International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Comparison of BER for IDMA and OFDM-IDMA Systems

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Abstract: ***The present paper aims to discover that the performance of OFDM-IDMA is better when compared to that of IDMA and CDMA. Inter-leavers with high performance attributes are needed particularly with OFDM to ensure high data rates for the communication system. MATLAB is used throughout the research to evaluate Bit Error Rate (BER) for OFDM-IDMA system models. The simulated model developed can be an invaluable tool for investigating the design and implementation of OFDM-IDMA systems.***

Keywords: OFDM, IDMA, CDMA, TDMA, FDMA, MUD, OFDM-IDMA

1. Introduction

Various multiple access technique like TDMA, CDMA, FDMA has been used in wireless network for communication. But OFDM i.e. orthogonal frequency division multiple access [1], offers number of advantages over these multiple access techniques, such as this scheme can provide simple treatment against ISI and also reduces cross cell interference. The IDMA in combination with OFDM allow effective and simple turbo type iterative MUD algorithm which can be easily implemented to large number of users, which help to obtaining high throughout. MUD (multiple user detection) also provides potential solution to MAI (multiple access technique) problem. IDMA also allow low cost chip by chip (CBC) MUD detection algorithm, but the complexity increases linearly with increase number of user as the path increase which concern for wideband system.

OFDM-CDMA is very promising technique for implementation of physical layer in 4G wireless systems. But then also there are some disadvantages related to OFDM-CDMA systems. To differentiate among different users OFDM-CDMA uses different orthogonal codes and due to this orthogonality distortion occurs among users in frequency selective channel (especially in uplink transmission), which may cause problem of MAI. For MAI problem, MUD is a promising technique which is very complex in practical application. The detectors for OFDM-IDMA system like the linear MMSE detector and other de-correlator have the quadratic complexity with the number of users say K [3]. This quadratic complexity occurs to resolving the correlation operations involved in spreading sequences. The computational prohibitive occur for practical implementation if value of K is large.

For coding in OFDM-CDMA systems using spreading sequences for separation of users is not good, because the spreading operation results in expansion of band- width with no coding gain. In [4] theoretical analysis has been made which shows that the capacity of multiple access channel can be reached if the entire bandwidth expansion is due to the use of FEC coding.

By using IDMA technique instead of CDMA in OFDM-CDMA, many of the disadvantages can be resolved. We can obtain many have many attractive features for OFDM-IDMA scheme like cross-cell interference mitigation and simple treatment of ISI. Some additional benefits may also occur by using IDMA technique. The IDMA [2] allows simple and effective turbo-type iterative MUD algorithm which for large number of users with higher throughput.

The CBC detection algorithm has linear complexity with the number of users K. Since random inter-leavers are employed to distinguish signals from different users, the spreading operation can be avoids in the OFDM-IDMA scheme. In this situation, the OFDM-IDMA scheme devotes entire bandwidth expansion to FEC coding and obtains additional coding gain. It is also difficult to analyze the performance of OFDM-CDMA systems. To accomplish this task, we need to characterize the correlation matrix among spreading sequences, because the system performance dependent on the choices of signature sequences. Although the performance is not sensitive to the choices of spreading sequences when long random spreading codes are employed, it is still mathematically demanding to evaluate the performance by large random matrix theory [5]. OFDM-IDMA does not involve signature sequences, which greatly simplifies the problem. A simple and accurate performance analysis method, SNR evolution, can be applied to OFDM-IDMA. Based on SNR evolution, we can further optimize the system performance by power allocation.

2. Principle of OFDM-IDMA

The uplink transmitter and receiver structures of OFDM-IDMA [6] with K simultaneous users are simultaneous users, where π_k is the inter-leaver of user-k. For simplicity, the above figure does not include the insertion and removing of the guard intervals between OFDM symbols, shown in Figure 1.

Let d_k be the data stream of user-k. This data stream is encoded by a forward error correction (FEC) code, generating a chip sequence c_k . (Here, “chip” is used instead of “bit” as the FEC encoding may include

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spreading or repetition coding.) Then c_k is permutated by a user-specific inter-leaver-k. After symbol mapping, the symbol sequence $x_k = [x_k(1), \ldots, x_k(j), \ldots, x_k(j)]^T$ is produced, where J is the frame length.

Then these symbols are modulated onto different subcarriers by IFFT. (For simplicity, the symbol mapping process is not shown in the Figure 1.

