Performance Comparison Of Iterative Division Multiple Access In SUI-3 Channel And AWGN Channel

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Abstract*—*This article investigates an uplink multiple access technique with Interleave Division Multiple Access using Random Interleaving and Stanford University Interim-3 (SUI-3) channel model. The crucial requirement is a better Bit-Error Rate performance of the proposed system. The article analyzes and compares the performance of proposed system, taking different block lengths and a different number of users, against that with AWGN channel. The simulation results show that with an increase in block length, the performance of IDMA with the SUI-3 channel catches up with the same with AWGN channel and we see that SUI-3 performs similarly to AWGN channel.

Keywords* - *IDMA, SUI-3, AWGN, Block length, BER.

I. Introduction

IDMA [1] is a non-orthogonal multiple access technique in which users are separated in interleaver domain. This means that every user is allotted with a different interleaver. If the number of errors in a code word exceed beyond the capability of error correcting code, the original code word fails to get recovered. Interleaver avoids burst errors by shuffling and rearranging code words. Thus a uniform distribution of errors is obtained.

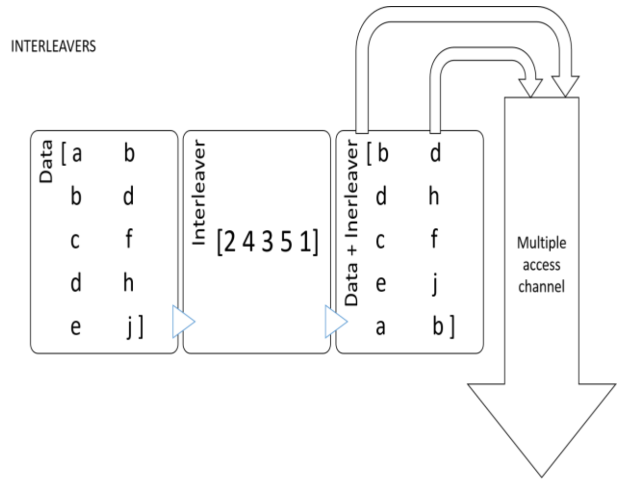

Fig 1 Interleaver Mechanism [2]

CDMA has many appealing benefits such as diversity against fading, dynamic channel sharing, mitigating worst-case cross-cell interference problem, robustness against fading, etc[1],[2]. IDMA is a unique form of CDMA, which inherits many benefits mentioned above. In IDMA, interleavers are employed to distinguish different users. The idea was first shown as a possibility in[3]. Also, [4]and [5] showed how performance enhancement is achieved by using different interleaver for different users in conventional CDMA system. This concept was reformulated and was introduced as IDMA in[1]. IDMA distinguishes different users based on turbo principle by combining iterative joint detection and channel decoding.

For fixed wireless applications, a collection of six channels is defined to represent three types of terrains, an array of LOS/NLOS conditions in the US, delay spread and Doppler spreads[6]. These are known as SUI channel models. These models are utilized for simulations, testing and design of technology appropriate for IEEE 802.16[7]. Each SUI channel model outlines specific parameters to represent microscopic effects in a wireless channel such as fading, tapped delay line, antenna directivity along with macroscopic channel effects like path loss and shadowing[8].

The contribution of this article includes introducing an IDMA system which uses the concept of random interleaving as a means of user separation, and then the system is simulated with Stanford University Interim-3 (SUI-3) channel. The proposed system's performance is compared with the same system but with AWGN channel.

The outline of this paper is as follows- Section II describes the system model for IDMA and SUI-3 channel followed by section III describing the proposed system. Section IV shows the simulation results and comparison between theperformance of SUI channel and AWGN channel models followed by section V which concludes the article.

