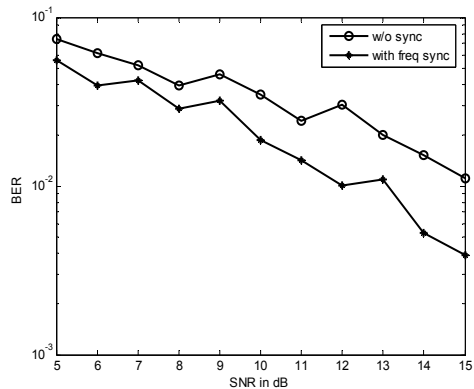


Fig. 4 Frequency synchronization (32 SC/ 2 VC)

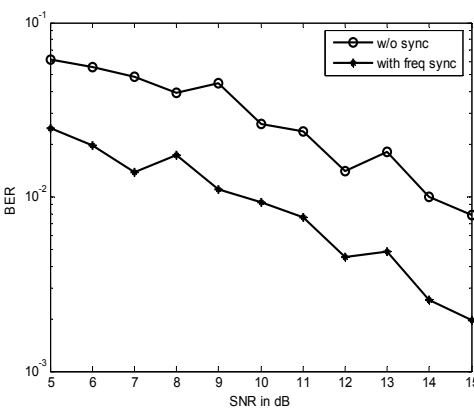


Fig. 5 Frequency synchronization (32 SC/ 4 VC)

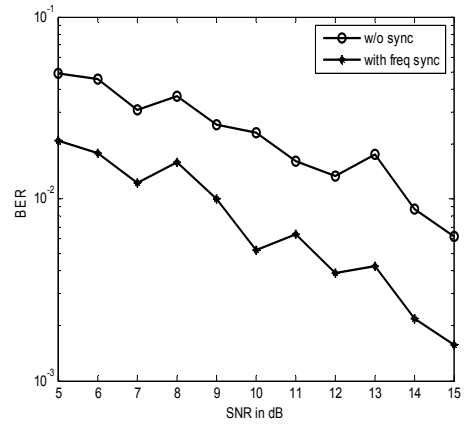


Fig. 6 Frequency synchronization (64 SC/ 2 VC)

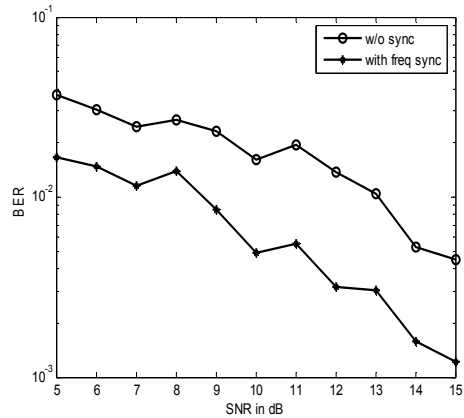


Fig. 7 Frequency synchronization (64 SC/ 4 VC)

III. CARRIER PHASE SYNCHRONIZATION IN MC CDMA

Communication in spread spectrum system is impossible unless the received spreading waveform and receiver generated replica of the spreading waveform are initially synchronized in both phase and frequency. A constant carrier phase offset ϕ between the carrier oscillators at the transmitter and the receiver introduces, for all multicarrier systems, a phase rotation over an angle ϕ of the samples at the input of the decision device, when no equalizer is used. This systematic phase rotation of the samples at the input of the decision device can be compensated without enhancing the noise power level. Several phase synchronization techniques [9,10,14] are available for multicarrier systems.

A. Virtual Sub Carrier based Phase Synchronization Algorithm

The energy from the virtual sub carriers is used as a measure of error and is used for frequency offset correction as explained earlier. For phase synchronization also, the same energy of the virtual sub carrier can be used. The rate at which energy changes will be an useful measure to give an idea regarding the phase error. Hence change in energy with respect to time is computed and is used to find the time offset. The time offset calculated is used for phase synchronization.

B. Performance of Frequency and Phase Synchronization Algorithm

MC CDMA system consisting of 16/32/64 sub carrier (2/4 virtual carrier) is simulated using both frequency and phase

synchronization algorithm. Figure 8 shows the performance of the MC CDMA system with frequency synchronization and with both frequency and phase synchronization for 16 sub carriers out of which 2 are virtual sub carriers. Simulation is performed for SNR from 0 dB to 10 dB in steps of 1 dB with a processing gain of 16 and the result implies that the system performs better with both frequency and phase synchronization.

Figure 9 shows the performance of the system with 16 SC/PG which includes 4 virtual carriers. This also shows that there is significant reduction in BER when both frequency and phase synchronization are used. Similarly Figures 10 and 11 show the performance of the system for 32 SC/PG which includes 2 and 4 VC respectively. In this case simulation is performed for SNR from 5 dB to 15 dB in steps of 1 dB with a processing gain of 32. These figures also depict that as the number of subcarrier increases the BER reduces. Performance of the 64 SC/PG MC CDMA systems with 2 VC and 4 VC are shown in Figures 12 and 13 respectively. In this case also there is good reduction in BER by employing both frequency and phase synchronization.