Consider QPSK signaling

$$x_k(j) = x_k^{Re}(j) + i_{x_k}^{Im}(j) \quad (1)$$

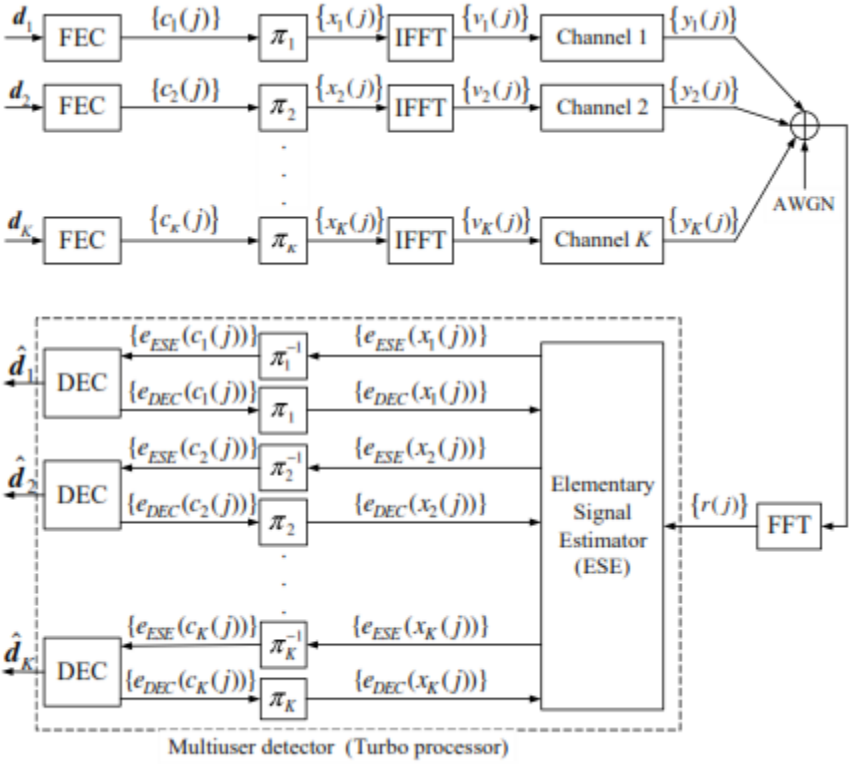


Figure 1: Transmitter and receiver structures of the OFDM-IDMA scheme with K

After OFDM modulation, the transmitted sequence can be expressed as $v_k = W^H x_k$. (x_k) is divided into blocks with length of N_C for OFDM transmission, where N_C is the number of subcarriers.) W is DFT matrix and the superscript "H" indicates Hermite transpose.

The (m^{th}, n^{th}) entry of W is

$$W[m,n] = \frac{1}{\sqrt{N_c}} e^{-i2\pi mn/N_c} \quad (2)$$

We assume an L-path channel model with fading coefficients $[h_k = h_k(0), h_k(1), \ldots\ldots, h_k(L-1)]$ for user-k. The output of multipath channel can be written as

$$y = \sum_k y_k + z = \sum_k h_k * v_k + z \quad (3)$$

Where '*'denotes the convolution and the elements of z are samples of additive noise. At the receiver side, OFDM demodulation is carried out before iterative MUD process as show in lower half of Figure 1. Assuming that the duration of cyclic prefix is longer than the maximum channel delay, the received signal after OFDM demodulation can be expressed as;

$$r(j) = \sum_k H_k(j) x_k(j) + z(j) \quad (4)$$

Where $H_k(j) = \sum_{l=0}^{L-1} h_k(l).\, e^{-i2\pi jl/N_c}$ is the fading coefficient of sub carrierj. z(j), FFT of z(j), is a complex white Gaussian noise with the variance σ^2 in each dimension. Then the CBC detection algorithm for complex single-path channel can be applied. The main difference between the detection process described in above chapters and detection algorithm proposed here is that the fading coefficients of OFDM subcarriers $\{H_k(j)\}$ are different for different j in a frequency selective channel in the OFDM-IDMA scheme, we can also consider multipath Quasi-static fading channels and the fading coefficients $\{h_k(l)\}$ are identical for all chips of user-k during one frame. (l is the path index.) The iterative detection process for OFDM-IDMA is carried out as follows:

(i) Initialization: Set E (xk (j)) = 0, **Cov**(x_k(j)) = I, ∀ k, j, where I is a 2 × 2 identity matrix.
(ii) Main operations: The iterative process indulge two process

