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Multi-band Carrier Code Division Multiple Access for 4G Mobile System with Improved Signal Quality

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Abstract: The proposed frequency band for a 4G mobile system is 2 to 8 GHz, while the proposed access for the system is MC-CDMA / OFDM. In this paper, a new access technique has been proposed, with the bandwidth of the system divided into ten sub-bands. Each sub-band has40 channels and the access is a multi-band of the carrier CDMA (MBC-CDMA). The proposed access provides more flexibility for the base stations to re-use the frequency than MC-CDMA because of the use of frequency hopping between the channels as well as the sub-bands. The hopping sequence depends on the spreading code. A comparison of the performance of the proposed access technique with MC-CDMA showed that there is an improvement in signal quality and BER performance, as an application, this proposed multiple access technique suitable for 4G mobile air interface for further interference reduction and in improvement in signal quality.

Key words: 4G mobile system · MC-CDMA · Frequency Hopping · MBC-CDMA

INTRODUCTION

There are a number of multiple access techniques to transmit several user signals simultaneously through one channel. In general, what are used are three-dimensional time, frequency and code. The use of multiple frequencies at the same time and one code, if digital, is referred to as frequency division multiple access (FDMA). On the other hand, the use of different time slots in one frame with the same frequency is referred to as time division multiple access (TDMA). Finally, the transmission of signals at the same time using the same frequency with different spreading codes is referred to as code division multiple access (CDMA).

Each of the multiple access techniques mentioned above has advantages and disadvantages. In the case of FDMA, a band of frequency is shared among users, which can cause interference. On the other hand, in TDMA, there must be synchronization in the number of users using time slots; otherwise, there is inter symbol interference (ISI). In the case of CDMA, the technique requires more complex receivers, such as the Rake receiver and synchronization between the transmitter and the receiver. Moreover, some systems also use hybrid techniques, including TDMA+FDMA-like GSM or TDMA+CDMA-like UMTS systems.

Therefore, Multi-Carriers CDMA (MCDMA) and Orthogonal FDMA (OFDMA) have been designed to improve signal quality, especially for next-generation wireless systems, such as the 4G mobile system, which will provide higher data rates of up to 200Mbps[1]. In this paper, the proposed multiple access technique was introduced using multiple bands for each band of multiple carriers with the CDMA system (MBC CDMA).In the next sections, further details on the proposed multiple access technique are provided, along with a comparison of the performance results of the proposed technique and the Multi Carrier CDMA (MC CDMA) technique.

4g Mobile System: The 4G mobile system is the future mobile system through which a higher data rate service will be provided. It is the integration of other wireless systems, including GSM, UMTS and WiMAX. With a higher frequency band, the cell radius of base stations will be smaller, about one third of that in the 3G mobile system. Some 4G specifications are converged data and voice over IP, hybrid Integration of Wireless LAN (WiFi, Bluetooth) and wide area as network architecture, 20 to 100 Mbps speed in mobile mode, Higher frequency bands (2–8 GHz), 100 MHz (or more) bandwidth, all digital with packetized voice of switching design, OFDM and MC-CDMA as access technology, forward Error Correction is

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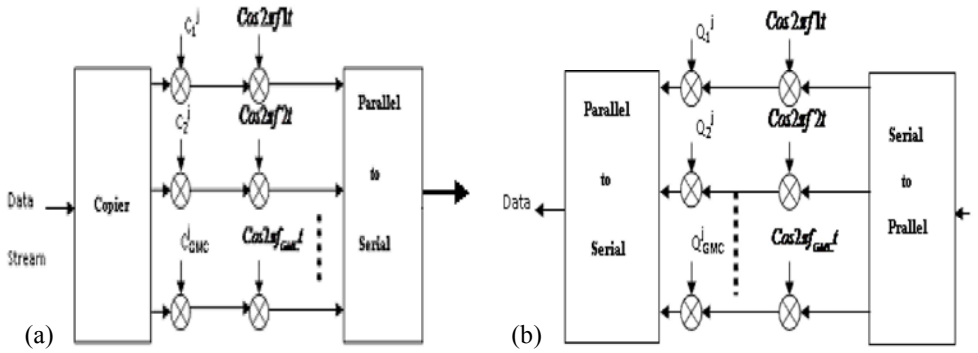

