Up-Link : Coded Cognitive MIMO MC-IDMA System for Frequency-Selective Channel

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Summary
The performance outcomes of Cognitive-coded MIMO Multi-carrier-IDMA system for uplink transmission. Cognitive Radio Network is a device for frequency-sensitive in wireless technology by which we can exploit available ideal spectrum, disperse the radio spectrum vigorously for mobile network. In IDMA, interleaving pattern is defined as user-specific and low-spreading code is exploited. We implement iterative decoding algorithm at base station to diminish the adverse issues of Primary users interference (P-MUI) and secondary multi-user interferences(S-MUI) thereby enhancing error-rate performance with lower value of SNR ratio. In our work, We split the spectrum carefully and we allocate the sub-band spectrum frequency for various users to enhance the bandwidth. We exploit V-BLAST architecture to achieve higher data rate. We build random-interleaver based user-specific pattern. Further we study and present the simulation results of cognitive MC-IDMA systems for frequency-selective channel with ZF-OSIC and MMSE-OSIC detection algorithm. Our simulation results reveal that coded-Cognitive MIMOMC-IDMA system provides robust error-rate performance while offering better data rate in the presence of multi-user interference for uplink communication. Subsequently we explored that Cognitive MC-IDMA system effectively accomplishes the solution to higher bandwidth.

Key words:
Channel encoder, Interleave division multiple accesses (IDMA), Minimum-MSE, Zero forcing (ZF).

1. Introduction

Cognitive network is the promising technique to offer higher bandwidth for the secondary users in mobile communication.5G wireless network expects higher data rate with reliable communication for transmission of Voice signals ,live telecast of video, picture and various multi-media etc., Presently, limited data rate are offering for wireless network 100 Mbps. Currently, limited bandwidth are available for licensed primary users in wireless networks. Many research papers [1,2,3] highlighted the importance of Cognitive radio network to overcome the problems of existing bandwidth limitation. CRN recognizes unused spectrum ranging from 80 M Hz to 800 MHz which can be utilized for mobile users for communication. We mean primary users if mobile network utilize licensed spectrum. If subscriber operates unlicensed CR spectrum, then we denote such subscriber as secondary users. In the recent past Federal Communication Commission (FCC) dictated the method to exploit ideal-TV band- spectrum for efficient communication in mobile network. The authors in [1] elucidated that cognitive network based MC-CDMA system offers better results for patient monitoring system in medical image transmission and suggested that we can exploit unused CRN spectrum for Internet of things (IOT) application.

The authors in [1] elucidated that Cognitive bandwidth can be exploited for real-time application such as patient monitoring system smart devices intelligent system for huge data processing .Further authors in [1,4] augmented the benefits of exploiting space-time processing unit using multiple-inputs multiple-outputs (MIMO's) with cognitive spectrum for health-care monitoring system in the context of IOT applications. Furthermore, the performance of MC-CDMA system with MIMO profile is presented and demonstrated that high picture quality images can be transmitted from home to hospital with less signal-to-noise ratio by invoking CRN un-licensed spectrum .

It is well justified that CDMA possess many advantages such as robustness against fast-fading, asynchronous transmission of information and provisions for more user population accommodation. But its error-rate performance is limited and exploits high spreading code sequence for user-separation. In the recent past, many researchers have suggested that Interleave division multiple access (IDMA) can be invoked for multi-user communication. IDMA exploit low spreading code and bears all the merits of CDMA .Viterbi clarified in [5,6] that we can achieve high processing gain by exploiting whole bandwidth for low-rate coding .Further, he suggested that it is feasible to achieve extended higher processing-gain(PG) along with more prominent capacity for multiuser channel.In [7] recommended IDMA system. In contrast to CDMA,IDMA identify the users by invoking user-specific interleaving pattern.In contrast to conventional-CDMA, the concept of user specific code spread CDMA is introduced by Frenger, his team and depicted that we can combine the concept of low-rate channel encoding and Direct-Sequence(DS)-spreading in order to exploit high bit-error-

