SC-FDM-IDMA Scheme Employing BCH Coding

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Article Info	ABSTRACT
	In OFDM-IDMA scheme, intersymbol interference (ISI) is resolved by the OFDM layer and multiple access interference (MAI) is suppressed by the IDMA layer at low cost . However OFDM-IDMA scheme suffers high peak-to-average power ratio (PAPR) problem. For removing high PAPR problem a hybrid multiple access scheme SC-FDM-IDMA has been proposed. In this paper, bit error rate (BER) performance comparison of SC-FDM-IDMA scheme, OFDM-IDMA scheme and IDMA scheme have been duly presented. Moreover, the BER performance of various subcarrier mapping methods for SC-FDM-IDMA scheme as well as other results with variation of different parameters have also been demonstrated. Finally simulation result for BER performance improvement has been shown employing BCH code. All the simulation results demonstrate the suitability of SC-FDM-IDMA scheme for wireless communication under AWGN channel environment.

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1. INTRODUCTION

In the literature, it has been reported by researchers that SC-FDMA-IDMA scheme may be used for the "Long Term Evolution" (LTE) of radio transmissions from cellular phones to base stations i.e. for uplink communication. OFDM-IDMA scheme may mostly be employed for downlink communication. This scheme has shown its unsuitability for uplink communication due to high PAPR (Peak to Average Power Ratio). High PAPR requires high resolution DAC and ADC as well as extremely linear transmitter circuitry because any nonlinearity may cause inter-modulation distortion raising phase noise which may further result in inter-carrier interference (ICI).

In this paper, the performance evaluation of SC-FDM-IDMA scheme has been presented employing BCH codes. Section II provides concept of SC-FDM-IDMA while a glimpse of BCH codes has been explained in section III. In section IV and V the simulation results and conclusion for this work have been presented.

2. SC-FDM-IDMA SCHEME

As a special case of CDMA system, IDMA system relies on interleaving as the only means to distinguish the signals from different users. The IDMA system adopts a very simple chip-by-chip iterative multi-user detection (MUD) strategy for extracting user-specific signals from received composite signal. The computational complexity of the MUD in IDMA systems is a linear function of the number of users. The IDMA scheme significantly outperforms conventional CDMA scheme in the terms of spectral efficiency, receiver complexity and the combination of coding gain and diversity gain [1], [2].

In this paper, SC-FDMA scheme has been considered instead of OFDM scheme to combine with IDMA technique as a solution for LTE uplink, known as SC-FDM-IDMA scheme. This hybrid multiple access scheme inherits many attractive features of SC-FDMA and IDMA schemes. On the one hand, SC-FDMA scheme has lower PAPR because of its inherent single carrier structure. On the other hand, IDMA scheme has a simple and effective iterative MUD in addition to other merits including simple treatment of inter-symbol interference, multiple access interference, and effective mitigation of cross-cell interference. In the simulations, different subcarrier mapping for SC-FDM-IDMA systems, i.e., localized subcarrier mapping, interleaved subcarrier mapping, have been duly iterated [3]. Numerical results show that SC-FDM-IDMA scheme performs better than OFDM-IDMA scheme for unlinking. Moreover, the BER performance of SC-FDM-IDMA scheme approaches OFDM-IDMA scheme.