Fig. 1: MC-CDMA system (a) Transmitter (b) Receiver

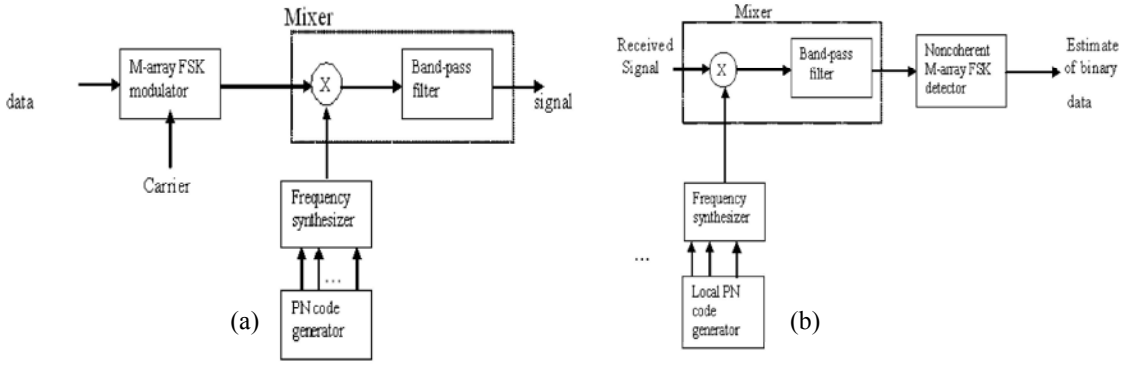

Fig. 2: Frequency-hop spread M-array frequency-shift keying (a) Transmitter (b) Receiver

the concatenated coding scheme, smarter Antennas, software multilane and wideband radios of the component design, all IP (IPv6.0) system.

MC-CDMA Access Technology: An MC-CDMA transmitter spreads the original signal using a given spreading code in the frequency domain. In other words, a fraction of the symbol corresponding to a chip of the spreading code is transmitted through a different subcarrier. For multicarrier transmissions, the establishment of frequency nonselective fading over each subcarrier is essential. Therefore, if the original symbol rate is high enough to become subject to frequency selective fading, the signal needs to be converted first from serial to parallel before spreading over the frequency domain.

The basic transmitter structure of an MC-CDMA scheme is similar to that of an OFDM scheme. The main difference is that the MC-CDMA scheme transmits the same symbol in parallel through different subcarriers, whereas the OFDM scheme transmits different symbols [2].

The multicarrier CDMA, which is a combination of OFDM signaling and the CDMA scheme, has one major advantage in that it can lower the symbol rate in each subcarrier. The longer symbol duration allows for easier quasi-synchronization of transmissions. The MC-CDMA transmitter spreads the original data stream over different subcarriers using a given spreading code in the frequency domain. A fraction of the symbol corresponding to a chip of the spreading code is transmitted through a different subcarrier. Figure (1) show the MC-CDMA transmitter and receiver, respectively.

Frequency Hopping (Fh) Spread Spectrum: The frequency hopping spread spectrum is a spread spectrum technique wherein the frequency of the signal is changed randomly according to the spreading sequence code. It has two types: fast and slow hopping. In slow hopping, there is only one hop per bit of data, while in fast hopping, there are several hops per bit [3]. A simple frequency hopping transmitter and receiver are shown in Figure (2). This technique reduces the possibility of interference in the transmitted signal with other undesired signals. One of the applications of FH is the Bluetooth wireless service system wherein there are multiple hops in frequency per bit. In this paper, the proposed MBC-CDMA technique uses FH of the 4G frequency band with MC-CDMA, the details of which are given in the next section.