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rate performance with less SNR. [7] explored mathematical model for IDMA system and elucidated that better error-rate performance can be possible by exploiting low spreading code and turbo processor in the presence of Inter-Symbol-Interference (ISI) and Multiple user Interference (MUI). In contrast to the conventional CDMA, spreading and interleaving are inverted in IDMA. In order to obtain higher data rate apart from the low complexity receiver [6], IDMA can be realized for Up-link (UL) transmission in future multi-user wireless network. In [6], Prof. Hanzoand his team illustrated performance analysis of MC-IDMA for downlink mobile communication under multi-user case. The authors[8] presented the error-rate behavior-analysis of multi-user transmitter preprocessing (MUTP)technique assisted IDMA scheme and suggested that we can support more users with assist of turbo decoder in the consideration of downlink transmission.

MIMOs system offers higher data rate no need of bandwidth enlargement. Such Multi Inputs/Outputs profile using VBLAST architecture is investigated for underwater communication in[9]. Further error-rate performance is elucidated using coded system for frequency-selective channels in [10]. The author Hanzo and his team [6] have presented the achievement of error-rate performance using turbo encoder for MC-IDMA system for downlink transmission.

The [4] presented performance of space-time block code assisted MIMO's–IDMA systems with dual-polarized antennas and suggested that IDMA supports more-user population .Further, In this article the authors studied error-rate performance for various channel models and exhibited that better results can be achieved with less SNR using IDMA system even when the user signals is contaminated by noise and MUI. Also, it has been exhibited that MIMO-IDMA systems can be invoked for high data-rate application. The [8] presented performance of coded Double Space-TTD assisted-IDMA for FDD using MUTP for SUI and LTE-channel specifications in the case of multi-user scenario in multi-cell. The authors considered vector-quantization technique to develop pre-processing matrix at base station. The authors elucidated error-rate results of coded system and suggested that D-STTD style of MIMO system obtain higher throughput with less SNR in the presence of multi-cell interference.

The authors in [11] explicated the performance of concatenated-channel encoder .The authors in [12] expounded the benefits of channel encoder using turbo code for information transmission in wireless communication. Many literature [13,14,15] exploited structure and decoding of turbo code .In [16], the author illustrated error-rate analysis of turbo code.

In the aforementioned work, researchers have discussed the performance of MIMO system and benefit of IDMA scheme.In this paper,

1.We exploit iterative decoding algorithm for MIMO Cognitive MC-IDMA system explore the problems of the reducing primary user interference (P-UI) in along with secondary–user interference for MIMO's-Multicarrier-CDMA system.
2.We present the behavior study of cognitive Multicarrier-IDMA system along with Zero-Forcing-ZF algorithm and minimum-MSE estimation technique for V-BLAST architecture.
3.We allocate the cognitive spectrum for secondary users depending upon the availability and present the error-rate results of channel encoded cognitive MIMO Multicarrier-IDMA system for realistic channel design model specification

The remaining content in the paper is arranged such as-Section-II elucidates the System-Architecture. Section III indicates the detailed algorithm of OSIC for detection. Then, error-rate results are described Section-IV and finally conclusions are presented in Section-V.

2. System Configuration

We contemplate K up-link Cognitive MIMO MultiCarrier-IDMA system in which BS is defined with 'N_r' receive antennas & each secondary user is defined with 'N_t' transmit antennas. We assume that the secondary users can utilize Cognitive spectrum ranges from 80 MHz - 800MHz.We chooses random interleaver for user-specific sequence. We realize parallel concatenated style of turbo code with ½ channel encoder. At BS, we realize iterative turbo processor unit to evade the conflicting effects of noise in addition to the multi-cell interference (MCI) and secondary users interferences (S-MUI).We perform MC-modulation using Inverse-FFT block by exploiting CR spectrum with sub-band frequency of channel space of 6MHz.

We reflect 'L' tap delay for transmission of signals from each MS to BS obeying the equation [17,18]

$$h_{wv}(t) = \sum_{l=1}^{L} h_{wv}^{l} \partial(t - \tau_l) \qquad (1)$$

Indicating h_{wv}^{l} - complex Gaussian random process with mean value= 0 and variance $\psi(\tau_l)$.

