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Performance Evaluation of Sc-IDMA & Of DM- IDMA in Impulsive Media

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Abstract: ***In this paper, we analyzed the working phenomenon of Single and Multi carrier IDMA in Non Gaussian Impulsive medium and also compared their relative performances. The performance comparison is evaluated under the following constraints; by varying the iteration count, impulsive constant, control parameters and no. of users etc. The multi user detection for these schemes can be realized with complexity (per user) strictly independent of number of users. The simulation result concludes that multicarrier IDMA outperforms the single carrier IDMA in impulsive non Gaussian channel as a medium.***

Index Terms: **SC-IDMA, OFDM-IDMA, multiuser detection, iterative receiver.**

I. INTRODUCTION

It is a type of very short duration undesired signal with the dominating amplitude in contrast to the else contributing background noises and its instantaneous presence is unpredictable. Mathematically, it is placed in the category of non-Gaussian noise.

Single Carrier IDMA involves the use of chip level user specific interleavers for distinguishing the signal from different users and it shows the dominating performance in comparison to Single Carrier CDMA in terms of bandwidth utilization and power efficiency. It involves the joint operation of spreading and coding rather than individually hence it results in attainment of better bandwidth utilization and expectable error resilient system. Improvement in time diversity [8] and use of user specific interleaving as a signature sequence are the major features associated with Single Carrier IDMA.

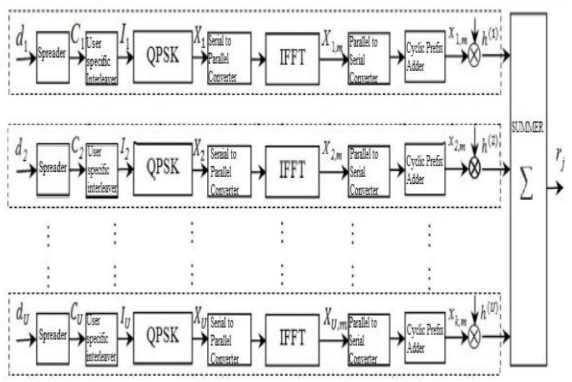
Multi carrier IDMA results by combining the single carrier IDMA with OFDM (orthogonal frequency division multiplexing). It involves the use of inverse FFT at the transmitter end and FFT at the receiver end.

The ISI convolution effect (in time domain) is converted to fluctuation effect in frequency domain. Multi carrier IDMA is highly sensitive and more correlated to sub carrier fading under low dispersion channels. Since interleaving is performed after spreading, the resulting chips mapped to various time and frequency slots in both the time and frequency domain. Multi carrier IDMA inherits advantage of time, frequency diversity and also achieves the benefits from Single carrier IDMA (SC-IDMA) and orthogonal frequency division multiplexing (OFDM). Chip by Chip estimation algorithm is used in both the receiver systems. Soft cancellation low cost iterative technique is used for optimizing MAI (multiple access interference) and ISI (Inter symbol interference). The multicarrier IDMA receiver complexity is independent of length of the channel and linearly varies with the user count. The Multi carrier IDMA [4], [5] exhibits higher efficiency (spectral), supports single and multi user transmission both and also achieves the MUG (multi user gain) in fading based channels. Complexity in Multi carrier IDMA is independent of users in count and length of the channel and its realization is also relatively simpler in contrast to the else similar counterparts. The performance of Multi Carrier IDMA can be improved by increasing the spread length and users in count. The increased spread length optimizes selectiveness of frequency among various unique sub-carriers.

This paper is organized as follows: Introduction and Multicarrier IDMA (OFDM-IDMA) Transceiver Model are described in section I to II. The performance comparison between single carrier IDMA and OFDM-IDMA is discussed in the section III and section IV concludes the paper.

II. Multicarrier IDMA (OFDM-IDMA) Transceiver Model:

A. Transmitter Model of Multicarrier IDMA (OFDM-IDMA)



Transmitter section consists of spreader, user specific interleaver, QPSK mapper, IFFT module, Parallel to Serial converter, cyclic prefix adder and Summer etc. At the transmitter end initially the data from different users are passed through spreader.