In the presented system data'd' of user 'k' with data length 'm' is transmitted for each chip 'j'. After forward error correction coding in coder 'C' block data is duly interleaved before DFT and subcarrier mapping operations. Further data is passed through IDFT block before its transfer to channel with AWGN disturbances. On the receiver side, received combined data is reconverted to the compatible data suitable for ESE Block [4]. Here, low complexity ESE algorithm is used for signal detection. This algorithm is derived through Gaussian approximation based on the assumption that the interfering symbols are independent of each other. This assumption is reasonable when the coded block is long enough due to user-specific interleavers. Since ISI is only present in the first Lg samples of received sequence $R(n)$, $n = Lg, \ldots, N-1$, these Lg samples are removed before FFT operation. Further, on received combined data FFT operation if performed [5-10].
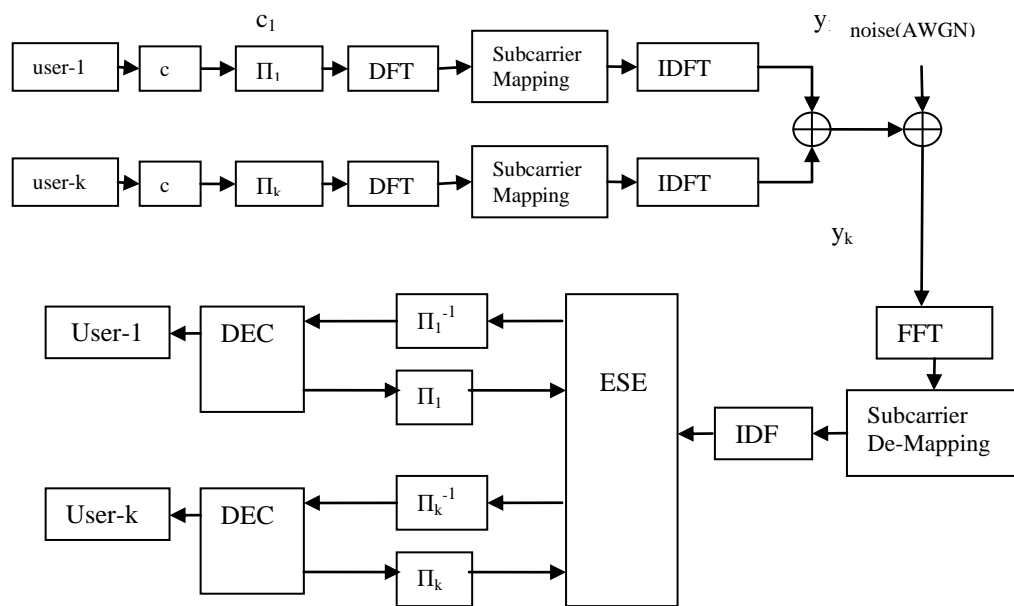

Figure1. SC-FDM-IDMA System

After FFT operation

$$\bar{Y}_v = \sum_{n=0}^{N-1} R_n e^{-j2\pi nv/N}$$

where v=0,…………N-1

Then, it implements subcarrier de-mapping, yielding Xm where m is the data length for specific user. After IDFT operation, producing r

$$r(j) = \frac{1}{M} \sum_{m=0}^{M-1} \overline{X_m} e^{j2\pi mv/M}$$

where v=0,…………M-1

In the process of IDMA detection, we reformulate the algorithm for QPSK signalling as following.

$r(j) = \sum_k h_k x_k(j) + n(j)$

$r(j) = h_k x_k(j) + \zeta_k(j)$

$x_k(j) = x_k^{Re}(j) + i x_k^{Im}(j)$

$h_k = h_k^{Re} + i h_k^{Im}$

The received complex signal can be expressed by:

$$r(j) = \sum_k (h_k^{Re} x_k^{Re}(j) - h_k^{Im} x_k^{Im}(j)) + i \sum_k (h_k^{Re} x_k^{Im}(j) + h_k^{Im} x_k^{Re}(j)) + n(j)$$

Further real and imaginary parts of x are obtained in a similar manner with the help of further analysis.

Step I: ESTIMATION OF INTERFERENCE MEAN AND VARIANCE

$$r(j) = \sum_k (h_k^{Re} x_k^{Re}(j) - h_k^{Im} x_k^{Im}(j)) + i \sum_k (h_k^{Re} x_k^{Im}(j) + h_k^{Im} x_k^{Re}(j)) + n(j)$$

$$E(r^{Re}(j)) = \sum_k (h_k^{Re} E(x_k^{Re}(j) - h_k^{Im} E(x_k^{Im}(j)))$$

$$Var(r^{Re}(j)) = \sum_k (h_k^{Re})^2 \, Var(x^{Re}(j)) + \sum_k (h_k^{Im})^2 \, Var(x_k^{Im}(j)) + \sigma^2$$

$$\psi(j) = \sum_k h_k^{Re} h_k^{Im} (Var(x_k^{Re}(j)) - Var(x_k^{Im}(j)))$$

$$Var(Re\overline{(h_k}\zeta_k(j)))$$
$$= (h_k^{Re})^2 Var(r^{Re}(j)) + (h_k^{Im})^2 Var(r^{Im}(j)) + 2 h_k^{Re} h_k^{Im} \psi(j)$$
$$- |h|_k^4 Var(x_k^{Re}(j))$$

