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MIMO OFDM System using Iterative Turbo Receiver

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ABSTRACT

Despite the assistance of well-recognized hot technologies such as Multiple-Input Multiple-Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM), cell-edge mobile users still suffer significant performance degradation in uplink, thus restricting the system coverage. Here we propose a hybrid solution which takes the advantages turbo processing, resulting in an enhanced MIMO OFDM receiver. Simulation results show that the proposed scheme is capable of achieving a good link performance.

INDEX TERMS

iterative channel estimation, Multiple-Input Multiple-Output (MIMO), Multi-User Detection (MUD), Orthogonal Frequency Division Multiplexing (OFDM), soft-input soft-output, turbo processing, Wireless world INitiative New Radio (WINNER).

INTRODUCTION:

Recently the International Telecommunication Union Radio communication sector (ITU-R) WP 8F has triggered an official process for a formal proposal of the International Mobile Telecommunications - Advanced (IMT-Advanced) system, which is expected to outperform existing wireless systems. It becomes then even more critical to get an insight understanding of current leading-edge systems, together with their key enabling technologies, in order to enhance their overall achievable performance. The Information Society Technologies (IST) projects WINNER and WINNER II within the European Sixth Framework Programme (FP6) already target these potential improvements, whilst considering the combination of promising technologies such as Multiple-Input Multiple-Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) as the keystone for enhancing the performance of high data rate mobile communication systems.

Whilst higher throughputs and capacity are the most common targets of these next-generation cellular systems, one possible approach towards the potential improvements is to boost the robustness for uplink cell-edge MIMO OFDM users, who suffer from significant performance degradation. One critical challenge in this scenario is to obtain accurate channel estimation at the Base Station (BS) receiver for enabling both coherent demodulation and interference cancellation. Compared with Single-Input Single-Output (SISO) systems, channel estimation in the MIMO scenario becomes more challenging, since a significantly increased number of independent transmitter-receiver channel links have to be estimated simultaneously for each OFDM sub carrier. Moreover, in the MIMO scenario the interfering signals from the other transmitter antennas have to be suppressed.

MIMO

In radio**,** multiple-input and multiple-output, or MIMO, is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology. MIMO technology has attracted attention in wireless communications, since it offers significant increases in data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency (more bits per second per hertz of bandwidth) and link reliability or diversity (reduced fading). Because of these properties, MIMO is a current theme of international wireless research.

Advantage of MIMO

- Array Gain: This is the gain achieved by using multiple antennas So that the signal adds coherently.
- Diversity Gain: This is the gain achieved by utilizing multiple paths so that the probability of any one path bad not limits the performances. Diversity may be exploited in the Spatial (antenna), Temporal (time) or spectral (frequency) dimensions.
- Co-channel interference rejection (CCIR): This is the rejection of the signal by making use of the different channel response of the interferers.
  A common Scheme is maximal ratio combining: This combines multiple receive paths to maximize Signal to Noise Ratio (SNR).
- Spectral Efficiency **:**MIMO Implies the point to point spectral efficiency by using multiple antennas and RF Chains at both the BS and SS.MIMO Achieves a multiplicative increased in throughput compared to Single Input, Single Output (SISO) architecture by carefully coding the transmitted signal across antennas, OFDM symbols and frequency tones.
- Cost: These gains are achieved at no cost in bandwidth or transmit power if we assume ideal channel estimation, channel estimating smoothing, & perfect synchronization

Orthogonal frequency-division multiplexing (OFDM)

essentially identical to Coded OFDM (COFDM) and Discrete multi-tone modulation (DMT) — is a frequency-division multiplexing (FDM) scheme utilized as a digital multi-carrier modulation method. A large number of closely-spaced orthogonal *sub-carriers* are used to carry data. The data are divided into several parallel data streams or channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase shift keying) at a low symbol rate, maintaining total data rates similar to conventional *single-carrier* modulation schemes in the same bandwidth.

Advantage of OFDM System

- Can easily adapt to severe channel conditions without complex equalization
- Robust against narrow-band co-channel interference

- Robust against Intersymbol interference (ISI) and fading caused by multipath propagation
- High spectral efficiency
- Efficient implementation using FFT
- Low sensitivity to time synchronization errors
- Tuned sub-channel receiver filters are not required (unlike conventional FDM)
- Facilitates Single Frequency Networks, *i.e.* transmitter macrodiversity

Combination of OFDM and MIMO technique there by achieving spectral efficiency & increased through output

Implementation of OFDM System (single user)

Random Data Generator

Random data generator is used to generate a serial random binary data. This binary data stream models the raw information that going to be transmitted. The serial binary data is then fed into OFDM transmitter.