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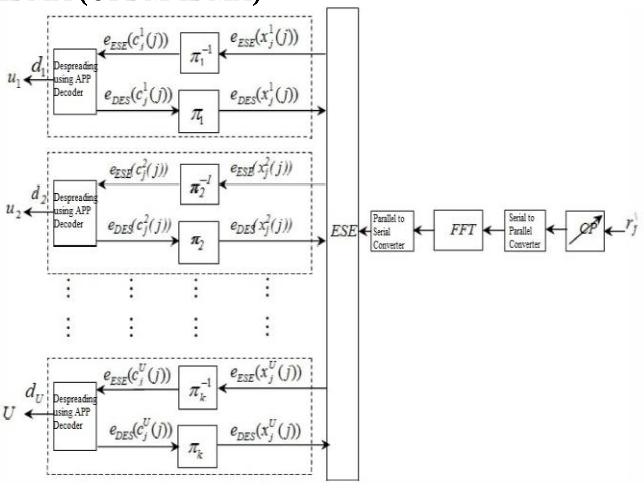
The resultant spreaded sequence is applied as an input to user specific interleaver. User specific random interleaver is used in order to generate the chip sequences. After the generation of chip sequence QPSK mapper (digital signal modulator) is used to convert these generated chip sequences in to corresponding complex symbols. These resultant mapped signals undergoes through transmission using IFFT module. The output of IFFT module is applied as an input to Parallel to Serial converter and this converted signal is added with cyclic prefix. The added signals from different users are finally applied to the summer. The resultant data sequence after the addition of cyclic prefix is denoted by:

$x_{k,m}$ =(1/ N_c) $\sum_{n=0}^{N_c-1} x_{u,m}(n) \quad e^{j2 \cdot pi \cdot n \cdot \frac{t}{N_c}}$, t= 0,.........,N_c -1 (1)

$x_{u,m}(n)$ is the m^{th} orthogonal frequency division multiplexing symbol of u^{th} subscriber which undergoes through the modulation process over the n^{th} sub-carrier. N_c is the aggregate number of subcarriers for the orthogonal frequency division multiplexing based transmission.

B. Chip by Chip Iterative Receiver Model of Multicarrier IDMA (OFDM-IDMA)



User-specific interleaver is the key ingredient used in the receiver system for improving the efficiency of both the single carrier and multi carrier IDMA systems. It is the only mean for distinguishing the signal from different users and also provides de-correlation among the bit sequences (adjacent). It also results in the convergence of chip-by-chip detection process [5], [7] and minimizes the MAI (multiple access interference) from other users.

It is assumed that the channel coefficients are well known at the receiver end, for simple ξanalysis these assumed channel coefficients are considered as real in nature and the established phenomenon can be further extended to complex channel coefficients [6]. This receiver system consists of ESE (Elementary Signal Estimator), a group of u single user APP (A Posteriori Probability) decoders for performing the de-spreading operation at the reception end, Cyclic Prefix removal system, serial to parallel converter, parallel to serial converter, FFT module and replica of interleaver (used at the transmission end) and the corresponding de-interleaver for supporting the chip-by-chip multi user detection process.

After elimination of cyclic prefix and FFT procedure, the signals received at instant j can be shown as:

$\frac{r_j}{\square} = \sum_{u=1}^{U} \boldsymbol{h}^u x_j^u + N_j$ where j may takes only the integral values from 1 to J (2)

and x_j^u shows the chip transmitted from the k^{th} user at any instant j, $\boldsymbol{h}^{(u)}$ the coefficient of channel for k^{th} user and N_j contains the two components n_j and In_j where n_j is the AWGN (Additive White Gaussian Noise) with zero mean and variance σ^2 =No/2 and In_j is the short term impulse noise with a mean of zero value and variance = KNo* ξ + (1-ξ) KNo.

The Elementary Signal Estimator is used as a signal detector for performing the chip by chip multi user detection. x_j^u in above equation can be further written as below:

$\frac{r_j}{\square} = \boldsymbol{h}^u x_j^u + \epsilon_j^u$ (3)

Where $\epsilon_j^u = \frac{r_j}{\square} - \boldsymbol{h}^u x_j^u$ shows the aggregated noise and can also be termed as distortion which is simply the sum of impulsive noise [3] and interference for user u. For performing the iteration x_j^u is assumed as a random variable and its initial mean and variance values are set as 0 and 1. Its mean and variance are represented by E (x_j^u) and Var (x_j^u).