Step II: LLR GENERATION & COMBINING

The output of elementary signal estimator block is as follows,

$$e_{ESE}(x_k^{Re}(j)) = 2 \, |h|_k^2 \, \frac{Re(\overline{h_k} r(j)) - E(Re(\overline{h_k}\zeta_k(j)))}{Var(Re(\overline{h_k}\zeta_k(j)))}$$

where Ψ(j) is the covariance of imaginary and real parts of received signal for j chip. The estimates E(.) and Var (.) denote the expectation and variance. The DEC carries out APP algorithm. The extrinsic LLRs will be used in the ESE to update the interference mean and variance in the next iteration [11].

$$(E(x_k^{Re}(j)) = \tanh(\frac{e_{DEC}(x_k^{Re}(j))}{2})$$

$$Var(x_k^{Re}(j)) = 1 - (E(x_k^{Re}(j)))^2$$

3. BCH CODE

The BCH codes form a class of cyclic error-correcting codes that are constructed employing finite fields. One of the key features of BCH codes is a precise control over the number of symbol errors correctable by the code during its code designing process. In addition to it, BCH can easily be decoded using an algebraic method known as syndrome decoding. BCH codes operate over finite fields or Galois fields. BCH codes can be defined by two parameters that are: codeword length (n) and the number of errors to be corrected, [12-14]. The BCH codes are a class of cycle codes whose generator polynomial is product of distinct minimum polynomials corresponding to $\alpha, \alpha^2, ... \alpha^{2t}$, where $\alpha \, \varepsilon \, GF(2^m)$ is a root of the primitive

polynomial g(x). An irreducible polynomial g(x) of degree m is said to be primitive if only if it divides polynomial form of degree n, x^n+1 for no n less than 2^m-1. In fact, every binary primitive polynomial g(x) of degree m is a factor of $x^{2m\,1}+1$.Let $m_i(x)$ be the minimal polynomial of α^i. Let

$$p(x) = p_0 + p_1x + p_2x^2 + ...+ p_{n-1}x^{n-1} \hspace{3cm} (1)$$

be a code polynomial with coefficients from GF(2). If p(x) has α, α^2… α^{2t} as its roots, $p(x)$ is divisible by the minimal polynomials $m_1(x)$, $m_2(x)$… $m_{2t-1}(x)$. The generator polynomial $g(x)$ of the t-error correcting BCH of length code words $n = 2^m - 1$ and rate codes k/n is the lowest degree polynomial over GF(2) [15-18]. Thus, the generator polynomial of the code must be the least common multiple (LCM) of these minimal polynomials: $g(x)$ =LCM{$m_1(x)$,m2 (x),......,m_{2t} (x) (2) In general, for any positive integer m≥3 and t <n / 2 , there is a binary BCH code with parameters of code words length n = 2^m - 1, number of parity check bits n-k ≤mt , and minimum distance d_0=2t +1≤ d_{min} . The designed distance of the code is d_0 = 2t + 1. The minimum distance d_{min} could be larger than d_0 [16]. Algorithm for designing BCH codes is:
1. Choose a primitive polynomial of degree m, and construct GF (2^m).
2. Find the minimal polynomial $m_i(x)$ of α^i for i = 1, 2… 2t.
3. Obtain g(x).
4. Determine k from n - k, which is the degree of g(x).
5. Find the minimum distance d_{min}≥2t+1.
First of all, performance of SC-FDM-IDMA scheme is evaluated by changing different parameters.