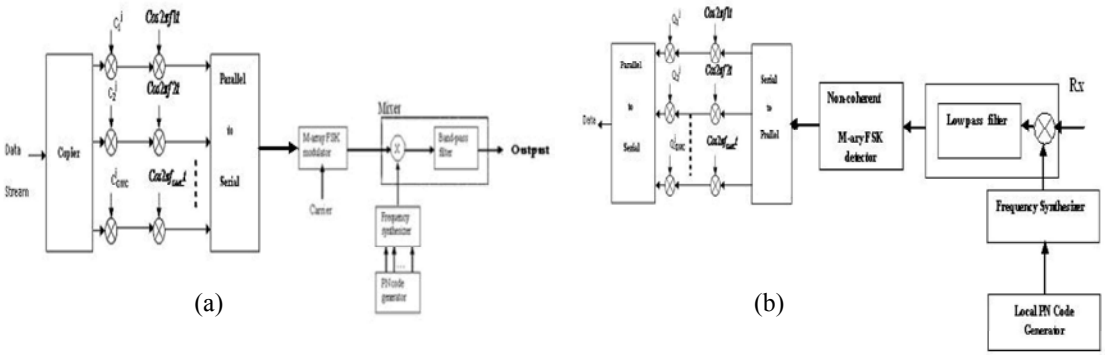

Fig. 3: MBC-CDMA (a) Transmitter (b) Receiver

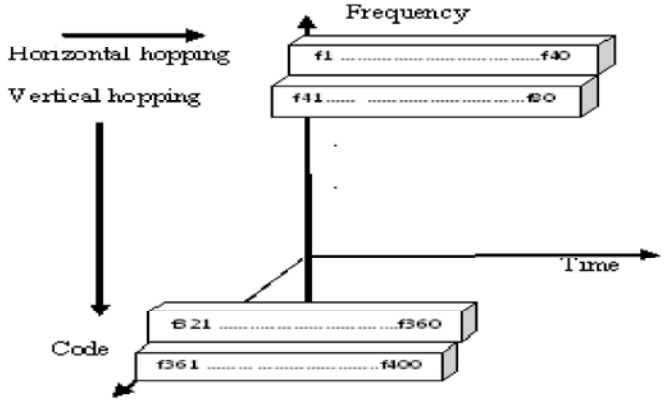

Fig. 4: Frequency hopping scenario

Table 1: Frequency hopping scenario

1st band	F1	F2	….	F40
2nd band	F41	F42	....	F80
3rd band	F81	F82	....	F120
4th band	F121	F122	....	F160
5th band	F161	F162	....	F200
6th band	F201	F202	....	F240
7th band	F241	F242	....	F280
8th band	F281	F282	....	F320
9th band	F321	F322	....	F360
10th band	F361	F362	....	F400

Table 2: Carrier frequency scenario

Down link frequency band used (Ghz)		Up link frequency band used (GHz)	
Upper edge	7.895	Upper edge	7.595
Lower edge	2.3	Lower edge	2

The Proposed Multiple Access (MBC-CDMA): In this paper, a novel multiple access technique is introduced for the 4G mobile system. The proposed frequency band is 2 to 8 GHz. This band is sub-divided into 10sub-bands, with each sub-band having 40 channels or a total of400 channels. In contrast with the MC-CDMA system that uses only one band of carriers with the CDMA technique, the proposed technique[Fig. (3)] combines FH with MC-CDMA. Thus, after frequency assignment for each channel, there is frequency hopping between sub-bands. Based on Table (1), this hopping depends on the random spreading sequence in the system.

There Are Two Types of Frequency Hopping: Horizontal and vertical. In horizontal hopping, each band hops horizontally according to the spreading code in the first stage with 5MHz carrier separation. On the other hand, vertical hopping occurs in the second stage of the system according to the frequency synthesizer, with 600MHz carrier separation. The duplex distance between the uplink and the downlink carrier frequencies is 300MHz. The hopping scenario is provided in Figure (4).

The carrier frequency scenario is shown in Table (2). In this case, each cluster uses a variable channel and different carrier frequencies, thereby minimizing the interference effect and increasing the signal-to-interference (SIR) and the signal quality. For the carrier frequency sub-bands, the lower edge is 1, the upper edge is 400, the number of channels is 10, the carrier distance is 40, the channel spacing is 5MHz and the total number of channels is 400.