Step 1: ESE Part
We concentrate on detection of $x_k(j)$ with user k and rewrite equation (4) as

$$\mathbf{r(j)} = H_k(j)\mathbf{x_k(j)} + \zeta_k(j) \quad (5)$$

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Where

$$\zeta_k(j) = \sum_{m \neq k} H_m(j) x_m(j) + z(j) \quad (6)$$

In order to detect $x_k(j)$, we generate

$$\acute{r}_k(j) = H_k^*(j) r(j) = |H_k(j)|^2 x_k(j) + \zeta_k(j) \quad (7)$$

Where

$$\tilde{\zeta_k}(j) = H_k^*(j) \zeta_k(j) \quad (8)$$

By the central limit theorem, $\tilde{\zeta_k}(j)$ can be approximated as a Gaussian variable. This approximation is used by ESE to generate LLR for $x_k(j)$. We have

$$e_{ESE}\left(x_k^{Re}(j)\right) = \frac{2|H_k(j)|^2 (\acute{r}_k^{Re}(j) - E(\tilde{\zeta_k}^{Re}(j)))}{Var(\tilde{\zeta_k}^{Re}(j))} \quad (5.9)$$

and $e_{ESE}\left(x_k^{Im}(j)\right)$ can be generated in similar way. The calculation related to $E(\tilde{\zeta_k}^{Re}(j))$ and $Var(\tilde{\zeta_k}^{Re}(j))$, in equation (9) are carried out as follows. According to equation (8), we have

$$\begin{cases} E(\tilde{\zeta_k}(j)) = H_k^*(j) E(\zeta_k(j)), \\ Var(\tilde{\zeta_k}^{Re}(j)) = R_k^T(j) Cov(\zeta_k(j)) R_k(j) \end{cases} \quad (10)$$

Where

$$R_k(j) = \begin{pmatrix} H_k^{Re}(j) & -H_k^{Im}(j) \\ H_k^{Im}(j) & H_k^{Re}(j) \end{pmatrix}$$

By equation (6), we have

$$\begin{cases} E(\zeta_k(j)) = E[r(j)] - H_k(j) E[x_k(j)] \\ Cov(\zeta_k(j)) = Cov(r(j)) - R_k(j) Cov(x_k(j) R_k^T(j)) \end{cases} \quad (11)$$

In equation (11), mean and variance of the received signal can be estimated as follows

$$\begin{cases} E(r(j)) = \sum_k H_k(j) E(x_k(j)), \\ Cov(r(j)) = \sum_k R_k(j) Cov(x_k(j)) R_k^T(j) + \sigma^2 I \end{cases} \quad (12)$$

Step 2: DEC Part

The DECs carry out APP decoding using the output of the ESE as the input. With QPSK signaling, outputs of the DEC-k are the extrinsic LLRs for $\{x_k^{Re}(j)\}$ and $\{x_k^{Im}(j)\}$. We use the extrinsic information to update the mean and variance of each chip

$$\begin{cases} E(x_k(j)) = \tanh\left(\frac{e_{DEC}(x_k^{Re}(j))}{2}\right) + i \tanh\left(\frac{e_{DEC}(x_k^{Im}(j))}{2}\right), \\ Cov(x_k(j)) = \begin{pmatrix} 1 - (E(x_k^{Re}(j)))^2 & 0 \\ 0 & 1 - (E(x_k^{Im}(j)))^2 \end{pmatrix} \end{cases} \quad (13)$$

Where we have assumed that the extrinsic LLRs for the real and imaginary parts of $x_k(j)$ are uncorrelated, and thus the off-diagonal entries of Cov $(x_k(j))$ are zeros. In the iterative process, ESE and DEC-k exchange the extrinsic information about $x_k(j)$. The CBC detection for OFDM-IDMA can be concluded as follows;

(1) ESE generates $\{e_{ESE}(x_k(j))\}$ by (37) for DEC-k.
(2) DEC-k generates $\{e_{DEC}(x_k(j))\}$, which are used to update mean and variance of $\{x_k(j)\}$.

3. Simulation Result of BER for IDMA System

Based on the following parameters the simulation result is shown in Figure 2.

