IMPACT: International Journal of Research in Engineering and Technology
ISSN (P): 2347–4599; ISSN (E): 2321–8843
Vol. 10, Issue 6, Jun 2022, 17–24

IMPROVED METHOD FOR CHANNEL ESTIMATION IN MIMO OFDM

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Received: 07 Jun 2022 **Accepted: 07 Jun 2022** **Published: 07 Jun 2022**

ABSTRACT

Due to its outstanding advantages in spectral efficiency and energy efficiency, multiple-input and multiple-output (MIMO), which employs a large number of antennas at the base station (BS) to simultaneously serve many user terminals (UTs), is one of the critical technologies in fifth-generation (5G) and future wireless communication systems. With the rise of wireless communication technologies, emphasis on increased data rates, system capacity, and service quality has piqued attention. To address these difficulties, proper channel modelling and precise assessment of channel state information are critical for the communication system's design. This paper proposes an improved channel estimation approach. Singular value decomposition is employed for precoding, followed by the VAMP approach for channel estimation.

KEYWORDS: *Massive MIMO-OFDM, Channel Estimation, Message Passing*

INTRODUCTION

Multiple-input multiple-output (MIMO) is an acronym for multiple-input multiple-output. This is a wireless radio communication and multi-path technology that is now being mentioned and employed in a number of new technologies. Using several antennas at the transmitter, receiver, or both, this technology was designed to improve the wireless communication system. The new MIMO wireless technology is used in Vo-LTE, LTE (Long Term Evolution), Wi-Max, Wi-Fi, and many other radio, wireless, and RF technologies to deliver increased connection capacity and spectrum efficiency, as well as improved link stability [1]–[4]. Using a single radio channel, multiple-in, multiple-out (MIMO) communication distributes the same information as different signals through multiple antennas at the same time as shown in Fig. 1.

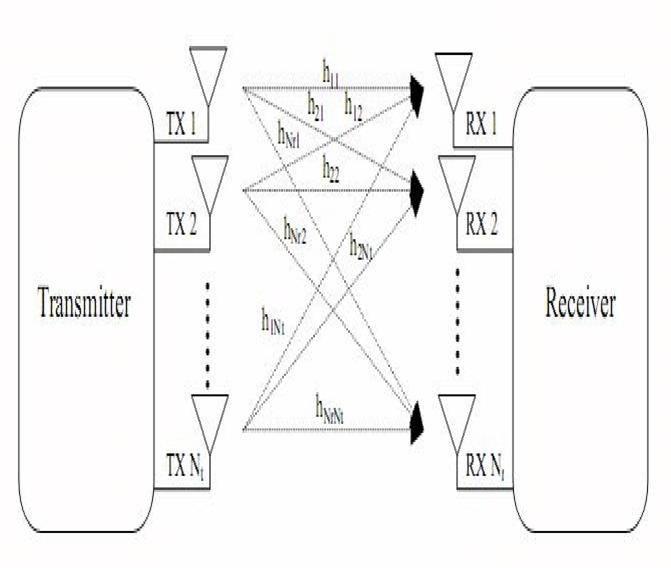

Figure 1: MIMO System.

OFDM is a customised FDM in which the sub-streams into which the main signal is divided must be orthogonal to each other. Signals that are perpendicular to one another are known as orthogonal signals. The fact that orthogonal signals do not interfere with each other is one of their most important characteristics [5]–[7].

Single user MIMO is a type of MIMO in which there is just one transmitting and receiving node, with the transmitter having multiple antennas. In multiuser MIMO, individual mobile cellular users broadcast to a base station using a single antenna, and the base station interprets the signals as if they were coming from many transmit antennas on a single node [8]–[11]. We propose to optimise the phases of the SVD per subcarrier, taking into account the phase non-uniqueness of SVD, such that the ensuing precoders can make the effective channel as smooth as feasible in the frequency domain, making channel estimation at the receiver easier.