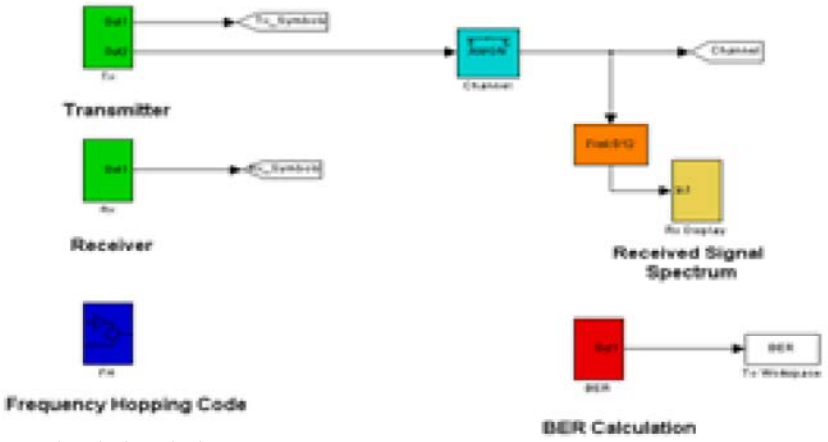

Fig. 5: MBC-CDMA Simulation design

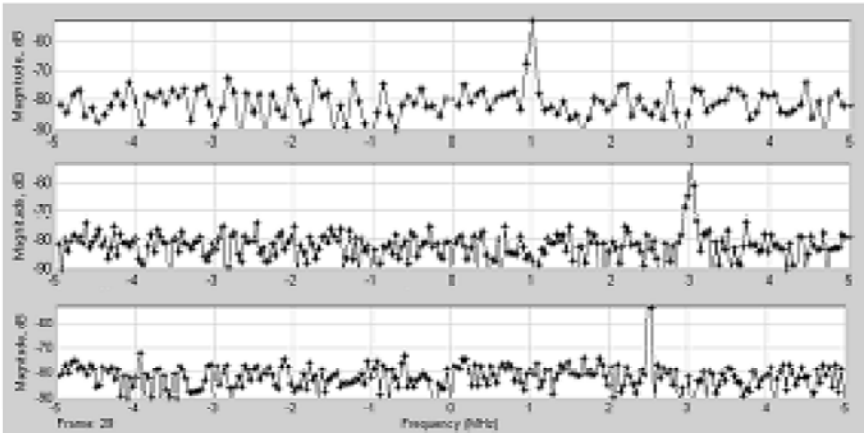

Fig. 6: Transmitted signal using MBC-CDMA with horizontal FH

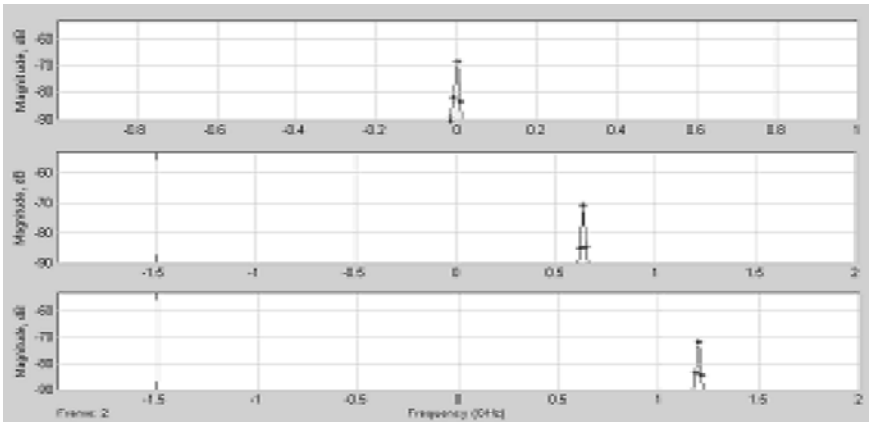

Fig. 7: Transmitted signal using MBC-CDMA with vertical FH

Related Work: Many proposals have been introduced for 4G access technology. For example, a very interesting BER comparison was conducted in [4] between OFDM and MC-CDMA, which showed that MC-CDMA had better BER performance than OFDM. The BDMA system was introduced in [5] as an approach for next-generation mobile telecommunication systems. The proposed system in [5] was based on a combination of TDMA slow frequency hopping (SFH-TDMA) and OFDM with good results. [6] also proposed a low-power-adaptive MC-CDMA receiver architecture. Other studies, including [7-10], examined the 4G MC-CDMA access technique.