At BS, we carry out multi-carrier demodulation using FFT block and non-linear OSIC based on ZF and MMSE algorithm.

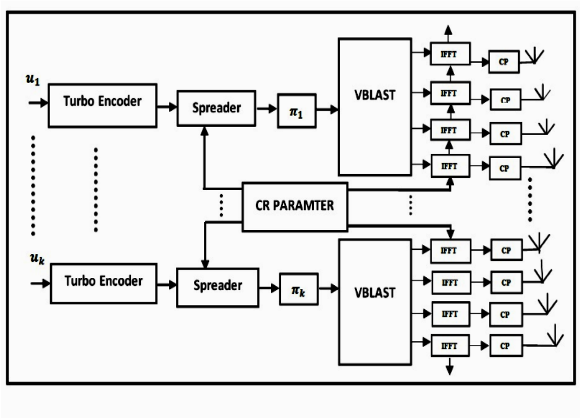

Fig. 1 elucidates Cognitive MIMOMC- IDMA system transmitter structure.

2.1 Signal representation from MS to channel

Let u_k -random data-bit stream corresponding to' k^{th} ' user. Considering BPSK modulation, we encode it using turbo code

Let

$$\boldsymbol{x_k} = \left[x_{k1}, x_{k2}, \ldots, x_{km}\right]^T \qquad for(k = 1, 2, \ldots, K) \tag{2}$$

be the encoded data bit stream transmitted to Base Station by k^{th} MS

where *m*–total number of bits in the encoded stream

Let spreading length of Frequency-domain spreading matrix be L_f

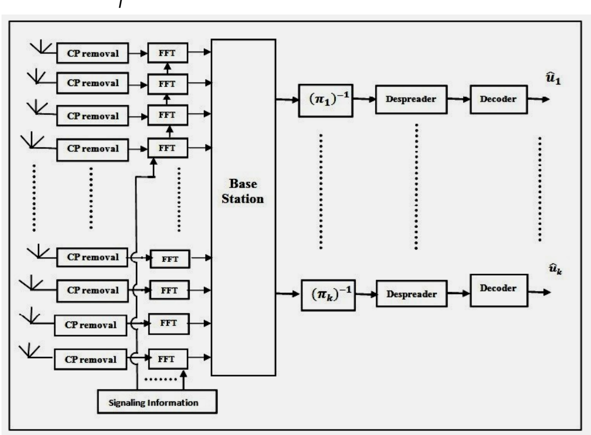

Fig. 2 elucidates Cognitive MIMOMC- IDMA system transceiver structure.

The Spreading sequence is represented as

$$\boldsymbol{s}_k = \frac{1}{\sqrt{L_f}}\left[s_{k0}, s_{k1}, \ldots, s_{k(L_f-1)}\right]^T \tag{3}$$

And is similar for all users in the reference of IDMA scheme.

The Code-Spreading matrix having $L_f m \times m$ matrix is represented as

$$\boldsymbol{S}_k = \boldsymbol{I}_m \otimes \boldsymbol{s}_k \text{ , for } k = 1, 2, \ldots, K \tag{4}$$

It is interleaved by predefined user-specific interleaver.
The interleaved data sequence is transmitted by VBLAST architecture.
Now we represent the transmitted sequence as

$$d_k = \boldsymbol{S_k x_k}, \quad k = 1, 2, 3, \ldots, K \tag{5}$$

Hence the bit stream is spatially transmitted by N_t transmitted antennas .Each block of bit stream from each antenna is multi-carrier modulated by Inverse FFT and 20 percentage of cyclic-prefix are added to reduce Inter-Carrier-Interference. Then are send to BS through multi-path environment.