C. Performance Improvement due to Frequency and Phase Synchronization Algorithm

The stack representation of BER reduction using both frequency and phase synchronization for 16 SC/PG with 2 VC and 4 VC are shown in Figures 14 and 15 respectively. Figures 16 and 17 indicate the reduction in BER for frequency and phase synchronization separately in a stack diagram form for 64 SC/PG with 2 VC and 4 VC respectively. The dark portions are the percentage reduction in BER due to phase synchronization and the white portion is the percentage reduction in BER due to frequency synchronization alone. From the simulation results it can be seen the performance with frequency and phase synchronization is better when compared with the frequency synchronization alone incorporated. As before the increase in processing gain and virtual subcarrier improves the performance.

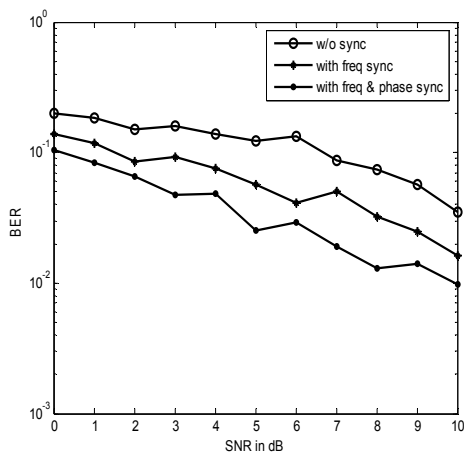


Fig. 8 Frequency and phase synchronization (16 SC/2VC)

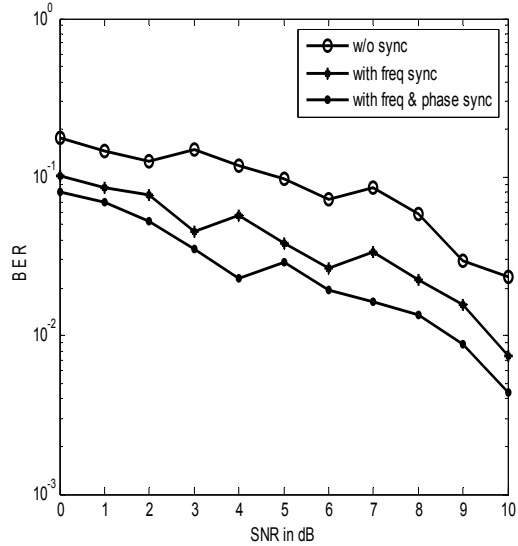


Fig. 9 Frequency and phase synchronization (16 SC/ 4 VC)

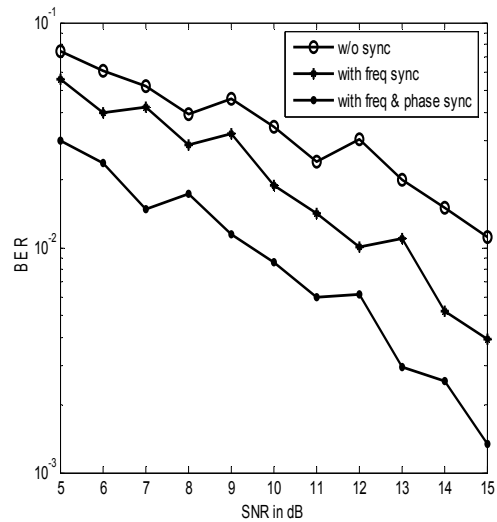


Fig. 10 Frequency and phase synchronization (32 SC/ 2 VC)

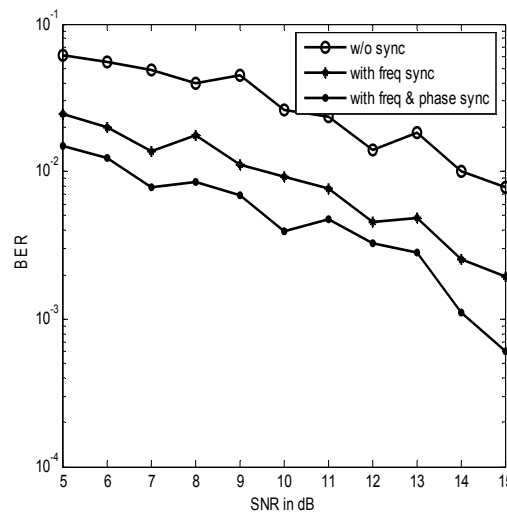


Fig. 11 Frequency and phase synchronization (32 SC/ 4 VC)

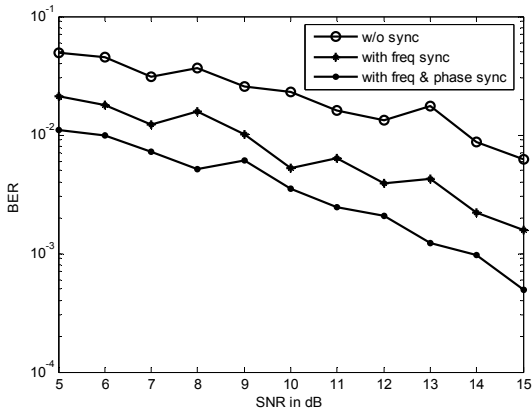


Fig. 12 Frequency and phase synchronization (64 SC/ 2 VC)