4. SIMULATION RESULT AND DISCUSSION

For simulation purpose, single cell environment has been scheduled with SC-FDM-IDMA scheme implemented with one transmitter and one receiver architecture. The signalling scheme is opted to be QPSK.
a. ber performance of SC-FDM-IDMA (IFDMA) with different no. of iterations. In Figure 2, the performance of SC-FDM-IDMA scheme has been observed in AWGN channel for 8 users. The simulation results shown by using different number of iterations from iteration 1 to 10 and it can be seen that system performance improves on increasing the number of iterations.
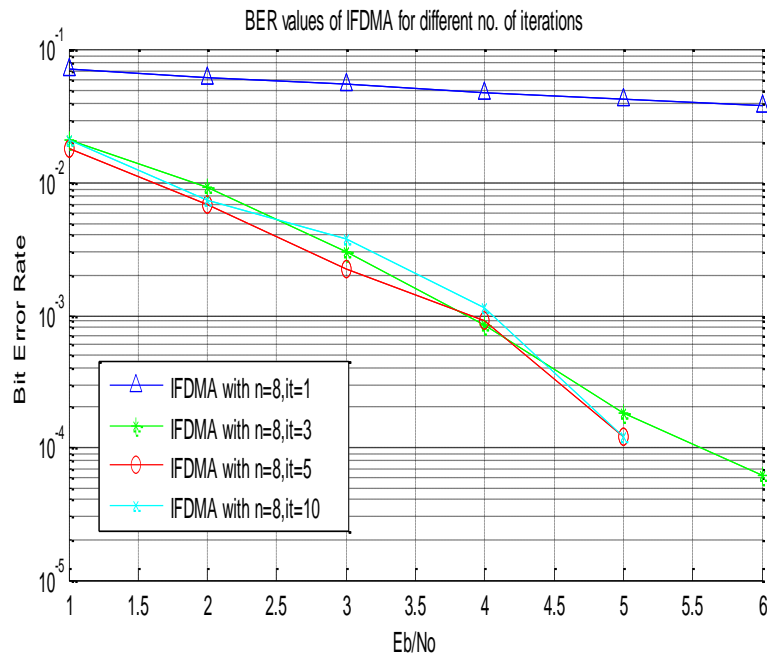

Figure 2. Values of BER at different no. of iterations vs. E_b/N_0 in IFDMA

b. ber performance of SC-FDM-IDMA (IFDMA) scheme with different no. of users simulation result shows that Values of Bit Error Rate increases on increasing value of no. of user
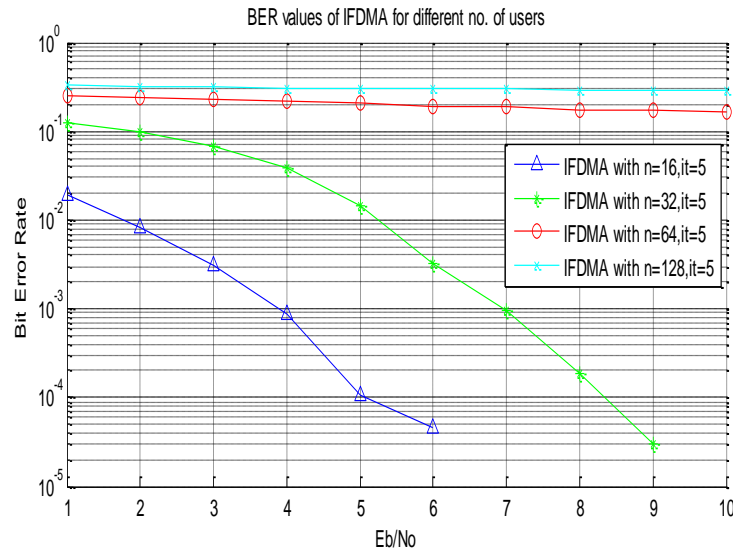
Figure 3. Values of BER at different no. of users vs. E_b/N_0 in IFDMA