2.2 Signal representation from channel to BS

Let R be the received sequence for the k^{th} desired user signal after multi-carrier demodulation. Where

$$R_{\perp} = \sum_{k=1}^{K} H_{\perp k}\, d_k + N \tag{6}$$

Clearly,

$$R_{\perp k} = \underbrace{H_{\perp k} d_k}_{\substack{Desired \\ SIgnal}} + \underbrace{\sum_{i=1, i\neq k}^{K} H_{\perp i}\, d_i}_{S-MUI} + \eta \tag{7}$$

$H_{\perp k}$ is $N_r \times N_t$ channel matrix

d_k is $N_t \times 1$ transmitted information from k^{th} users

$R_{\perp k}$ - $N_r \times 1$ received vector

η -Indicates sum of primary user interference and noise which is assumed to be follow Gaussian complex random distribution. Then the received signal is estimated using MUD. We consider *ZF-OSIC* and *MMSE-OSIC*-MUD for our analysis. The defined detection algorithm is detailed in the further section.

3. Symbol Detection Techniques

Notations: $H_\perp$ - cognitive radio channel matrix.

$(\cdot)^+$ - Moore-Penrose pseudo-inverse

$(\cdot)_{z_i}$ - Sub-matrix defined by considering z_i row matrix

$\left(H_{\perp\bar{z}_i}\right)^+$ - Restructured channel matrix by forcing value 0in the column z_i of $H_\perp$

$\hat{d}_{z_i}$ - Estimated information for the specific layer of matching user

$Q(\cdot)$- quantized value of *argument* $(\ )$ and is nearer to constellation

$(\cdot)^H$ - *Hermitian transpose* and

$(\cdot)^{-1}$ - *Inverse of argument* $(\ )$

3.1. VBLAST/ZF-OSIC Detection

We consider recursive based ZF algorithm for the estimation of users signals .we extracts user signals based on ordering of the indices of layered data d . Assuming that BS having pre-knowledge of channel matrix $H_\perp$,It first selects desired layer which is having high channel gain .Then we execute nulling operation followed by quantization operation based on decision statistics. Further, we carry out cancellation operation after selecting the layer and finally new pseudo- inverse of $H_\perp$ is calculated for successive iteration [19].

Let us define the relationship between transmitter, channel matrix and receiver by the equation

$$R_\perp = H_\perp\, d + N_\perp \tag{8}$$

We Initialize $H_\perp$ and $R_\perp$ as $H_{\perp i}$ *and* $R_{\perp i}$

Let $Y_{\perp i}$ be $H^+_{\perp i}$.

The index of layer is decided by

$$z_i = \arg\min \left\|(Y_{\perp i})\right\| \tag{9}$$

Compute $c_{\perp z_i}$ such that

$$c_{\perp z_i} = (Y_{\perp i})_{z_i} R_{\perp i} . \tag{10}$$

Quantize the value such that

$$\hat{d}_{z_i} = Q\left(c_{\perp z_i}\right) \tag{11}$$

We choose $R_{\perp i+1} = R_{\perp i} - \hat{d}_{z_i}\left(H_{\perp z_i}\right)$ (12)

for the remaining layer to be detected

From above equation, we eliminates estimated symbol from established vector for the particular user.

Then we modify $H_\perp$ to $\left(H_{\perp\bar{z}_i}\right)^+$ We repeat the above mentioned rule for the remaining layer to be detected. The defined algorithm is clearly summarized as-.

Initialize:

$$\mathrm{i} \leftarrow 1 \tag{13}$$

$$\boldsymbol{Y}_{\perp i} = \left(\boldsymbol{H}_{\perp i}\right)^+ \tag{14}$$

$$z_i = \arg\min \left\|(Y_{\perp i})\right\| \tag{15}$$

On Recursion

$$W_{z_i} = \left(Y_{\perp i}\right)_{z_i} \tag{16}$$

$$c_{\perp z_i} = (W_i)_{z_i} R_{\perp i} \tag{17}$$

$$\hat{d}_{z_i} = Q\left(c_{\perp z_i}\right) \tag{18}$$

$$R_{\perp i+1} = R_{\perp i} - \hat{d}_{z_i}\left(H_{\perp z_i}\right) \tag{19}$$

$$\boldsymbol{Y}_{\perp i+1} = \left(\boldsymbol{H}_{\perp\bar{z}_i}\right)^+ \tag{20}$$

$$z_{i+1} = \arg\min \left\|(Y_{\perp i+1})_f\right\| \tag{21}$$

$$f \notin \{z_1 \ldots z_i\}\,,\ i \leftarrow i+1 \tag{22}$$

3.2 VBLAST/MMSE–OSIC Detection

VBLAST/MMSE-OSIC estimation technique is alternative method of ZF-estimation in which both noise and secondary users get suppressed .In general, MMSE rule offers superior performance [19]. MMSE weighing matrix is represented by

$$Y_\perp = \left[(H_\perp)^H H_\perp + \sigma^2 I_M\right]^{-1}(H_\perp)^H \tag{23}$$