Therefore, E($\frac{r_j}{\square}$)=$\sum_{\downarrow}(u = 1)^{\uparrow}U ≣ 〖\boldsymbol{h}^{\uparrow}u \ E(x_{\downarrow}j^{\uparrow}u〗$ (4)

&

Variance=

$\sum_{\downarrow}(u = 1)^{\uparrow}U ≣ 〖〖〖|\boldsymbol{h}〗^{\uparrow}u|〗^{\uparrow}2 \ Var(x_{\downarrow}j^{\uparrow}u〗) + \sigma^2$ (5)

The outputs of Elementary Signal estimators are Log likelihood ratios regarding x_j^u based on the equation 2 and 3.

L($x_{\downarrow}j^{\uparrow}u$) =log((Pr($x_j^u$)=+1/r_j)/((Pr(x_j^u)=-1/r_j)) (6)

The elementary signal outputs are passed through the user specific de-interleaver in order to L($c_{\downarrow}j^{\uparrow}u$) from L($x_{\downarrow}j^{\uparrow}u$) for every user in operation. The resultant output is applied as an input to chip by chip de-spreader. The extrinsic log likelihood ratio from the output of de-spreader is fed back to the elementary signal estimator after passing it through the user specific interleaver. During the next iterative cycle extrinsic log likelihood ratio of x_j^u are used to update the mean and variance of x_j^u in the following way.

E(x_j^u)= tanh(extrinsic log likelihood ratio of x_j^u / 2) (7)

Var(x_j^u)=1 - $\mathbf{E}\left(x_j^u\right)^2$ (8)

For the evaluation of the performance the noise model used is GMM [1],[2] with the probability density function [10] as;

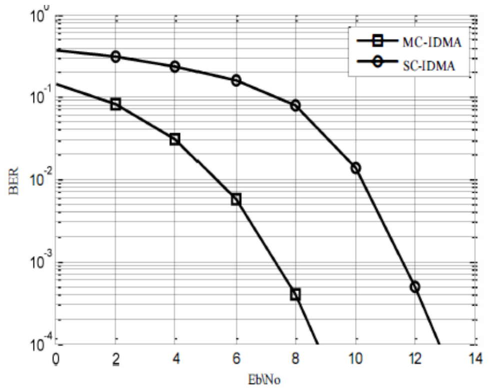
f(x) = (1-€) p(x) + € r(x)

where p(.) denotes the standardized/nominal Gaussian pdf and r(.) represents the pdf for Gaussian signal with heavier tail.

III. COMPARISON OF PERFORMANCE

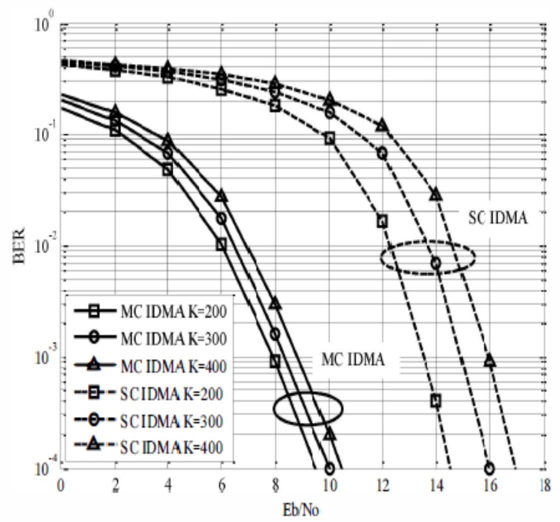
Performance comparison on BER (Bit Error Rate) versus Eb/No basis.

(a)Single and Multi Carrier IDMA in the transmission medium (Non Gaussian)