Serial to Parallel Conversion

The input serial binary data stream is formatted into word size required for transmission, ex. 2 bit/words for QPSK, and shifted into parallel format. The parallel data is then transmitted in parallel by assigning each data word to one carrier in the transmission.

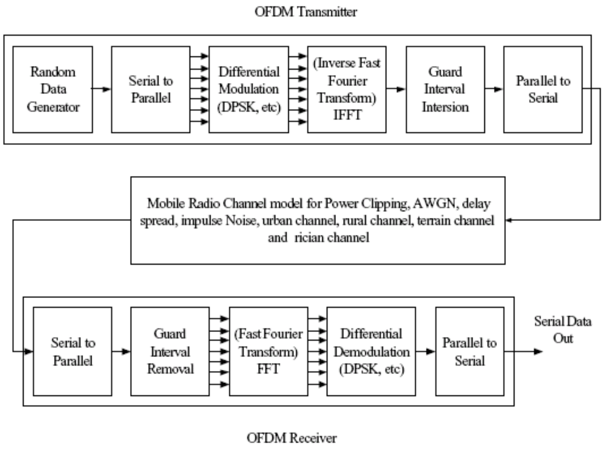


Fig-1 OFDM transmitter and receiver system

Modulation of Data

The data to be transmitted on each carrier is then differential encoded with previous symbols, then mapped into a Phase Shift Keying (PSK) format. Since differential encoding requires an initial phase reference, an extra symbol is added at the start for this purpose. The data on each symbol is then mapped to a phase angle based on the modulation method. For example, for QPSK the phase angles used are 0, 90, 180, and 270 degrees. The use of phase shift keying produces a constant amplitude signal and was chosen for its simplicity and to reduce problems with amplitude fluctuations due to fading.

Inverse Fourier Transform

After the required spectrum is worked out, an Inverse Fourier Transform is used to find the corresponding time waveform. The guard period is then added to the start of each symbol.

Guard Period

The type of guard period used in this simulation was a cyclic extension of the symbol. The length of guard period was chosen 25 percent of the length of symbol.

Parallel to Serial Converter

After guard period has been added, the symbol is then converted back to a serial time waveform. This signal is the base band signal for the OFDM transmission.

Channel

A channel model is then applied to the transmitted signal. The effect of mobile radio channel impairments such as peak power clipping, AWGN, delay spread and impulse noise were simulated separately.

Receiver

The receiver basically does the reverse operation to the transmitter. The guard period is removed and The FFT of each symbol is then taken to find the original transmitted spectrum. The phase angle of each transmission carrier is then evaluated and converted back to the data word by demodulating the received phase. The data words are then combined back to the same word size as the original data and converted back to original binary form.

Implementation of OFDM MIMO System (multi user)

We would implement an uplink multi-user MIMO OFDM system depicted in Fig. 1, where the different users are assumed to be synchronized. For simplicity, each of the Nt User Terminals (UTs) is assumed to be equipped with a single transmit antenna1, although the BS employs Nr receiver antennas. More specifically, at the *kth* subcarrier during the *nth* OFDM symbol duration, we have

$$\mathbf{x}[n, k] = \mathbf{H}[n, k] \cdot \mathbf{s}[n, k] + \mathbf{n}[n, k] \qquad (1)$$

Where the $(Nr \times 1)$-dimensional vector $\mathbf{x}$, the $(Nt \times 1)$-dimensional vector $\mathbf{s}$ and the $(Nr \times 1)$-dimensional vector $\mathbf{n}$ are the received, transmitted, and noise signals, respectively. As shown in the upper half of Fig. 1, the information bit blocks $\mathbf{b}(nt)$ $(nt = 1, \cdots, Nt)$ of the Nt number of UTs are first encoded by the Nt independent Forward Error Correction (FEC) encoders, followed by the corresponding bit padding operations, where zero bits are appended to each user's bit sequence for being conformable to a specific size. The number of padding bits depends on frame size, number of OFDM sub carriers, codeword length, modulation scheme, etc. The resultant appended coded bits are then interleaved and mapped to Quadrature Amplitude Modulation (QAM) or Phase-Shift Keying (PSK) constellation symbols, which are modulated by the length-K Inverse Fast Fourier Transform (IFFT) based OFDM modulators following the sub carrier mapping operation, as seen in Fig. 1. Then each user's signal is independently transmitted over the MIMO channel.