The defined algorithm is summarized such as

Initialize:

$$\mathrm{i} \leftarrow 1,\ Y_\perp = \left[(H_\perp)^H H_\perp + \sigma^2 I_M\right]^{-1}(H_\perp)^H \tag{24}$$

$$z_i = \arg\min \left\|(Y_{\perp i})\right\| \tag{25}$$

Recursion

$$W_{z_i} = \left(Y_{\perp i}\right)_{z_i} \tag{26}$$

$$c_{\perp z_i} = (W_i)_{z_i} R_{\perp i} \tag{27}$$

$$\hat{d}_{z_i} = Q\left(c_{\perp z_i}\right) \tag{28}$$

$$R_{\perp i+1} = R_{\perp i} - \hat{d}_{z_i}\left(H_{\perp z_i}\right) \tag{29}$$

$$Y_{\perp i+1} = ((H^{H}_{\bar{\perp z_i}} H_{\bar{\perp z_i}} + \sigma^2 I_M)^{-1} H^{H}_{\bar{\perp z_i}}) \tag{30}$$

$$z_{i+1} = \arg\min \left\|(Y_{\perp i+1})_f\right\| \tag{31}$$

$$f \notin \{z_1 ... z_i\} \; i \leftarrow i+1 \tag{32}$$

The estimated information is then de-interleaved & despread. Absolutely, the sequence is decoded using turbo decoder [10][20].

4. Performance Results And Discussion

We exhibit BER results of coded CR MIMO's MC-IDMA system for frequency-selective channels. We investigate error outputs for SUI-1[17] and LTE-vehicular [18] channel models. We detail channel model in Table-I and Table-II

Table 1: Power Delay Profile

Path number	SUI-1 channel model		LTE Extended Vehicular Channel Model	
	Delay(ms)	Power(dB)	Delay(ms)	Power(dB)
1	0	0	0	0
2	0.4	-15	30	-1.5
3	0.9	-20	150	0
4			310	-1.5
5			370	-0.6
6			710	-9.1
7			1090	-7
8			1730	-12
9			2510	-16.9

Table 2: Channel Model Parameter

Channel Models	Doppler Shift Frequency (Hz)	Antenna Correlation	Vehicular Speed (km/h)
SUI-1	0.5	0.7	-
LTE-Extended Vehicular Channel Model	300	0.7	162

For our analysis, we consider Cognitive spectrum having 54 MHz - 648 MHz frequency-range. Further, we evaluate performance curve of MIMO MC-IDMA with CR spectrum for 25k channel realizations in each SNRratio. We allocate cognitive spectrum randomly for the secondary users depending on the availability of bandwidth and minimum of 6MHz among the users. We presume F domain spreading matrix along spreading length as 128. We specify the simulation parameters in the Table-III. We incorporated Iterative algorithm based on Log-MAP decoder at BS to study error-rate analysis.

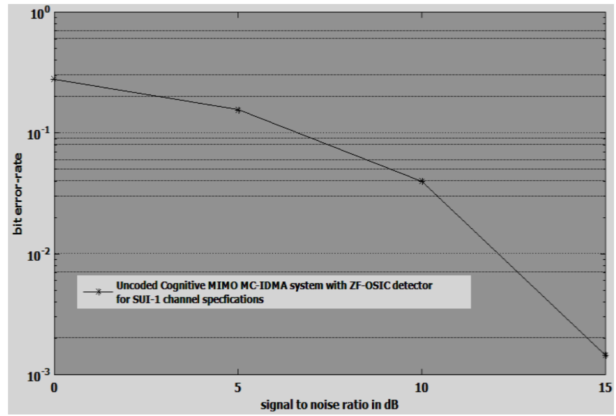

Fig. 3 error-rate results of uncoded Cognitive MIMO MC-IDMA system with ZF-OSIC detector for SUI-1 channel model

Fig 3 illustrates the err-rate results of uncoded MIMO'sMC-IDMA system utilizing cognitive spectrum with Zero-Forcing-OSIC detector for SUI-1 channel model.