II. System Model

A. Interleave Division Multiple Access (IDMA)

Firstly, the uncoded input user data is spread by spreading sequence. This data after being spread is denoted by $d_{i,m}$ (where i denotes the ith user and m gives the m^{th} chip in spread data). This $d_i$is then randomly permuted by a random interleaver$\pi_i$producing x_i. In MATLAB, the random interleaver module randomly chooses a permutation table using the 'Initial Seed' parameter. This same 'Initial Seed' is used in a corresponding Random Deinterleaver module to restore the original ordering.

At receiver (Fig 13), the signal being received is the combination of all users' transmitted signal and channel noise. This is expressed as [1]

$$r(m) = \sum_{i=1}^{K} h_i x_i(m) + n(m)$$

Where, n(m) is the channel noise with variance σ_n^2. For the kth user, the interference from other users can be seen as a part of noise. Therefore, the above equation can be written as[1]:

$$r(m) = h_i x_i(m) + \zeta_i(m)$$

Where,

$$\zeta_i(m) = \sum_{i' \neq i} h_{i'} x_{i'}(m) + n(m)$$

Therefore, $\zeta_i(m)$ includes Multiple Access Interference (MAI) from different users and also channel noise.

1) Transmitter and Receiver Structure of IDMA with SUI-3 channel

Fig 2 and Fig 3 show the transmitter and receiver structure of IDMA scheme where K users simultaneously access the channel. It has to be noted that we have used uncoded IDMA system i.e. no Forward-Error-correction (FEC) is applied to input data.

2) IDMA- Deinterleaving and Multi-User Detection

Multi-User Detection is a technique employed at the receiver of any communication system which enhances performance by processing the signals altogether from different users accessing the multiple access channel[9]. IDMA performs better because it employs a low complexity chip-by-chip iterative MUD technique on systems with quite a large number of users. Here, the normalized MUD cost per user doesn't depend on the number of users in the system[1].

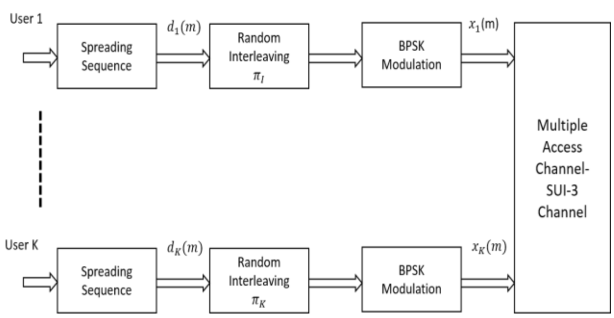

Fig 2 IDMA Transmitter with SUI-3 Channel

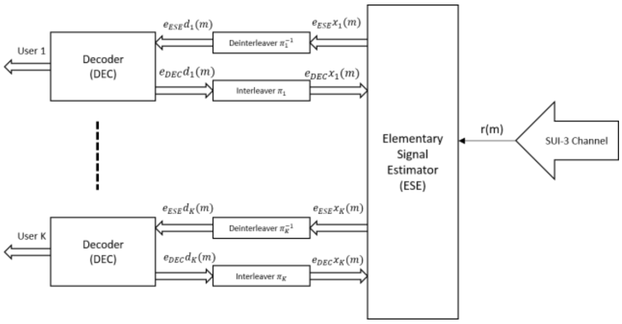

Fig 3 IDMA Receiver with SUI-3 Channel

IDMA uses an Elementary Signal Estimator (ESE) and single user a-posteriori probability (APP) decoders (DEC)[1]. The work of ESE is to find a joint solution considering all users and hence the complexity per user depends on the number of users. DEC, on the other hand, handles data only for one user, so its complexity per user is not dependent on user count[1].The ESE as well as DEC blocks estimate about $x_i(m)$ and their outputs are extrinsic log-likelihood ratios (LLR) given as[1], [10]

$$e(x_i(m)) = \log\left(\frac{p(y|x_i(m) = +1)}{p(y|x_i(m) = -1)}\right) \quad \forall\, i, m$$

$e_{ESE}(x_i(m))$ is the LLR output from ESE block and $e_{DEC}(x_i(m))$ is the LLR output from DEC block.