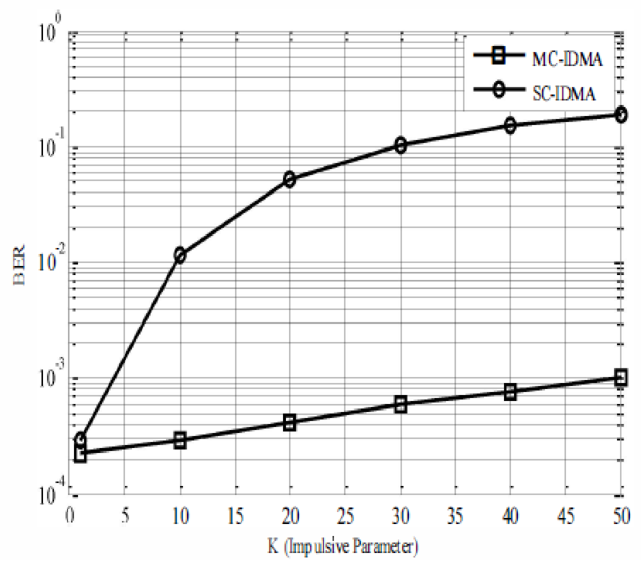
The above figure is the result for comparing the performance of Single and Multi Carrier IDMA in the followed transmission medium as Non Gaussian (Impulsive GMM [1],[2] noise model is used). Similar simulation environment is maintained with Spread Length=16, No. of iteration count=3, Subscribers =8, data length=256 bits, FFT size=256, Guard Interval=0.25, Control parameter=0.01 and Impulsive constant is assumed to be 100 in magnitude. The above figure concludes that Multi Carrier IDMA outperforms the Single Carrier IDMA by approximately 4 dB at 0.0001 Bit Error Rate.

(b) Single and Multi Carrier IDMA under the constraint (large extent variation in impulsive parameter)



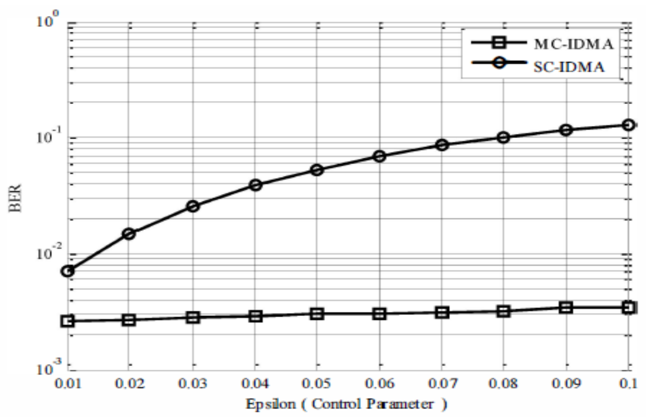
In the above figure the Multi carrier and Single carrier IDMA simulation is performed for 8 users. As a result of simulation the Bit Error Rate versus Eb/No performance decreases for both MC-IDMA and SC-IDMA with increase in impulsive constant from 200 to 400. For same value of impulsive constant the MC-IDMA performs better than SC-IDMA. In single carrier IDMA, with increase in impulsive constant from 200 to 400 the BER performance gets reduced by around 2.2 dB while in MC-IDMA the performance degradation occurs by around 0.9 dB. At impulsive parameter with value of 200 the SC-IDMA performance reduces by around 5 dB, reduces by around 6 dB at impulsive constant with the value of 300 and by 6.5 dB at 400. Hence it implies that with increase in the value of impulsive parameter the performance degradation in SC-IDMA and MC-IDMA increases by large extent.

(c) Single and Multi Carrier IDMA under the constraint by small extent variation in impulsive parameter



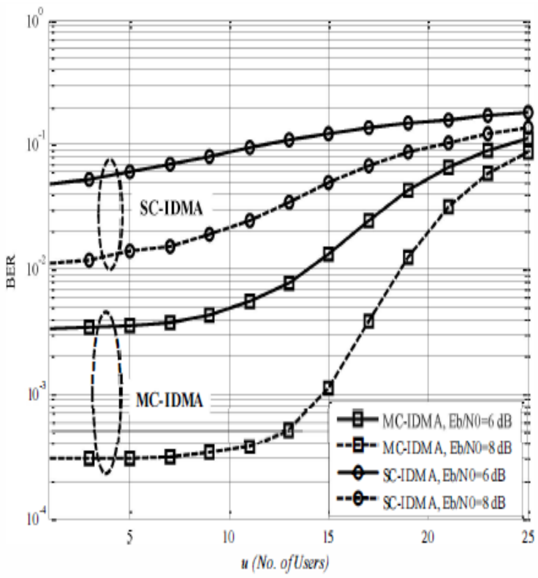
The above plot represents the variation of BER against varying Impulsive constants for both the Single carrier and Multi carrier IDMA schemes. From the above plot it is clear that BER increases with increase in the value of impulsive parameter for both the Single carrier and Multi carrier IDMA. BER variation for single carrier IDMA is quite larger than in case of multi carrier IDMA. In case of Additive White Gaussian Noise i.e; at K=1 the BER for both the single carrier and multi carrier IDMA is approximately same but with increase in the impulsive parameter the BER performance for single carrier is varying by large extent in comparison to multi carrier which concludes that single carrier IDMA is highly sensitive and more prone in contrast to multi carrier IDMA under the impulsive noise [3] constraints. At K=50 the BER for Single carrier IDMA is approximately 0.184 and the BER for multi carrier IDMA is around 0.0098. Hence the multi carrier IDMA is the most suitable candidate for impulsive noise [3] considerations in comparison to single carrier IDMA.