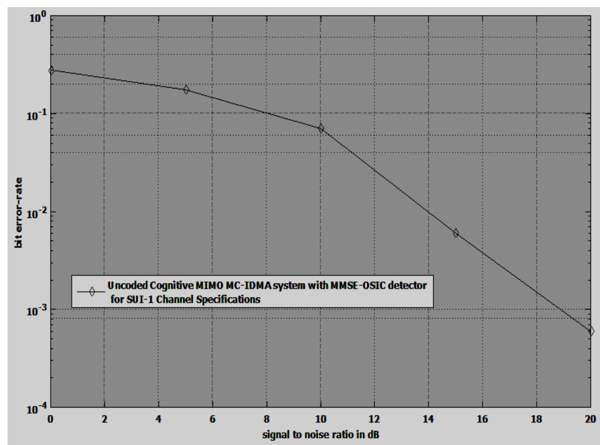

Fig. 4 error-rate results of uncoded Cognitive MIMO MC-IDMA system with MMSE-OSIC detector for SUI-1 channel model

Fig 4 illustrate the error-rate outcomes of uncoded MIMO MCIDMA system utilizing cognitive spectrum with MMSE-OSIC detector. We observed from the figures that non-linear based MMSE detector for uncoded system generates better results of 1 bit error for 1000 bits with SNR of 19 dB when compared to ZF-detector.

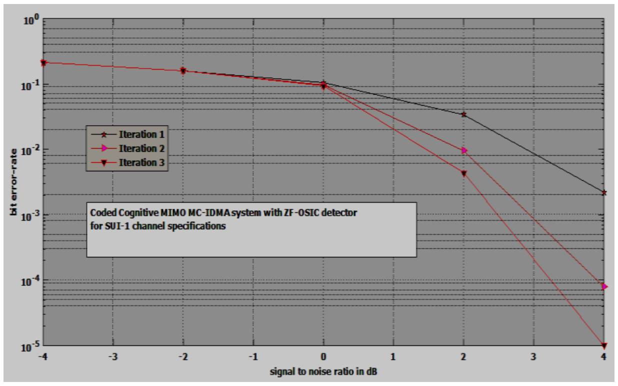

Fig. 5 error-rate results of turbo coded Cognitive MIMO MC-IDMA system with ZF-OSIC detector for SUI-1 channel model

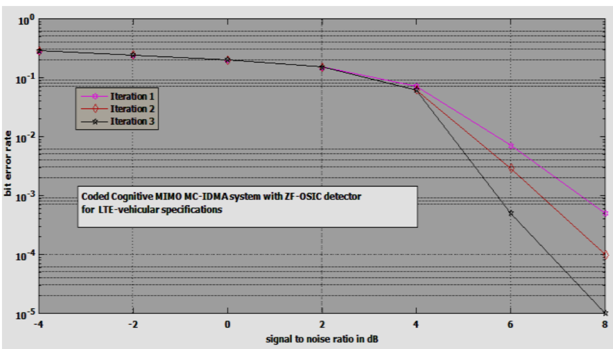

Fig. 6 error-rate results of turbo coded Cognitive MIMO MC-IDMA system with ZF-OSIC detector for LTE-Vehicular channel model

Fig 5 and 6 illustrate the coded system performance of Cognitive MIMO MCIDMA system for SUI1 and LTE-vehicular channel environments using ZF-OSIC detector. As system offers higher bandwidth for the secondary users, we can achieve better bandwidth efficiency .As well as, we obtain error-rate results using turbo coded system with ZF-detector for SUI-1 and LTE-vehicular channel model. The turbo coded system along ZeroForcing-OSIC detector swell error-rate of 10-5with SNR of 4 dB for SUI-1 and 8 dB for LTE-vehicular channel environments respectively.