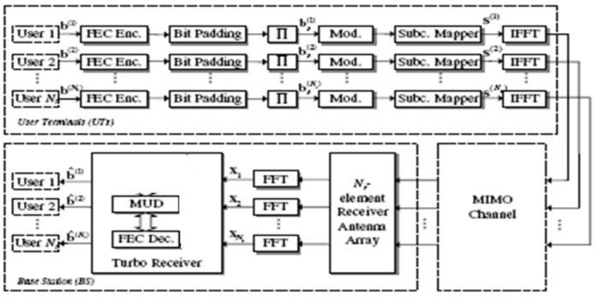


Figure2- Schematic of an uplink Multi-user MIMO OFDM system employing the proposed Iterative turbo receiver.

At the BS illustrated at the lower half of Fig. 1, the received signal constituted by the noise-contaminated superposition of all users' transmitted signals, is first subject to Fast Fourier Transform (FFT) based OFDM demodulation at each of the *Nr* receiver antenna elements. Finally, the OFDM-demodulated signal is forwarded to the turbo receiver for iterative channel estimation, Multi-User Detection (MUD), and channel decoder . Note that for simplicity the cyclic prefix related operations are not plotted in Fig. 2. We would evaluate the performance for different levels of noise present in transmission channels.

ITERATIVE TURBO MIMO OFDM RECEIVER Using MMSE CHANNEL ESTIMATION

In this section, we elaborate on the proposed design of the turbo receiver portrayed in Fig.2, which is further detailed in Fig.3. More specifically, the receiver consists of two major parts, namely the outer loop associated with the channel decoder, as well as the inner loop with the channel estimator and the MUD, as shown at the left-and right-hand side of Fig.3, respectively.

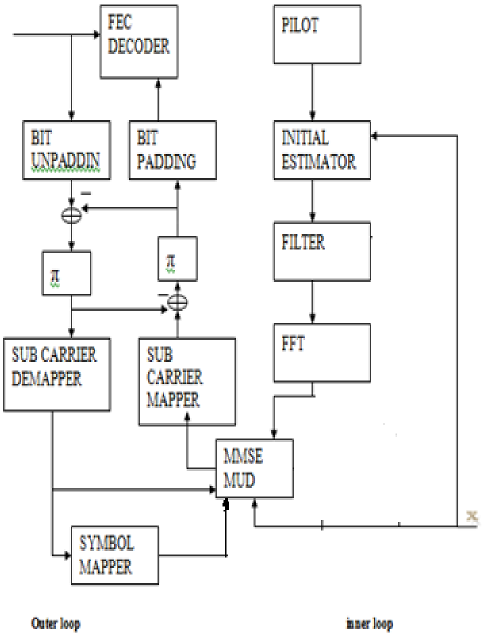


Figure 3. The structure of MIMO OFDM turbo receiver

SIMULATION RESULTS

In this section, the performance of a 16Qpsk MIMO OFDM system using the proposed using proposed Turbo receiver technique is quantified. frame size of *NF* = 10 OFDM symbols, each constituted by *K* = 2048 number of subcarriers and a cyclic prefix of 128 samples were used . The complex-valued channel envelope was assumed to remain unchanged within OFDM symbol duration, but varied from one OFDM symbol to another. As a simple example, *Nt* = 2 uplink users were supported by *Nr* = 2 BS receiver antennas, while each UT employs a single transmit antenna. In Fig. 4.1 we provide the Bit Error Ratio (BER) versus *Eb/N*0 performance of simple ofdm for single user Here the BER vs SNR performance is observed giving 10^-2.8 at snr 14.

Fig 4.2(a,b,c,d) shows the multi-user turbo MIMO OFDM system for different iteration. Note that in Fig. 4.2(a)-(d) the number of iterations can changed from 1,2,4,6,10 respectively. it is observed that at each iteration performance increased as well as overall performance increases for e.g. In fig a. the BER is 10^-4 at snr =7db,while in fig b ber is 10^-4 at SNR = 6.7 db, while for iteration 4 BER =10^-4 for SNR = 6 db thus over all performance increased.