Block = 20
Number of user (n) = 24
Data length (m) = 512
Spread length (sl) = 16

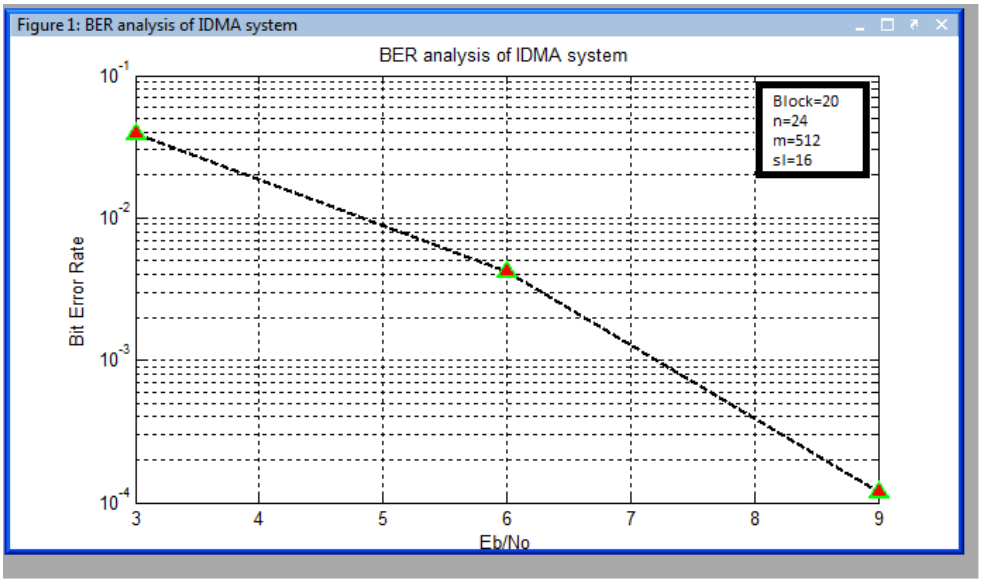


Figure 2: BER analysis of IDMA system for m= 512 and sl =16

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The simulation result in Figure 2 shows that the IDMA technique for 24 users with data length 512, keeping spread length of 16 bits have Bit Error Ratio (BER) of approx. $2*10^{-4}$ which shows that there 2 bits errors out of 40,000 bits.

Number of iterations taken is equal to 15 for the IDMA system simulation.

4. Simulation Results of BER for OFDM-IDMA Scheme

The results are based on the following parameters

Case 1: Block = 20
Number of user (n) = 24
Data length (m) = 512
Spread length (sl) = 16

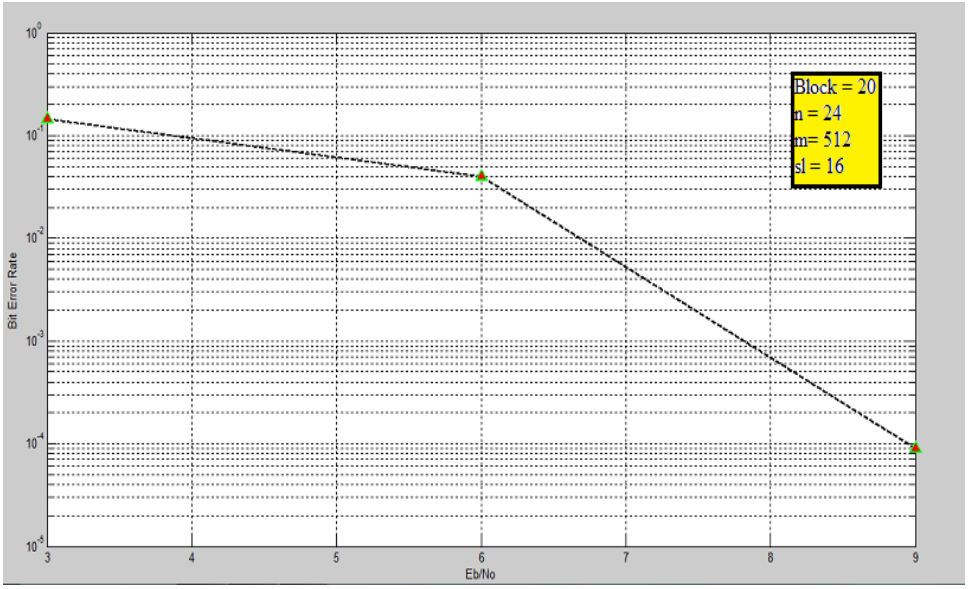


Figure 3: BER analysis of OFDM-IDMA system for m= 512 and sl =16

The simulation result in Figure 3 shows that the OFDM-IDMA technique for 24 users with data length 512, keeping spread length of 16 bits have Bit Error Ratio (BER) of approx. $8*10^{-5}$ which shows that there 8 bits errors out of 100,000 bits.

