A Frequency Hopping Code Division Multiple Access Technique

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ABSTRACT: *The synchronization of code used between a given authorized transmitter and receiver is the toughest job in a code division multiple access scheme. Further, the efficient utilization of spectrum requires a judiciously distributed set of codes among various users. In this paper a novel frequency hopping spread spectrum multiple access technique is proposed, wherein the used capacity is increased and the complexity of code synchronization is drastically reduced.*

Key words: FH-CDMA, Code synchronization, Frequency hopping

I. INTRODUCTION

Spread spectrum (SS) modulation techniques were used by military for more than thirty years as an anti-jamming technique against active attacks. Due to its various advantages *viz* multiple access capability, intersymbol interference (ISI) cancellation and anti-jamming ability its use was later on extended to commercial mobile radio applications [1,2]. In SS modulation techniques the signal spectrum at the transmitter is expanded by means of a code known as pseudorandom (PN) code, which appears to be random in appearance but can be reproduced by deterministic means. Code division multiple access (CDMA) works on SS modulation techniques and is classified as Frequency Hopping CDMA (FH-CDMA) and Direct Sequence CDMA (DS-CDMA). The CDMA system allows multiple users to share the same spectrum, within a given acceptable signal to noise ratio, by assigning a set of codes to each user. In FH-CDMA system the carrier frequency is hopped pseudo randomly which achieved by a frequency synthesizer governed by a PN code. The same code is used at the receiver to recover the original baseband signal. Acquiring the code synchronization between the authorized transmitter and the receiver requires the most complex circuitry in SS system [7]. In this work a simple technique is proposed with reduced hardware to acquire code synchronization with optimized user capacity in a limited bandwidth. The rest of the paper is organized as follows: In Section II the background of FH-CDMA is discussed briefly. Section III discusses the proposed technique. Finally, in Sections IV and V experimental results and conclusion are respectively presented.

II BACKGROUND

In an FH-CDMA system, a set of frequencies is used wherein each frequency is generated by a unique code. The total number of available frequencies is distributed among a certain number of users in a given geographical region, such that each user is assigned a sub-set of allowable frequencies and the carrier used by that user is made to hop among that particular set of frequencies [3-5]. However, the sets of frequencies allocated to different users in a given region are usually chosen as disjoint, so that the frequencies transmitted by any two users at a time are always different [6-7]. Hence out of a set of, say 5000, allowable frequencies, if each user is allocated a sub-set of 100 frequencies, the total number of users (operating simultaneously) under FH-CDMA will be 50. Fig. 1 shows an example of FH-CDMA scheme, where a set of 15 available frequencies are being shared by 3 users with 5 frequencies per user. Allocation of channel frequencies in such a way ensures that there is no interference among the transmitted signals even if all the users transmit their signals, simultaneously, using FHSS modulation [7]. It is evident from Fig.1, that only a subset of frequencies are used at a time (if all the users operating in the given CDMA system are not communicating), and the rest of the frequencies are unused at that particular instant of time. Thus there is a scope to increase the total number of users in a given CDMA system by operating additional users on the unused channel frequencies and then exchanging the channel frequencies among the users for the purpose of frequency hopping (as shown in Fig. 2). One way of utilizing the given frequency band efficiently is to use codes which have a poor cross-correlation distributed among the users. However, the simultaneous transmission of different users with poor cross-correlation results in mutual interference among the users. For example consider two users A and B operating in a band having a set of frequencies $f_1, f_2, \ldots f_{10}$ corresponding to codes $c_1, c_2, \ldots c_{10}$, with codes c_1, c_4, c_7 & c_9 assigned to user A and c_2, c_3, c_7 & c_{10} assigned to user B. It can be shown that in both the users, three codes are different from each other and only one code 'c_7' is common to both. This is known as partial code correlation. Now, if the two users at any instant of time happen to transmit on the frequency corresponding to code c_1, the system will result in the mutual interference between the users. However, if the time at which a particular code is used is known to other users, the mutual interference can be avoided. The concept though simple in itself, however, requires a very complex architecture, since all the users operating under such a CDMA system have to operate under a high degree of network time synchronization among them.

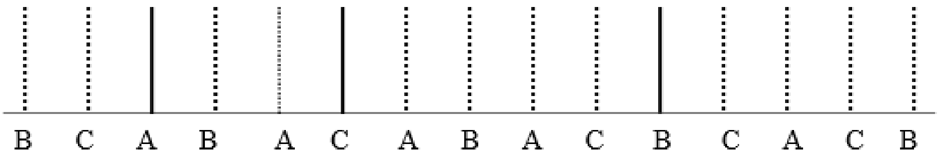


Fig. 1: Spectrum of a conventional FH/CDMA system using 15 frequencies with 3 users.