B. SUI-3 Channel Model

Each SUI channel model outlines specific parameters to represent microscopic effects in a wireless channel such as fading, tapped delay line, antenna directivity along with macroscopic channel effects like path loss and shadowing[8].

Table 1 SUI-3 Channel [7]

	Tap 1	**Tap 2**	**Tap 3**	**Units**
Delay	0	0.5	1	µs
Power (omni ant.) K Factor (omni ant.)	0 1	-5 0	-10 0	dB
Power (30 deg ant.) K Factor (30 deg ant.)	0 3	-11 0	-22 0	dB
Doppler	0.4	0.4	0.4	Hz
Antenna Correlation: ρ_{ENV} =0.4 Gain Reduction Factor: GRF = 3dB Normalization Factor: $F_{omni} = -1.5113$ dB, $F_{30} = -0.3573$ dB				

In this article, we have used SUI-3 model. There are three taps in each SUI channel model. Parameters relative delay, relative power, K-Factor and maximum Doppler Shift characterize each tap. The multipath fading is modeled as a tappeddelay line with three taps with non-uniform delays. The gain associated with each tap is marked by a distribution (Ricean with a K-factor > 0, or Rayleigh with K-factor = 0) and the maximum Doppler frequency[7].The objective of the simulation of SUI channel model is to generate channel coefficients at arbitrary sampling rate [38].Below is the specification of SUI-3 channel as provided in[7]

III. Proposed Methodology

The proposed approach uses IDMA with random interleaving to enhance BER performance. In this proposed methodology, we're using random interleavers. Here, we have evaluated BER performance by taking four different block sizes- 50,100,150,200. Also, BER performance is calculated for three cases taking four users, six users, and eight users separately. Data length taken is 128 bits and the spreading sequence length is 6. Number of iterations performed in this simulation are five. The modulation technique used in the proposed methodology is Binary Phase Shift Keying (BPSK) and the simulation of the proposed system is performed in MATLAB. We simulate IDMA system along with SUI-3 channel using MATLAB.

C. Algorithm for simulation of IDMA system in SUI-3 Channel

Step 1: Select thenumber of users and block length and initialize simulation model.

Step 2: Generate data for transmission as well as spreading sequence to spread the data.

Step 3: Perform Random Interleaving on chips.

Step 4: Modulate the data using BPSK modulation technique.

Step 5: Generate noise to be added to thesignal.

Step 6: Combine signal at receiver with noise and receive signal serially.

Step 7: Estimation of the received signal by performing a specific numberof iterations. The algorithm of multi-user chip-by-chip detection is as follows[1]:

1. If prior information is not available, the means and variances of all transmitted chips are set to zero and one respectively. So we initialize the LLR output of DEC as zero i.e. $e_{DEC}\left(x_i(m)\right) = 0$.
2. Calculate the value $E\left(x_i(m)\right)$ and $Var\left(x_i(m)\right)$
$$E\left(x_i(m)\right) = \tanh(e_{DEC}\,(x_i(m))/2)$$
$$Var\left(x_i(m)\right) = 1 - \left(E\left(x_i(m)\right)\right)^2$$
These values of $E\left(x_i(m)\right)$ and $Var\left(x_i(m)\right)$ are used by ESE to update interference mean and variance.
3. Estimate the mean and variance of r(m)
$$E\left(r(m)\right) = \sum_i h_i E(x_i(m))$$
$$Var\left(r(m)\right) = \sum_i |h_i|^2\, Var\left(x_i(m)\right) + \sigma_n{}^2$$
4. Estimate the mean and variance of $\zeta_i(m)$
$$E\left(\zeta_i(m)\right) = E\left(r(m) - h_i E\left(x_i(m)\right)\right)$$
$$Var\left(\zeta_i(m)\right) = Var\left(r(m)\right) - |h_i|^2 Var\left(x_i(m)\right)$$
5. LLR output of ESE
$$e_{ESE}\left(x_i(m)\right) = 2h_i\left(\frac{r(m) - E\left(\zeta_i(m)\right)}{Var\left(\zeta_i(m)\right)}\right)$$
6. This $e_{ESE}\left(x_i(m)\right)$ is used as an input to the DEC block. The DEC block applies APP decoding for $x_i(m)$ and updates the mean and variance for the next iteration. In the last iteration, DEC gives 'hard' decisions.