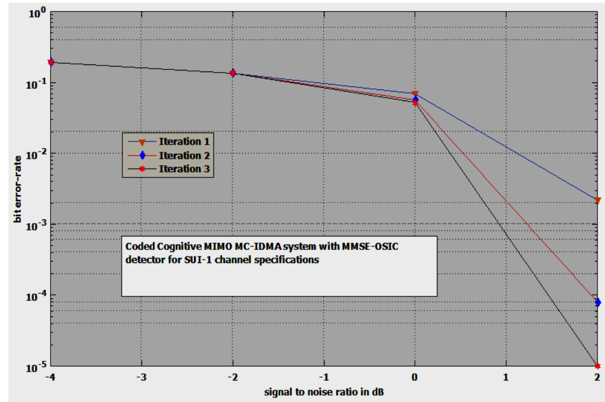

Fig. 7 error-rate results of turbo coded Cognitive MIMO MC-IDMA system with MMSE-OSIC detector for SUI-1 channel model

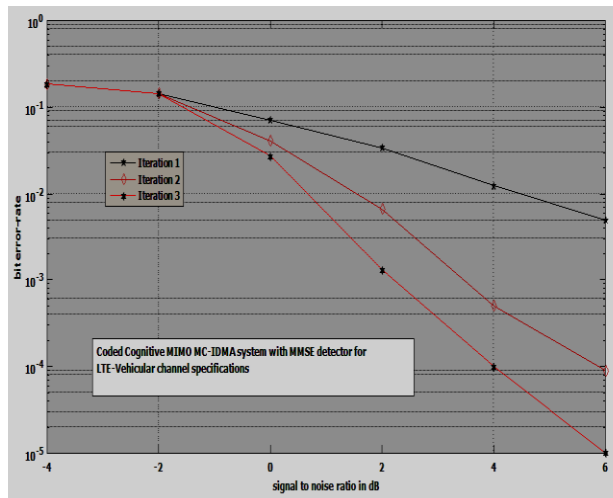

Fig. 8 error-rate results of turbo coded Cognitive MIMO MC-IDMA system with .MMSE-OSIC detector for LTE-Vehicular channel model

Fig 7 and 8 illustrate the error-rate curve of Cognitive MIMO MC-IDMA system with turbo channel encoder for SUI-1 and LTE-vehicular channel environments using MMSE-OSIC detector. We swell error-rate of 10-5 BER with SNR of 2 dB for SUI-1 and 6 dB for LTE-vehicular channel environments respectively.

The above error-rate curve reveals that coded Cognitive MIMO MC-IDMA system with MinimumMSE –OSIC detector offers desire error –rate outcomes with less SNR on comparison with ZF-OSIC detector .Also we observed that channel model such as LTE-Vehicular with multi-path fading effects cause irreducible error-rate results for our considered system. Further, we observed that it is possible to exploit idle Cognitive Radio spectrum to confront the issues of high data rate

5. Conclusion

We investigated the error-rate performance of coded MIMO MC-IDMA system using cognitive spectrum for SUI-1 and LTE-vehicular channel conditions in the context of up-link transmission. We extricated TV spectrum to offer higher bandwidth for mobile communication through up-link transmission. We materialized the cognitive environment for bandwidth distribution among secondary users .Further we tested MIMO MC-IDMA system performance using turbo coded system .and presented error-rate performance for realistic channel model. The simulation results revealed that iterative decoder with MMSE-OSIC detector provides attainable error-rate results with less SNR for Cognitive MIMO MC-IDMA in the presence of noise contamination and multi-user interference .Further we conclude that MIMO MC-IDMA scheme with Cognitive radio network supports more users while offering higher data rate and superior performance in the context of up-link transmission. Furthermore we observe that allocating variable spectrum using CRN for secondary users in the context of MIMO MC-IDMA scheme is not a trivial operation, but achievement in concern with bandwidth efficiency, error-rate performance in presence of noise, less SNR and accommodation of more users are relatively better.

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