Chip length can be calculated by multiplying data length (m) with the spread length (sl).Number of iterations taken is equal to 15.

Case 2: Block = 20
Number of user (n) = 24
Data length (m) = 256
Spread length (sl) = 16

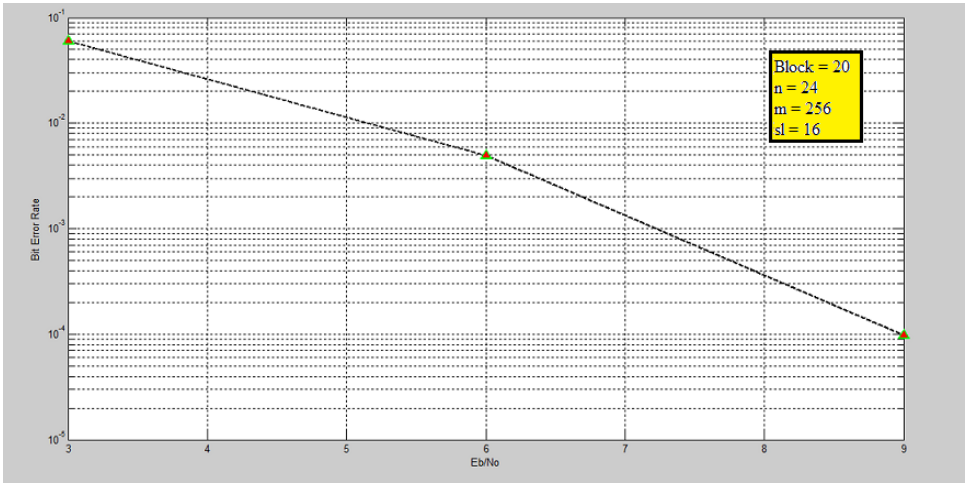


Figure 4: BER analysis of OFDM-IDMA system for m = 256 and sl = 16

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The simulation result in Figure 4 shows that the OFDM-IDMA technique for 24 users with data length 256, keeping spread length of 16 bits have Bit Error Ratio (BER) of approx. $9* 10^{-5}$, which shows that there 9 bits errors out of 100,000 bits. Chip length can be calculated by multiplying data length (m) with the spread length (sl). Number of iterations taken is equal to 15.

Case 3: Block = 20
Number of user (n) = 24
Data length (m) = 256
Spread length (sl) = 32

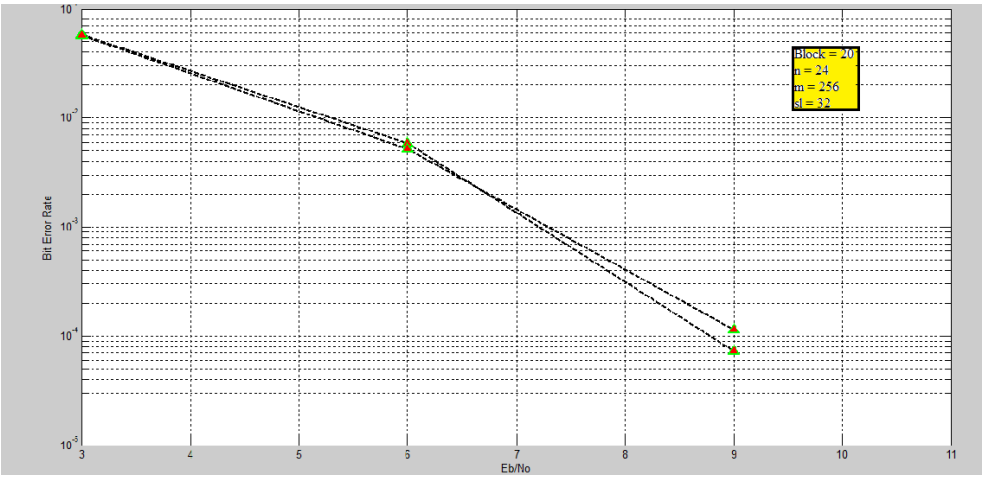


Figure 5: BER analysis of OFDM-IDMA system for m = 256 and sl = 32

The simulation result in Figure 5 shows that the OFDM-IDMA technique for 24 users with data length 256, keeping spread length of 32 bits have Bit Error Ratio (BER) of approx. $7* 10^{-5}$, which shows that there 7 bits errors out of 100,000 bits.