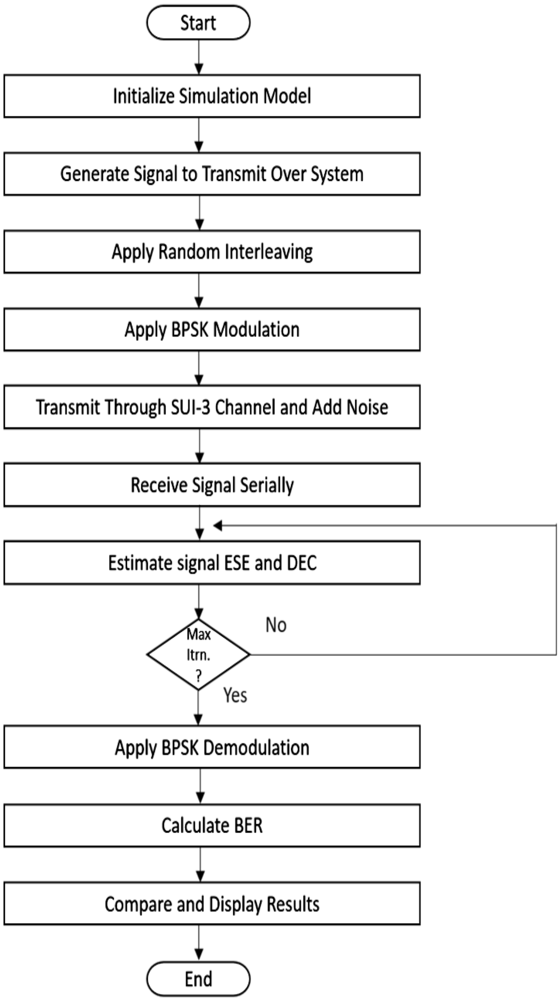

Fig 4 Flowchart of System Model.

Step 8: Perform BPSK Demodulation.

Step 9: Calculate Bit-Error Ratio

Step 10: Repeat steps 1-9 for other set of users.

Step 11: Display Results

D. Flowchart

The flow chart (Fig 4) depicts step-by-step procedure of this simulation.

IV. Simulation Results and Comparison

A series of MATLAB based simulations was carried outto validate the effectiveness of proposed IDMA system with the SUI-3 channel in terms of low BER. The performance of IDMA in SUI-3 channel for block lengths 50, 100, 150 and 200 is shown in Fig 5, Fig 7, Fig 9 and Fig 11 respectively. The performance of IDMA in AWGN channel for block lengths 50, 100, 150 and 200 is shown in Fig 6, Fig 8, Fig 10 and Fig 12 respectively

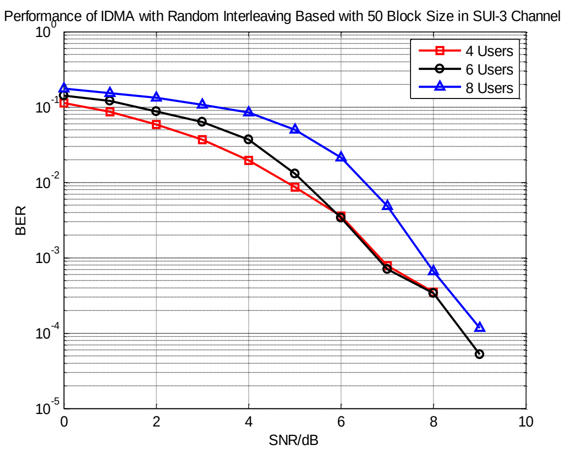

Fig 5 BER-SNR Performanceover SUI-3 channel with 50 block size.