4. RESULTS

i. BER Vs Eb/No Performance of simple OFDM system For Single user

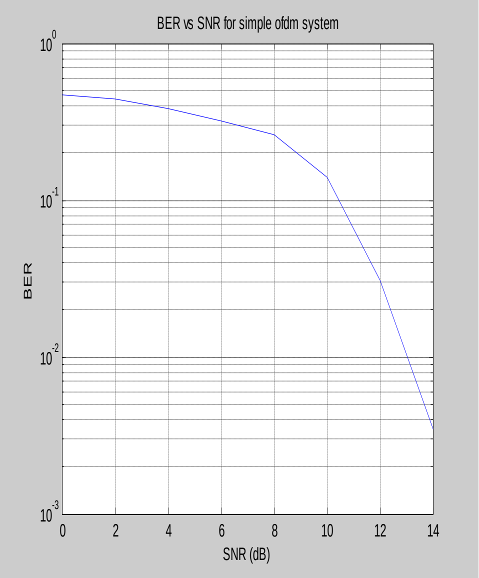
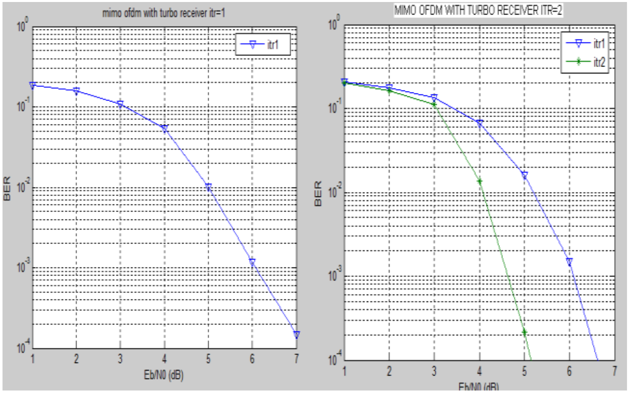


Fig 4.1 BER performace of simple ofdm system

ii. BER Vs Eb/No performance of Multi-user MIMO OFDM with Iterative Turbo Receiver system.



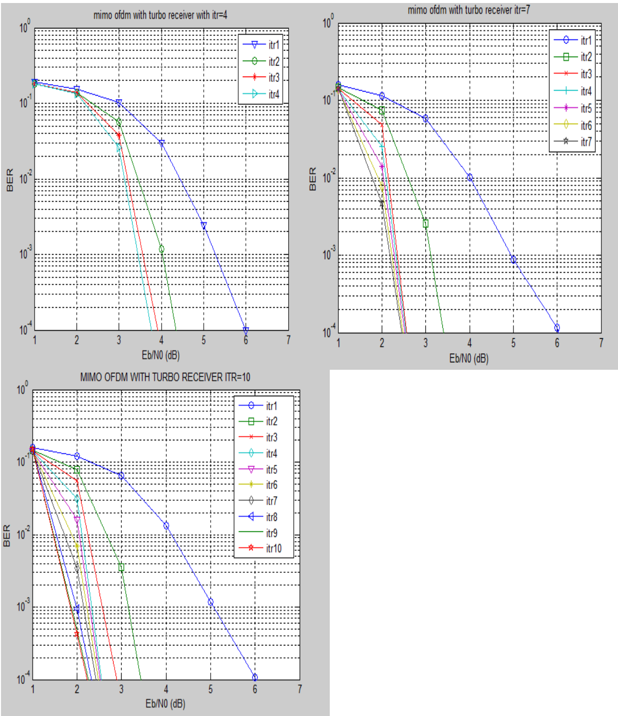


Fig 4.2 (a,b,c,d,e) shows BER Vs Eb/No performance of Iterative turbo receiver for multi-user MIMO OFDM system with MMSE MUD.

CONCLUSIONS

In this paper (uplink Multi-user MIMO OFDM with Iterative Turbo receiver), Simulation results show that the proposed scheme provides a good performance, which can be improved as the number of turbo processing iterations increase. Our future work includes system-level simulations targeting the evaluation of the overall gain in terms of uplink coverage extension.

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