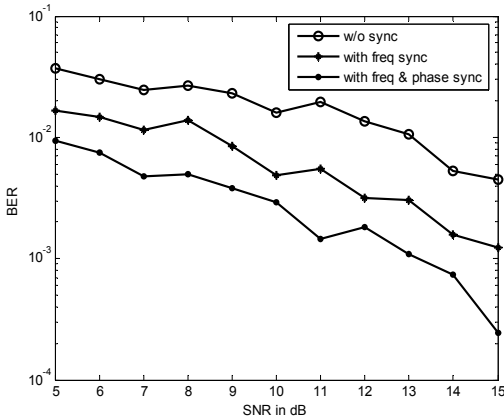


Fig. 13 Frequency and Phase synchronization (64 SC/ 4 VC)

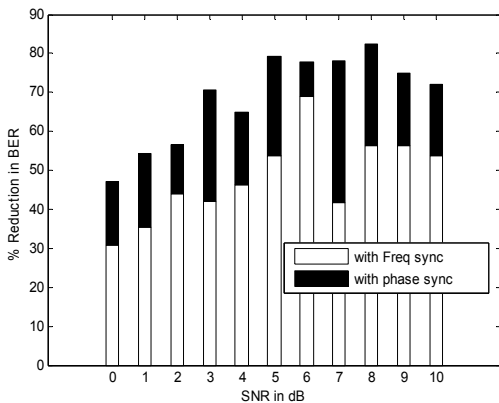


Fig. 14 Reduction in BER (16 SC/2VC)

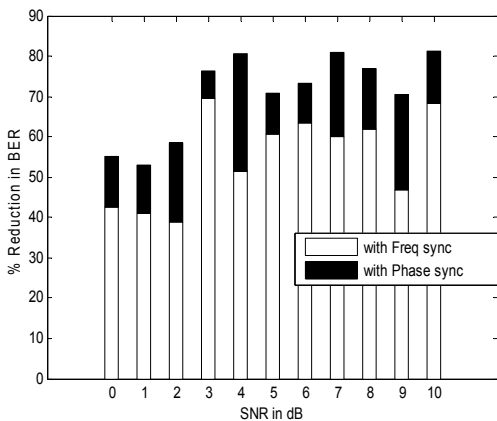


Fig. 15 Reduction in BER (16 SC/4VC)

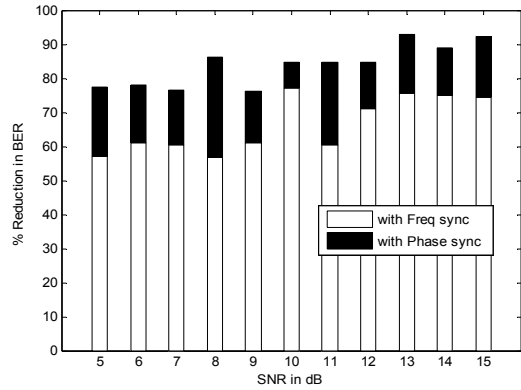


Fig. 16 Reduction in BER (64 SC/2VC)

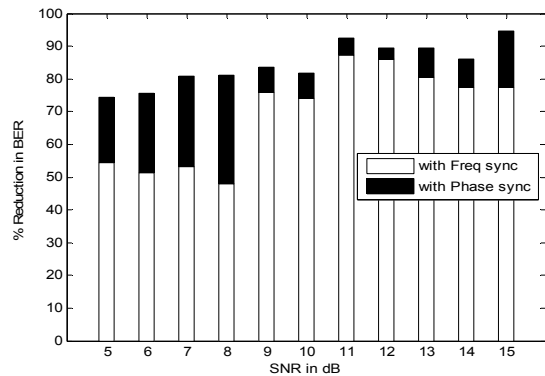


Fig. 17 Reduction in BER (64 SC/4VC)

IV. CONCLUSION

In future wireless communication system, the main aim is to integrate all the multimedia services (voice, data and video services) in a single unit. Hence systems which incorporate high data rate services are required to provide the users with all the facilities at a better performance. Also the channel capacity of the system should be improved in order to accommodate more number of users. This paper presents the “Virtual sub carrier based frequency and phase Synchronization algorithm for MC CDMA systems”, which forms a very important issue in MC CDMA transmission in Rayleigh fading channel. The simulated MC CDMA transceiver with synchronization model provides a good performance by giving a reduced BER. The bit error rate reduces as the number of sub carriers/processing gain increases. Simulated results of BER with and without carrier frequency and phase synchronization are being compared, and it is proved that the BER reduces by incorporating the proposed synchronization algorithm. Since BER is reduced, more number of users can be accommodated. Since, capacity of CDMA based system is interference limited, more number of users can be accommodated for a fixed BER provided the proposed virtual subcarrier based frequency and phase synchronization algorithm is used.

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