c. ber performance of SC-FDM-IDMA (IFDMA) scheme with different no. of iterations & blocks No. of iterations used 1,3,7 No. of blocks 4,16 and Spreading Factor=2, If value of Iteration is changed from 1 to 3 then it is evident from obtained plot that a large change in values of Bit Error Rate is obtained. Now value of BER is drastically reduced compared to earlier cases.
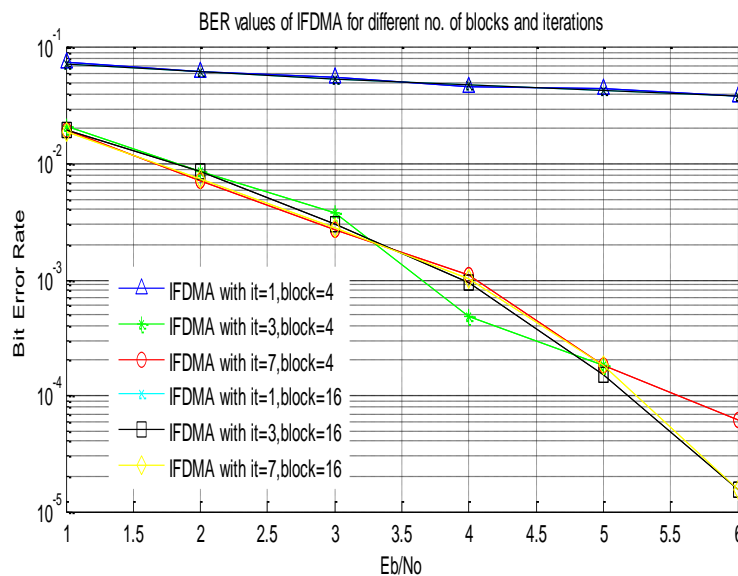

Figure 4. Values of BER at different no. of iterations and blocks vs. E_b/N_0 in IFDMA

d. ber performance comparison of SC-FDM-IDMA with different subcarrier mapping schemes (LFDMA & IFDMA) & ofdm-idma with & without bch code.The simulation which has been carried out shows the comparison between Localized subcarrier mapping and Interleaved Subcarrier Mapping case of SC-FDM-IDMA and OFDM-IDMA. Here value of spreading factor used is 2 for Interleaved Subcarrier Mapping. These two Subcarrier mapping schemes defines the way in which subcarriers are assigned to message signals. No. of users 8 No. of Blocks 5and No. of Iterations=5 .Values of BER in the case of OFDM-IDMA is maximum in comparison to LFDMA and IFDMA case value of BER increases on changing the

subcarrier mapping scheme from localized subcarrier mapping scheme to interleave subcarrier mapping scheme. Value of BER is reduces on applying BCH code in the case of OFDM-IDMA.Value of BER is zero for all the values of Eb/N_0 in the case of LFDMA & IFDMA on applying BCH code. It means that no error bit is obtained on applying BCH code.This is evident from above table that value of bit error rate reduces on increasing the values of Eb/N_0. This trend is normally followed in all preceding plots as well.
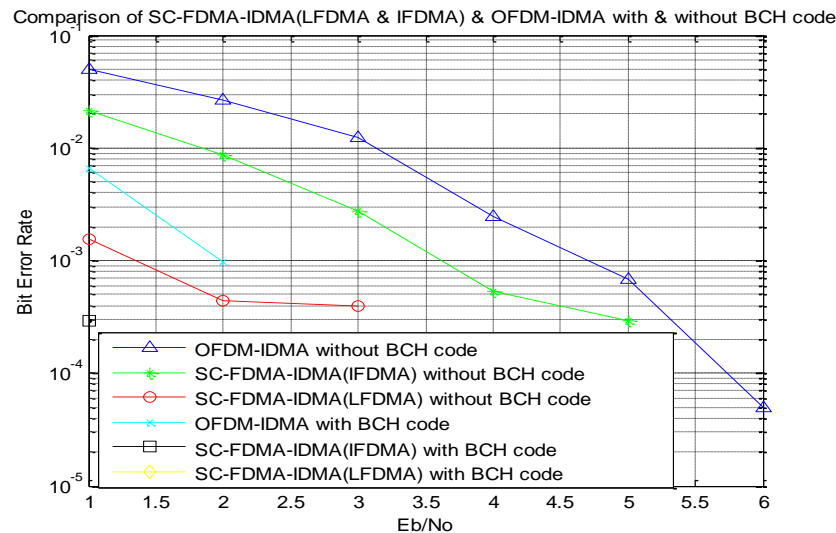

Figure 5. BER performance comparison of SC-FDM-IDMA (LFDMA & IFDMA) & OFDM-IDMA with & without BCH code

5.   CONCLUSIONS

In this paper we have investigated SC-FDM-IDMA Scheme for LTE Uplink and further improvement in performance is obtained with the help of using BCH code. This improvement in performance is obtained in the terms of reduced Bit Error Rate. Reduced bit error rate is clearly shown in the Results and Discussions section of this paper. The plus point of using BCH code is that a high improvement in performance is obtained without much increase in complexity.

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