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# SPARSE CHANNEL ESTIMATION AND CHANNEL CAPACITY MAXIMIZATION USING MIMO OFDM SYSTEMS

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**Abstract:**

*Increased spectral efficiency and improved link reliability are the major challenges in future wireless communications designs. Multiple Input Multiple Outputs MIMO schemes are widely used in many wireless standards allowing higher throughput. In this, Time Frequency Training OFDM can be easily extended to MIMO system, the transmission frame scheme is composed of one preamble and subsequent TFT OFDM sub frames for MIMO systems and the corresponding time-frequency joint channel estimation method is accurately track the channel variation, then the received time domain Training Sequence is used for path delay estimation while the frequency domain pilots are used for path gains acquisition under the compressive sensing based estimation method. Simulation results shows that better performance and higher spectral efficiency. Moreover, reduction in pilot density can maintain better channel estimation accuracy with the aid of Compressive Sensing algorithm.*

**Index Terms:** MIMO-OFDM, Compressive Sensing, Time Frequency Joint Channel Estimation, Sparse Common Support & Spectrum Efficient

## 1. Introduction:

Over the last few decades wireless communications has become one of the fastest growing researches fields in the engineering community. Multiple Input Multiple Outputs (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) have been chosen due to their superior performance.

MIMO systems are often combined with a spectrally efficient transmission technique called OFDM, whereby support high data rates and high performance, the coding over the space, time, and frequency domains provided by the MIMO-OFDM enables a much more reliable and robust transmission over the harsh wireless environment and these enable high capacities suited for internet and multimedia services and also dramatically increase range and reliability and the major advantages are increased capacity, coverage and reliability.

In many applications the estimation of the wireless channel connecting a transmitter with a receiver is indispensable. Channel estimation is a crucial and challenging issue in receiver design. In CS is a rather young mathematical theory in which the concept of randomness is utilized to recover so called sparse or compressible signals that are only constituted of few essential contributions, from measurements. Its accuracy has significant impact on the overall performance of the MIMO-OFDM system.

**Notation**:

The lowercase and uppercase boldface letters denote vectors and matrices, respectively. $(.)^T$, $(.)^H$, $(.)^{-1}$, $(.)^{\dagger}$, diag$(.)$, and $||.||_p$ denote the transpose, Hermitian transpose, matrix inversion, matrix pseudo inversion, diagonal matrix, and $l_p$ norm operations, respectively. Finally $\Phi_\pi$ represents the sub matrix comprised of the $\pi$ columns of the matrix$\Phi$.

## 2. System Model:

- **Block Diagram**

Based on this analysis this section includes various blocks are discussed under the transmitter and receiver side. In this channel estimation block is necessary to estimate the channel impulse response.

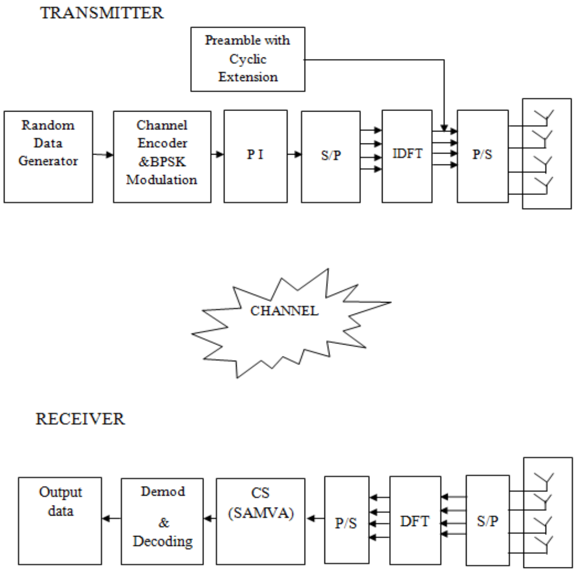


Figure 1: MIMO-OFDM transceiver block diagram.

The block diagram which explains as the randomly generated binary data is encoded modulated and then allocates the pilots randomly over time and frequency resource grid in efforts. Then serially received data is converted into parallel data which is then implemented as IDFT where the frequency domain data streams into time domain representation and the cyclic prefix is replaced by known preamble to improve the spectral efficiency. After, parallel to serial conversion is performed and the converted analog signal is transmitted over multipath fading channel. AWGN is added and then sum signal is received.

Due to the multipath channel there is some ISI in the received signal. Then in receiver side, the ISI is protected by cyclic extension. The serial to parallel conversion, transformation and parallel to serial conversion are performed. Finally, Compressive sensing channels estimation capable of recovering a signal by using sparsity adaptive measurement vector algorithm.