HIERARCHICAL HYBRID MESSAGE PASSING (HHMP) ALGORITHM

In the angle-delay domain, a hierarchical hybrid message passing (HHMP) technique is developed for estimating time-varying sparse channels with low pilot overhead and high estimated accuracy. The first order derivative of the Lagrange function is used to determine channel estimate using this method. Without knowing hidden Markov channel parameters, the proposed method may adaptively learn the sparse structure and temporal correlation of multiuser channels. Channel discontinuities, channel capacity loss, and computational complexity all plague hierarchical hybrid message forwarding.

VECTOR APPROXIMATE MESSAGE PASSING WITH SINGULAR VALUE DECOMPOSITION

It is proposed that the phases of the SVD per subcarrier be optimised so that the resultant precoders can make the effective channel as smooth as feasible to make channel estimation easier at the receiver. In contrast to the aforementioned state-of-the-art approaches, the phase-rotated SVD (PR-SVD) has no capacity loss. Because the PR-SVD is still an exact SVD and the effective channel per subcarrier is still exactly orthogonal. Computer simulation is used to verify the sparse channel estimation's efficacy, but the MP technique is not very stable. For channel estimation, the VAMP (Vector Approximate Message Passing) approach is utilised. The block diagram of the suggested system is shown in Figure 2. The suggested approach reduces channel capacity loss while also improving Bit Error Rate.

Process Flow of the Proposed System

- Produce an input signal
- The input signal is modulated using QPSK Modulation, which includes serial to parallel conversion, Inverse Fourier Transform, and pilots.
- Singular Value Decomposition with phase rotation is used to encode the modulated signal.
- Send the signal along the channel.
- At the receiver end, channel estimation is calculated.
- Decode the received signal
- Demodulate the signal, reversing the modulation process to obtain the signal

Modulation and De-modulation

The process of modulating a low-frequency signal to a high-frequency signal and then transmitting the high-frequency signal is known as modulation. The modulating signal or baseband signal is the low-frequency signal that carries the original information [5]. The carrier signal is the high-frequency signal. The resultant signal is referred to as the modulated wave after the carrier signal has been modulated by the modulating signal. Modulation is a common communication system procedure in which a very high-frequency carrier wave is used to convey a low-frequency message signal, ensuring that the transmitted signal retains all of the information included in the original message signal.

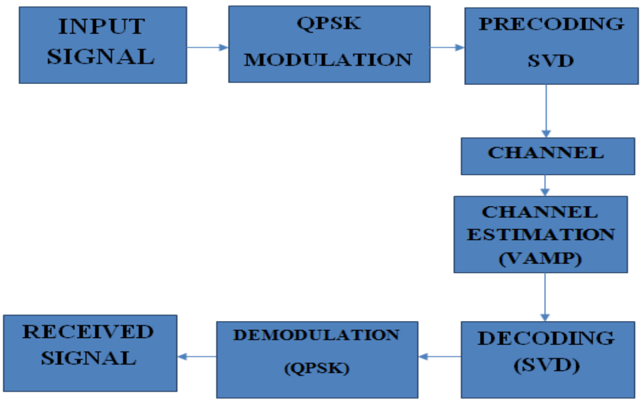

Figure 2: Block Diagram of Proposed System.

It is the modulation process in reverse. The modulated signal is demodulated, and the original signal is retrieved. Amplitude Shift Keying, Frequency Shift Keying, Phase Shift Keying, Differential Phase Shift Keying, Quadrature Phase Shift Keying, Minimum Shift Keying, Gaussian Minimum Shift Keying, Orthogonal Frequency Division Multiplexing, and other types of digital modulation are used depending on the type of signal and application. We use Quadrature Phase Shift Keying (QPSK) modulation in our work. The modulation technique quadrature phase shift keying (QPSK) is particularly intriguing because it sends two bits per symbol.

$$s_i(t)=\sqrt{\frac{2E_s}{T}}\cos\left(2\pi f_c t+(2n-1)\frac{\pi}{4}\right), n=1,2,3,4 \qquad (1)$$

In other words, a QPSK symbol symbolises 00, 01, 10, or 11 rather than 0 or 1. We have 360 degrees of phase and four phase states to work with, so the separation should be 360°/4 = 90 degrees. So 45°, 135°, 225°, and 315° are our four QPSK phase shifts.