Chip length can be calculated by multiplying data length (m) with the spread length (sl). Number of iterations taken is equal to 15.

Case 4: Block = 20
Number of user (n) = 24
Data length (m) = 512
Spread length (sl) = 32

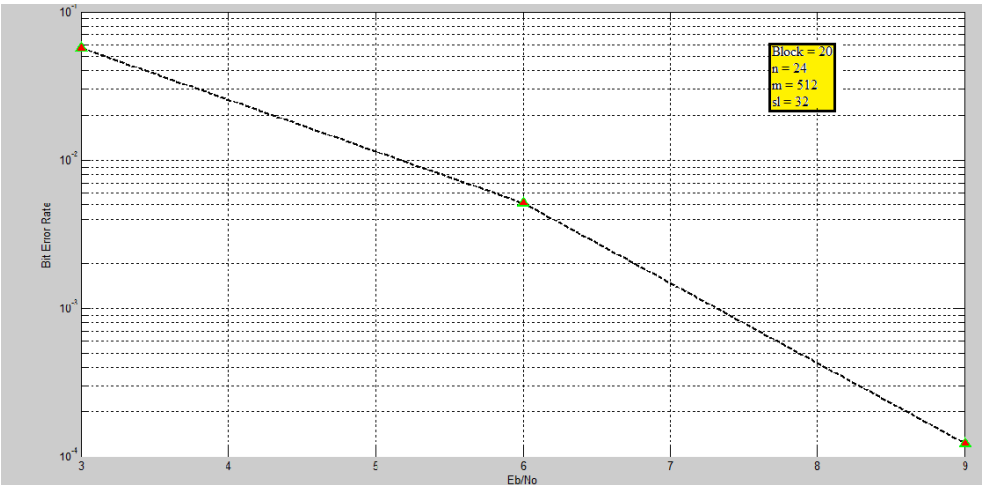


Figure 6: BER analysis of OFDM-IDMA system for m = 512 and sl = 32

The simulation result in Figure 6 shows that the OFDM-IDMA technique for 24 users with data length 512, keeping spread length of 32 bits have Bit Error Ratio (BER) of approx. $10* 10^{-5}$, which shows that there 10 bits errors out of 100,000 bits.

Chip length can be calculated by multiplying data length (m) with the spread length (sl). Number of iterations taken is equal to 15.

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5. Result Comparison of IDMA and OFDM-IDMA System for Different Parameters

Table 1: Result Comparison of IDMA and OFDM-IDMA System for Different Parameters

Parameters →		*Block*	*No. of users (n)*	*Data Length (m)*	*Spread Length (sl)*	*BER*
IDMA		20	24	512	16	$2 *10^{-4}$
OFDM-IDMA	Case 1	20	24	512	16	$8*10^{-5}$
	Case 2	20	24	256	16	$9*10^{-5}$
	Case 3	20	24	256	32	$7*10^{-5}$
	Case 4	20	24	512	32	$10*10^{-5}$

From the above comparisons it is observed that when number of users are kept 24 for block of length 20, keeping spread length 16 and data length 512 the BER for IDMA is $2 *10^{-4}$ means there are 20 erroneous bits when100,000 bits are transmitted, whereas for OFDM-IDMA system the BER is $8*10^{-5}$ means there are 8 erroneous bits when 100,000 bits are transmitted, showing high data rate for OFDM-IDMA system with less number of error bits. Other results for BER are analyzed with different spread length for OFDM-IDMA system with same number of users and same and different data length showing better results for high spread length.

6. Conclusion

On the basis of proposed simulation, the performance of OFDM-IDMA system is better than the other methods. The bit error rate of 24 users with 16 and 32 spread length is almost same in Figure 2 and Figure 3.

In the proposed work, the performance comparison of two multiple access techniques i.e. between CDMA and IDMA have been presented. Comparisons between different Multiple access techniques have been made on the basis of parameters like number of users, spreading length used among the users, etc. On the comparison basis the IDMA shows its better suitability for the applications to support multimedia services in broadband wireless network for fourth generation communication. Whereas, OFDM with IDMA is better in performance. In Figure 2 and Figure 3 shows OFDM-IDMA performance gain over CDMA and IDMA. Although the performance IDMA technique is well suited for next generation, but still there are some challenging issues in this scheme such as inter-leaver design, coding scheme, channel behavior, optimum signaling scheme etc. These issues can be resolved to some extend when used with OFDM scheme as the problem of ISI can be eliminated.

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