- **MIMO Supporting with OFDM Systems:**

**MIMO:** Multiple Input Multiple Output (MIMO) system has been recently added to wireless system. Where there is more than one antenna at either end of the radio link. There are many formats of MIMO that can be used from SISO, through SIMO and MISO to full MIMO systems. Main reasons to increase coverage, data rates and achieves better BER Compare to SISO counterpart at the same SNR is by STBC, that's the coverage can be enhanced and delivers higher data rate due to transmission of multiple data symbols simultaneously using multiple antennas, this technique called spatial multiplexing by its data rate can be enhanced. Also in MIMO system, we can increase the capacity instead by a linear function of power i.e. if 10 times increase in power; 10 times increase in capacity.

**OFDM:** The spectral efficiency of a system is defined by the transmitted bit rate in the frequency domain. In the multicarrier transmission, the spacing between two subcarriers is important in order to have a bandwidth efficient system.

To solve the bandwidth inefficiency OFDM is introduced. In here bandwidth is efficiently required in figure shows that almost 50% of the bandwidth are saved by allowing the subcarriers to overlap.

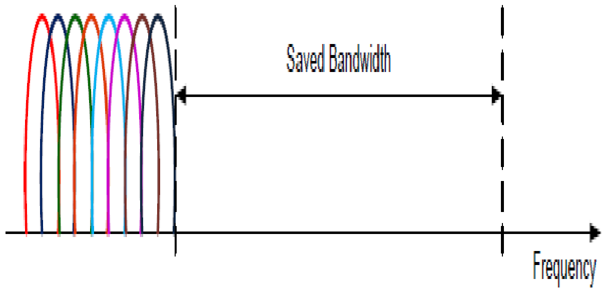


Figure 2: OFDM

OFDM system provides higher data rate compare to FDM system in the same bandwidth usage. Also it has multipath interference is more compare to FDM systems but can be avoided or reduced using high end algorithms such as cyclic prefix insertion etc,. In OFDM system supports more subscriber/channels compare to FDM ie., FDM, entire BW is used by user/subscriber but in OFDM, BW is divided into many narrowband channels and each is allocated to user/subscriber. Broadband multicarrier modulation method that offers superior performance and benefits over more traditional single carrier modulation methods. Because, it has high speed data requirement

**MIMO-OFDM:** Potential to achieve high system capacity and transmit receives diversity for reliable communication links of any wireless system. Hence it is considered as the future of wireless communication systems. It provides higher data rates, supports a large number of users with flexibility in QoS and provide high quality transmission in comparisons to other schemes. Hence, MIMO-OFDM has been widely adopted in the latest communication standards, such as LTE, IEEE 802.11, etc., and it is also considered as a key technique for future wireless communications. As one of the major challenges for practical MIMO-OFDM systems, accurate channel estimation is essential to guarantee the system performance.

- **TFT-OFDM for MIMO Systems:**

Large number of pilots are commonly used in OFDM MIMO systems thus reduces the spectral efficiency in practice. To solve those problem, time frequency training (TFT) OFDM MIMO have been introduced. In that, both time and frequency domain training information for OFDM data block.

The TFT-OFDM based transmission frame composed of one preamble and subsequent TFT-OFDM sub frames, whereby the preamble is used to provide an initial reliable channel estimate and leading higher spectral efficiency. TFT-OFDM symbol without cyclic prefix adopts the time domain training sequence (TS) and the frequency domain orthogonal grouped pilots as the training information. At the receiver, the corresponding time-frequency joint channel estimation method is proposed to accurately track the channel variation, whereby the received time-domain TS is used for path delays estimation without interference cancellation, while the path gains are acquired by the frequency domain pilot.

**Preamble:** In this the standard cyclic prefix (CP) is replaced by the known preamble to improve the spectral efficiency while sacrificing the cyclicity property of the received OFDM block under multipath fading channels. Hence, the cyclicity reconstruction is required to obtain the pilot for accurate channel recovery. Then it can be implemented by extending OLA operations above to every transmit antenna.

- **Multipath Propagation:**

There are many different phenomena affecting the transmit signal on its way through the radio channel. First of all, since electromagnetic waves weaken as they propagate, the received signal strength decreases as the distance between transmitter and receiver grows, which is known as free space path loss. Furthermore, in addition to the direct Line of Sight (LOS) connection between transmitter and receiver, which might be blocked by walls, buildings, etc., the spherical propagation of electromagnetic waves yields that the signal also takes several other paths? This multipath propagation is due to the fact that copies of the signal typically are reflected by large, smooth surfaces (e.g. walls of a building), scattered by smaller, rougher surfaces (e.g. leaves of a tree), diffracted on the edges of some objects (e.g. houses, cars, mountains) or refracted (e.g. by the ionosphere). Therefore, the receiver sees a superposition of several multipath components (MPCs) with distinct amplitude, phase shift and time delay, leading to constructive or destructive interference at the receiver. This, in turn, causes the signal power seen at the receiver to fluctuate over time, frequency and/or space, which is known as fading.