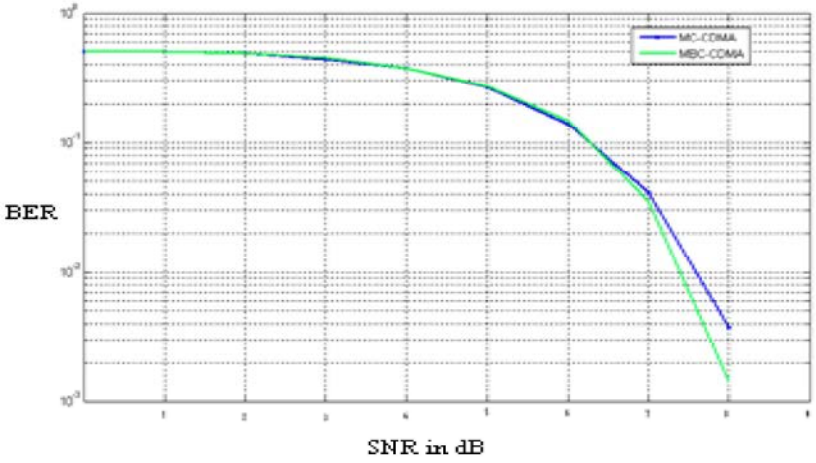

Fig. 8: BER vs. SNR

RESULTS

The simulation of the proposed access (MBC-CDMA) via Simulink [Fig. (5)] indicated that horizontal frequency hopping prevented the interference between base station carriers. Moreover, as shown in Fig.(6), vertical hopping of the carrier frequency caused an improvement in the signal, because the interfered signals will be removed as compared to the same signal in Fig. (7) after horizontal hoping. According to the proposed multiple access technique, there is vertical hopping of carrier frequencies between sub-bands to cancel the interference and signal quality is improved further. Fig. (8) shows the comparison of BER performance between MC-CDMA and MBC-CDMA. The results showed that as SNR further increased, MBC-CDMA performed better than MC-CDMA , for example, when SNR is 7dB, BER will be improved 10% from 3 x $10^{-2}$to 2 x 10^{-2} , further increasing SNR, BER will be further improved, for example, when SNR is 8dB, BER will be improved about 17% from 2.8 x 10^{-3} to 0.5 x 10^{-3} ,the proposed model is applicable to the 4G mobile system because this system includes a higher number of base stations using a higher frequency band due to the smaller coverage of the base stations and this proposed technique improves signal quality due to the improved signal-to-interference (SIR) because for each 1 dB increase in SNR, BER improved about 8%. This proposed technique for 4G mobile system suitable with 8QAM and 64QAM modulation technique, because there is improvement in BER performance and these two digital modulations 8QAM and 64QAM are with better BER performance with higher SNR using this proposed multiple access technique.

CONCLUSIONS

In this paper, a new multiple access technique for CDMA has been proposed wherein the transmitted signal is frequency hopped vertically and horizontally. The interference effect is approximately negligible and the signal quality is improved. This technique is very important for the 4G mobile system because it has a higher number of base stations and a higher frequency band width. Further, the proposed MBC-CDMA technique has greater flexibility in terms of frequency assignment than MC-CDMA, also over OFDMA because already MC-CDMA is better than OFDMA and more suitable with 4G mobile system. This is because the latter uses carrier frequencies in one band, whereas MBC-CDMA uses multiple sub-bands according to the frequency synthesizer used in the proposed technique and the spreading sequence code.

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