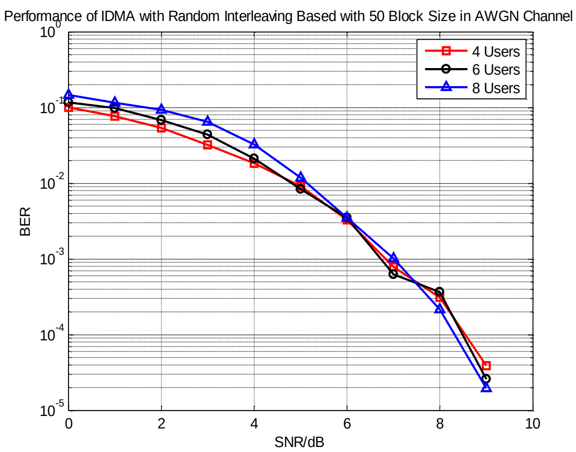

Fig 6BER-SNR Performance over AWGN channel with 50 block size

The simulation results show that with an increase in block length, the performance of IDMA with the SUI-3 channel catches up with the same with AWGN channeland we see that SUI-3 performs similarly to AWGN channel even better sometimes. The optimum performance of the proposed system is obtained at 200 block length with 8 users.

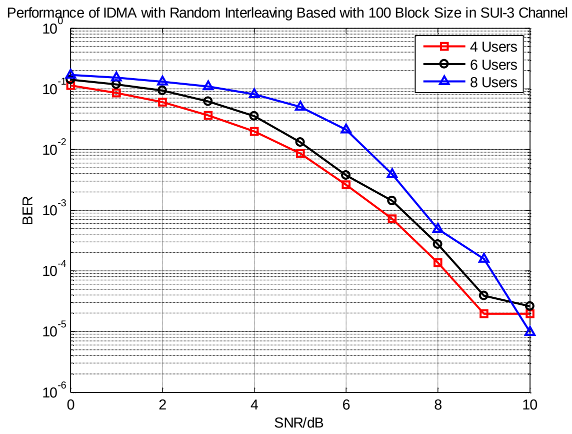

Fig 7BER-SNR Performance over SUI-3 channel with 100 block size.

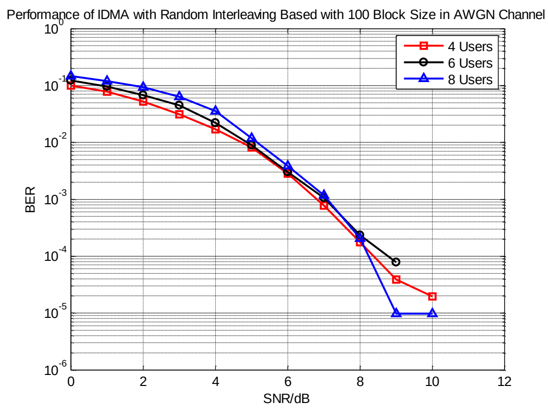

Fig 8BER-SNR Performance over AWGN channel with 100 block size.

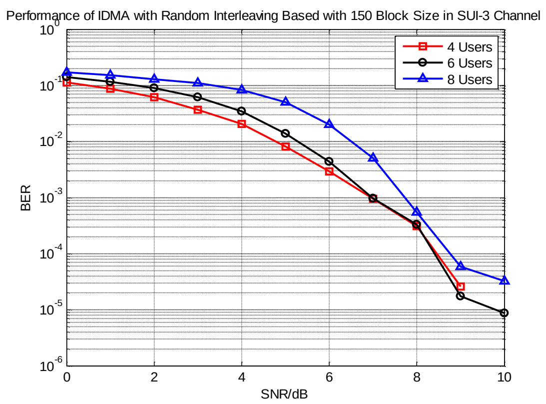

Fig 9 BER-SNR Performance over SUI-3 channel with 150 block size.