- **Channel Estimation:**

The channel estimator estimates the channel impulse response (CIR) for each burst separately from the well known transmitted bits and corresponding received samples.

The problem of re-obtaining the transmit symbols from the demodulated symbols at the receiver, which are disturbed by the wireless channel, is called equalization. The most natural approach to channel equalization, which is widely used in practice, is to estimate its effects and revert them.

The goal is to estimate the representation of the channel (impulse response). In order to choose the channel estimation technique for the MIMO-OFDM system under consideration, many different aspects of implementations, including the required performance, computational complexity and time variation of the channel must be taken into account.

- **Compressive Sensing:**

The application of CS techniques to the problem of channel estimation was first proposed in 2008, and since then several similar channel estimators have been introduced, which we all subsume under the name of compressive channel estimation. Compressive sensing (CS) has attracted much attention due to its ability to recover a high dimensional signal from a small number of measurements. In conventional channel estimation are semi blind, blind and training based methods. These linear channel estimation methods do not take advantage of channel sparsity and they decrease estimation performance.

So, I have proposed a sparse channel estimation scheme, which is different from linear methods, the channel to enable to exploit sparsity.

- **SAMV Algorithm:**

Spasity Adaptive Measurement Vector (SAMV) algorithm, the pilot allocation strategy inspired by the CS principle this reduces the pilot overhead yet maintains reliable downlink channel estimation performance. This algorithm attempts to reduce the pilot density over time-frequency grid.

**Algorithm – SAMV:**

**Inputs**:

1) Initial channel common support $T_0$.
2) Channel sparsity level K;
3) Noisy measurements $M \triangleq U_i$;
4) Observation matrix $\Phi \triangleq F^{(1)}$.

**Output**: The K-sparse estimate $\bar{H} \triangleq \bar{H}_i$.

***Initial Configuration***:

1: $\Pi \leftarrow T_0$;
2: $\bar{H}^{(0)} \leftarrow 0; \bar{H}^{(0)}_{\Pi} \leftarrow \Phi^{\dagger}_{\Pi} M$;
3: $R \leftarrow M - \Phi\bar{H}^{(0)}$;

***Iteration***:

4: for $k = 1 : K - ;||T_0||_0$ do
5: $P \leftarrow g + 1$;
6: $P' \leftarrow \Phi^{H} R$;
7: $\Pi \leftarrow \Pi \cup \{\arg\max_i \Sigma_j || P_{t,f} ||_1\}$;
8: $\bar{H}^{(k)} \leftarrow 0; \bar{H}^{(k)} \leftarrow \Phi^{\dagger}_{\Pi} M$;
9: $R \leftarrow M - \Phi\bar{H}^{(k)}$;
10: end for
11: $\bar{H} \leftarrow \bar{H}^{(k)}$.

## 3. Estimation Theory:

In this section, by fully exploiting the time frequency training feature of MIMO-TFT-OFDM scheme and the channel sparse common support property. The proposed channel estimation is composed of three steps as follows.

**Step 1: Partial Common Support Acquisition:**

In this step, the preamble needs to acquire the partial channel support information. Hence, the preamble length here only needs to be no less than the channel length, i.e., $M \geq L$.

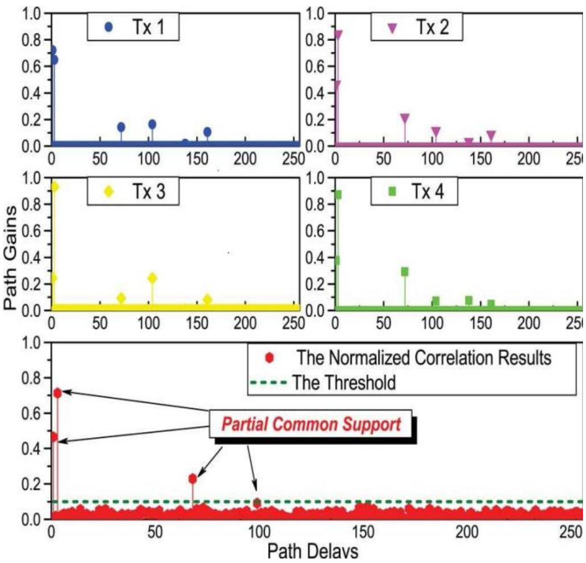


Figure 3: Illustration- PCSI Acquisition in 4X4 MIMO System

At the receiver, received preamble without interference removal to correlate with the local preamble to obtain the partial sparse common support and the correlate result is rough estimate of superposition of all CIRs associated with the transmit antennas.

$$\bar{z}_i = \frac{1}{M\,Nt} c \otimes \hat{c}_i = \frac{1}{Nt} \sum_{p=1}^{N} h_i^{(p)} + v_i \qquad (1)$$

Due to the channel sparse common support property and the good correlation property of the preamble, the partial common support information $T_0 = \{ l : \| \bar{z}_{i,l} \|_2 \geq a \}_{l=0}^{L-1}$ can be obtained by appropriately selecting the threshold.