(Only three frequencies are used at a time)

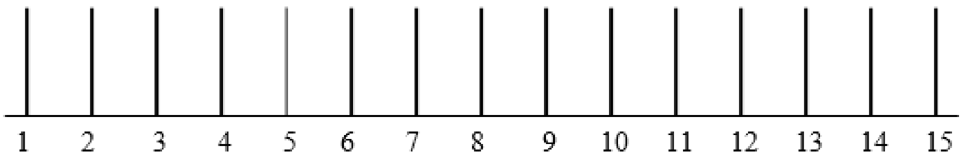


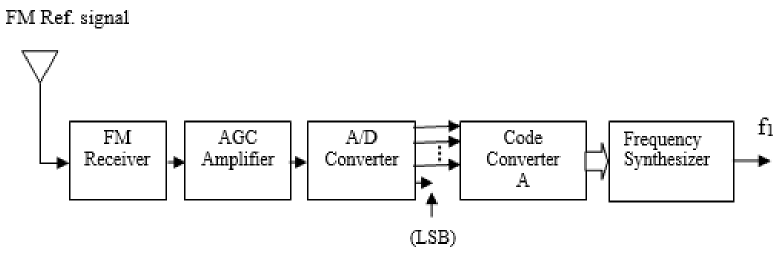
Fig. 2: Spectrum of the FH/CDMA system using 15 frequencies and 15 simultaneous users.

(All the frequencies are used at a time)

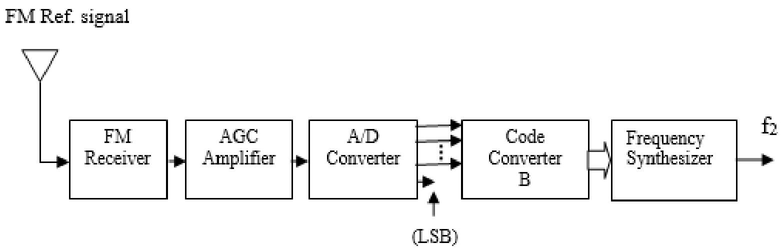
In order to demodulate the intended received signal successfully in a spread spectrum system, the receiver must employ a synchronized replica of the PN-code signal used at the transmitter. Several techniques for achieving synchronization have been developed [8, 9]. The technique used in the system, depends upon the application, the amount of time allowed and the amount of uncertainty involved. The process of synchronizing the locally generated PN-code signal with that at the transmitter is usually carried out in two steps viz. Acquisition (initial synchronization) and Tracking [7,10]. The acquisition is the most difficult job of synchronization. The process of acquisition brings the two spreading signals into coarse alignment with one another. This incorporates time delay in getting the two signals in step with each other. Scientists and engineers have put their efforts to overcome the problem of complexity of circuits used to attain acquisition with small time delay [1], [10-13]. Further, once the received spread spectrum signal has been synchronized with the signal locally generated at the receiver, the tracking takes place. The job of tracking is to operate the receiver in such a way that it maintains the code continuously locked in alignment with the incoming signal as precisely as possible. Various methods has been reported in the literature to reduce the circuit complexity for tracking circuits [1, 10, 14, 15].

III PROPOSED FH-CDMA SYSTEM

The proposed technique is implemented by transmitting a modulated reference signal to all the users in a given locality from a secret transmitter (for example an FM transmitter). The received signal is demodulated by each user using corresponding receiver. Fig. 3 shows a block diagram of such a system for two receivers. The automatic gain control (AGC) circuit in each receiver amplifies the received demodulated signals by equal gain constants. Thereby, the received demodulated signals at any instant of time are of same amplitude at all the receivers with different users in the CDMA system.



(a)



(b)

Fig. 3: Proposed FH/CDMA scheme (for two users) (a) User A, (b) User B

The analog voltage signals are next converted into digital form by A/D converters in each receiver, as shown in Fig. 3. Hence, with proper design of the receivers, the digital signal output generated at a particular time at the A/D converters of all the receivers will be the same. However, to account for any differences in the demodulated reference signals received at different receivers, one or two least significant bits (LSBs) in all the receivers are discarded. Hence, the next higher positioned-bits in the digital word generated by the A/D converters of all the receivers corresponding to the transmitted reference signal at a particular time will be the same. Code converters are now used by each user, so that different frequencies, out of the given library of allowable frequencies, are generated by the frequency synthesizers at different receivers. Hence for each received digital output the code converter generates a unique code for each receiver. The reference signal transmitted may be any unpredictable signal (say a speech or a music signal transmitted over an FM broadcast channel). Hence the received code words at the A/D output in each receiver change in an unpredictable manner, thereby generating a randomly hopping carrier signal by a frequency synthesizer. Code converters could be designed so that all the allowable frequencies are utilized simultaneously with almost zero cross correlation.

Hence the user capacity gets drastically increased and the synchronization can be achieved easily, as the codes utilized by the users are readily available.

IV EXPERIMENTAL RESULTS

The practical implementation of proposed FH-CDMA system is shown in Fig. 4. For laboratory demonstration, two FM receivers were separately used to demodulate a typical local FM broadcast signal, so as to facilitate two different users with the analog reference signal for random code generation. The FM receivers tuned to demodulate the same local broadcast FM signal were found to reproduce similar analog signals at their output. The waveforms obtained at the output of FM receivers have been presented in Fig. 6. The received analog FM signals were converted into digital form using ADC 0808 IC by setting the IC in free running mode.