This superior performance of SUI-3 channel over AWGN channel is obtained when the length of interleaver is large. For large block size interleavers, most random interleavers perform well because of low correlation between information input data and soft output of decoder [11].

The performance is analyzed, which shows satisfactory BER for higher SNR. This result is compared with the performance of IDMA system using AWGN channel. BER gets affected by numerous factors. By modifying

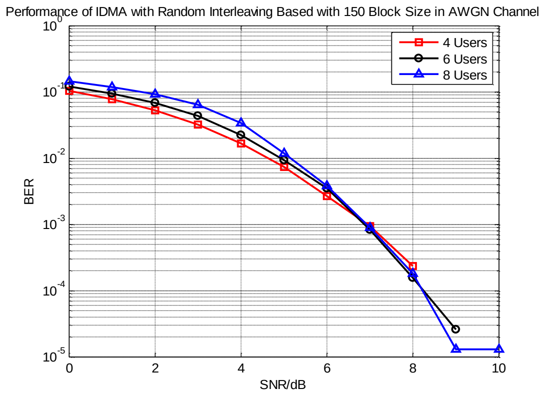

Fig 10 BER-SNR Performance over AWGN channel with 150 block size.

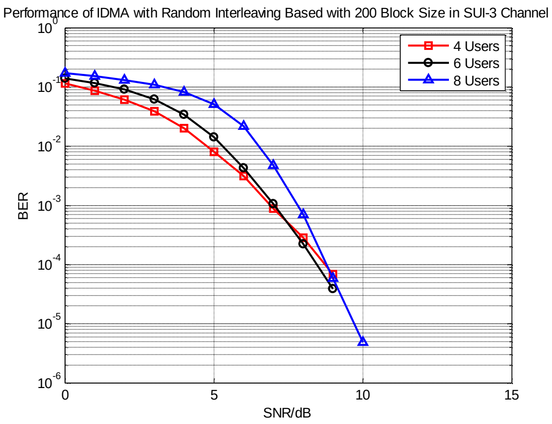

Fig 11 BER-SNR Performance over SUI-3 channel with 200 block size.

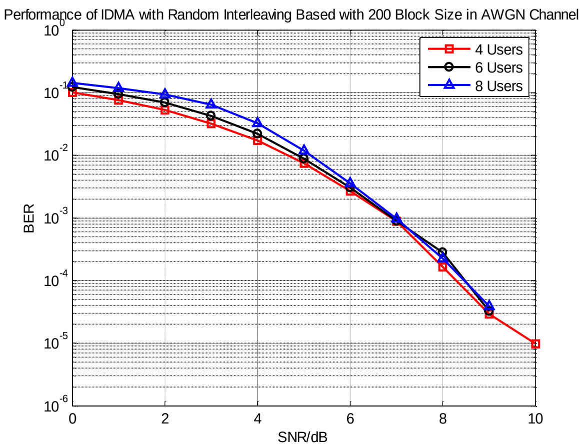

Fig 12 BER-SNR Performance over AWGN channel with 200 block size.

The variables that can be controlled, it is possible to devise a system which could provide optimum and desired levels of performance. Here, the variables are block length and number of users. This article shows the better performance of IDMA system using SUI-3 channel than AWGN channel.

V. Conclusions

In this study, the performance of IDMA system in transmission over the SUI-3 channel catches up with the same with AWGN channel and we see that SUI-3 performs similarly to AWGN channel even better sometimes. Hence, with SUI channel modeling, it is possible to get better performance compared to AWGN channel. AWGN is not a suitable model for many terrestrial links due to interference and multipath terrain blocking but SUI model considers these effects. Hence, SUI channel model is a more practical model as compared to the ideal AWGN model and the proposed system shows that its performance in the practical scenario is similar to the ideal case.

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