Also the channel sparsity level can be estimated by adding compensation factor, i.e., $K = \|T0\|_0 + b$.

**Step 2: Cyclicity Reconstruction of OFDM Block:**

In MIMO-TFT-OFDM scheme, the standard cyclic prefix (CP) is replaced by the known preamble to improve the spectral efficiency while sacrificing the cyclicity property of the received OFDM block under multipath fading channels. Hence, cyclicity reconstruction of the OFDM block in MIMO systems can be implemented by extending the OLA operations and the pilot can be extracted for accurate channel estimation in following step 3.

**Step 3: Accurate Channel Estimation Based on SAMV algorithm:**

After cyclicity reconstruction, the received OFDM block in the frequency domain can be written as,

$$\bar{y}_i = \sum_{p=1}^{N} \mathrm{diag}(\tilde{x}_i^{(p)})\, F_L\, h_i^{(p)} + w_i \qquad (2)$$

Where $F_L$ is the N X L partial DFT matrix containing the first L columns of F. Now, I have only focus on the received OFDM block pilots located at $D^{(P)} = \{d_n^{(p)}\}_{n=1}^{N}$ and the above equations can be simplified as

$$u_i^{(p)} = F^{(p)} h_i^{(p)} + \hat{w}_i^{(p)},\ 1 \leq p \leq N_t \qquad (3)$$

Where $u_i^{(p)}$ and $F^{(p)}$ is the Np x L partial DFT matrix with the (n+1,k+1)-th entry being exponential function. Therefore, a matrix formulation can be defined as

$$U_i = F^{(1)} H_i + \hat{W}_i \qquad (4)$$

where $H_i = [\, h_i^{(1)}, \Theta\, h_i^{(2)}, \ldots\ldots, \Theta^{N-1} h_i^{(N)}$ contains all the CIR information which needs to be estimated and $\hat{W}_i$ denotes the noise.

**4. Simulation Results:**

This section investigates the performance of the MIMO-TFT-OFDM scheme. The below figure illustrates the MSE performance of different schemes in 4 x 4 MIMO systems.

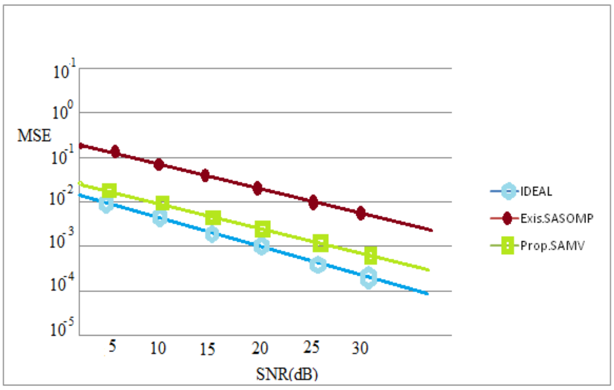


Figure 4: Comparison of MSE performance of different schemes in 4 x 4 MIMO systems

The correct recovery is defined as the estimation mean square error is expecting lower than $10^{-2}$ with low signal to noise ratio. The MSE of the ideal channel estimation is illustrated as benchmark, which shows the optimal estimation performance. The existing SASOMP scheme is evaluated for comparison. It could be seen that the proposed SAMV scheme performs better than existing scheme.

Also the proposed SAMV scheme demonstrates higher spectral efficiency than the conventional schemes.

**Table 1: Spectral Efficiency Comparison**

| S.No | SCHEME | S.E (%) |
|---|---|---|
| 1 | Time domain preamble | 76.19 |
| 2 | Frequency domain pilots | 70.59 |
| 3 | Existing SASOMP | 91.82 |
| 4 | Proposed SAMV | 94.12 |

## 5. Conclusion:

In this letter, reduction of pilots density by Compressive Sensing principle compared to the conventional system. In spite of this reduction, which can maintain good channel estimation accuracy with the aid of the Sparsity Adaptive Measurement Vector (SAMV) based sparse signal recovery algorithm for MIMO-OFDM systems. Thus, provides reliable downlink channel estimation performance with less computational complexity. Also the spectral efficiency can be greatly improved compared with conventional system.

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