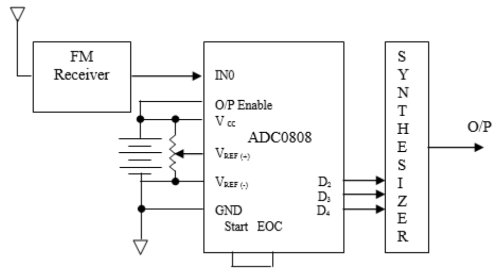


Fig. 4: Circuit implementation of proposed FH-CDMA system

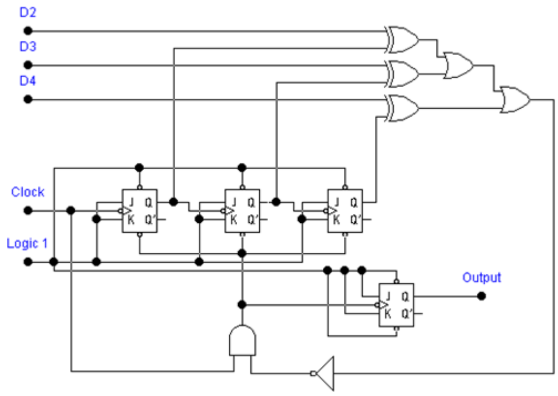


Fig. 5: Circuit Diagram of Digital Frequency Synthesizer

The least significant bits D_0 and D_1 of each A/D converter have been discarded and the next higher significant bits viz D_2, D_3 and D_4 in each A/D converter have been used to drive the frequency synthesizers. Since the synthesizer in this case uses three bits as the input code, only eight different frequencies (2^3) can be produced. As the system was implemented for only two users, therefore code converters were not incorporated. The results obtained in the laboratory are shown in Fig. 6. Fig. 6(b) shows the synthesized carrier frequency corresponding to the analog reference signal, whereas, Fig. 6(c) shows the synthesized frequency hopped carrier frequencies at the two receivers obtained individually. It can be seen that exactly same frequency hopped carrier signals have been obtained at the two users at two different locations. Further, due to the non-availability of frequency synthesizers it was also designed and implemented in the laboratory as shown in the Fig. 5.

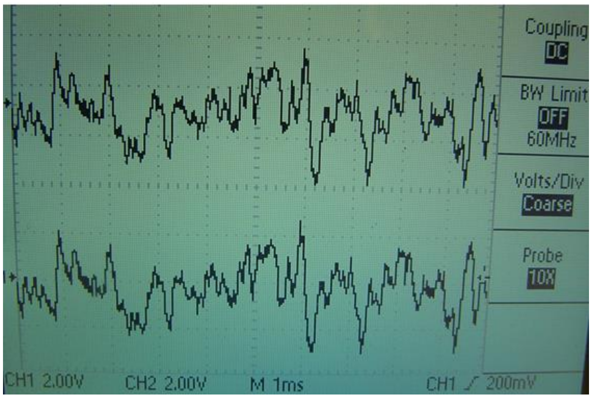


Fig. 6(a): Waveforms at the outputs of two independent FM receivers.

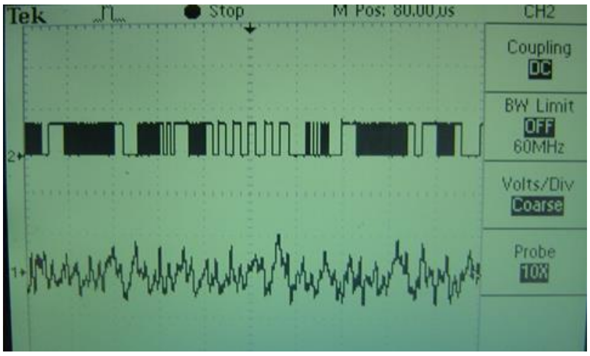


Fig. 6(b): Waveforms generated by the circuit shown in Fig. 4.

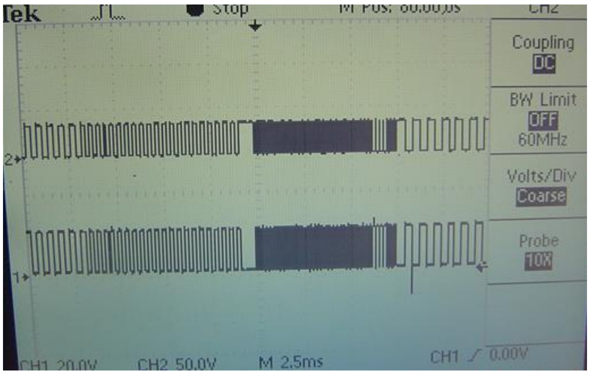


Fig. 6(c): FH carrier signals at two independent users

V CONCLUSION

In a CDMA system acquiring code synchronization and maintaining it between the transmitter and receiver is the toughest job. An attempt has been made in this work to reduce the complexity of the code synchronization and optimize the user capacity in a given portion of bandwidth.

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