(d) Single and Multi Carrier IDMA under the condition of variation in controlling parameter



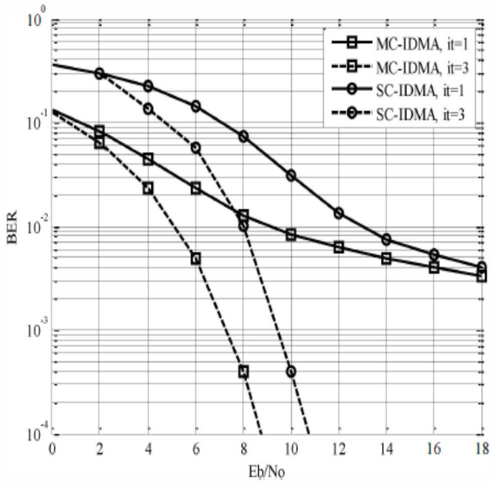
The above figure represents the variation of Bit Error Rate versus Control Parameter (in Impulsive Noise [3]) for both the Single carrier and Multi carrier IDMA systems. At 0.01 value of control parameter the BER for single carrier IDMA is around 0.0069 and for multi carrier IDMA the BER is around 0.0025 respectively which in turn concludes that the performance of multi carrier IDMA is around 2.76 times better than the performance of single carrier IDMA in impulsive noise scenario. With increase in the control parameter single carrier IDMA performance changes by large extent in comparison to the multi carrier IDMA hence it clarifies that SC-IDMA is more sensitive and prone in contrast to MC-IDMA in impulsive noise. At 0.1 value of control parameter the BER for single carrier IDMA is around 0.1296 and for multi carrier IDMA it is around 0.0037, so the performance of multi carrier IDMA is around 35 times better than single carrier IDMA for the same value of control parameter.

(e) Single and Multi Carrier IDMA against different Eb/No values



In the above plot the variation of Bit Error rate against number of users is shown for different Eb/No values. By varying the number of users from 1 to 15 the performance of multi carrier IDMA is much better than single carrier IDMA for both the values of Eb/No 6 and 8 dB. The BER for SC-IDMA under the considered simulating condition varies in the order of 0.01 to 0.1 while for MC-IDMA the BER varies in the order of 0.0001 to 0.01. In case of multi carrier IDMA the bit error rate performance decreases rapidly with increase in the users from 16 to 25, because the spread length considered for simulation is 16 but for achieving the desired performance we have to increase the spread length from 16 to 32. Hence for MC-IDMA with large number of users better performance can be expected with increase in the spread length.

(f) Single and Multi Carrier IDMA by varying the iteration count



The above plot expresses the control of iteration count on the BER versus Eb/No performance of single and multi carrier IDMA. The simulation is performed for the iteration count 1 and 3. For Eb/No of 8.6 at iteration count 3 the BER performance approaches towards 0 while at the same Eb/No value for iteration count 1 the BER performance approaches towards 0.01. It concludes that the better performance can be expected with 3 iteration counts in case of multicarrier IDMA. For single carrier IDMA at 3 iterations and Eb/No around 10.6dB the BER performance approaches 0 and at 1iteration with same Eb/No value of 10.6dB BER performance is in between 0.01 and 0.1. With iteration count 3 SC-IDMA and MC-IDMA performs better than for iteration count 1 in the impulsive noise communication medium.

IV. CONCLUSION

In this paper performance of both the Single carrier IDMA and Multi carrier IDMA over the medium Impulsive Noise (Non Gaussian medium) and from the corresponding simulations it can be concluded that multi carrier IDMA outperforms over the single carrier IDMA by around 4 dB at the bit error rate value of 0.0001 for the same constraints. For the impulsive constant of 50 the bit error performance of multi carrier IDMA is 185 times that of single carrier IDMA. The entire simulation performed concludes that the multi carrier IDMA is much better and robust than the single carrier IDMA for non Gaussian medium (impulsive noise based).

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