Precoding

Applying the same precoder to a band of consecutive subcarriers is a typical (and simplistic) cure for maintaining the smoothness of the effective channel. As a result, the effective channel within the band will stay smooth, but this remedy comes at the cost of capacity loss, and the subcarriers near the band's edge will continue to experience channel discontinuities, which can make channel estimation difficult. To avoid such gaps, it was suggested that the precoding matrices be interpolated. Singular value decomposition with phase rotation is employed for precoding in our research.

Precoding (Singular Value Decomposition):

The SVD of the MIMO channel matrix is utilised to obtain the precoding matrix used to achieve the channel capacity utilising optimal power allocation. The receiver estimates the MIMO channel matrix, and the transmitter has no prior knowledge of it. As a result, in order to reap the benefits of SVD precoders at the transmitter, the receiver must quantize and feedback the precoders it receives from the SVD of the MIMO channel matrix. The receiver must quantize and feedback the precoders it derives from the SVD of the MIMO channel matrix, which is one of the advantages of SVD precoders at the transmitter. Quantization must be done with relatively few bits to adhere to the bit budget imposed by restricted feedback CSI methods.

Channel Estimation

Channel state information (CSI) offers the known channel attributes of a wireless communication link. The CSI should be calculated at the receiver and given back to the transmitter in most cases. As a result, the CSI of the transmitter and receiver may differ. The information on the Channel State can be real-time or statistical. The current channel conditions are known in Instantaneous CSI, which may be examined by knowing the transmitted sequence's impulse response. Statistical CSI, on the other hand, includes statistical properties like fading distribution, channel gain, and spatial correlation, among others.

VAMP

The vector AMP algorithm employs a non-loopy network with vector-valued nodes, hence the name. Only a limited number of adopted values may accurately reconstruct the original sparse signal in compressed sensing theory, which makes full use of the channel's sparse properties. The Matching Pursuit (MP) algorithm is used to suggest a sparse channel estimation approach. Computer simulation is used to verify the sparse channel estimation's efficacy, but the MP technique is not very stable. This study proposes a novel vector approximate message forwarding method. Calculate the residual, Onsager correction, and variance after first calculating the channel vector matrix.

- STEP 1: Convert input data into real number representation about transmission matrix and channel.

$$\begin{bmatrix} y^{(r)} \\ y^{(i)} \end{bmatrix} = \begin{bmatrix} A^{(r)} & -A^{(i)} \\ A^{(i)} & A^{(r)} \end{bmatrix} \begin{bmatrix} h^{(r)} \\ h^{(i)} \end{bmatrix} \Rightarrow \quad y^{(ri)} = A^{(ri)} h^{(ri)} \tag{2}$$

- STEP 2: Calculate the residual, Onsager correction, and variance of transmission matrix A after decomposing it.

1) Estimate $\tilde{h}_t^{(ri)}$, set $\tilde{h}_t^{(ri)} = \tilde{\eta}(\tilde{r}_{t;}\tilde{\sigma}_{t,}\tilde{\theta})$ (3)

$$\tilde{\eta}\left(\tilde{r}_t;\tilde{\sigma}_t,\tilde{\theta}\right) = \boldsymbol{V}\left(Diag(\boldsymbol{s})^2 + \frac{\sigma_m^2}{\tilde{\sigma}_t^2}\boldsymbol{I}_R\right)^{-1}\left(Diag(\boldsymbol{s})\boldsymbol{U}^{\top}y^{(ri)} + \frac{\sigma_m^2}{\tilde{\sigma}_t^2}\boldsymbol{V}^{\top}\tilde{r}_t\right)$$

$$v_t = \langle \eta'(r_t;\sigma_t,\theta_t)\rangle \triangleq \frac{1}{N}\sum_{j=1}^{N}\frac{\partial\left[\eta(r;\sigma,\theta)\right]_j}{\partial r_j}$$

$$\tilde{r}_{t+1} = \left(\hat{h}_t^{(ri)} - v_t r_t\right)/(1 - v_t)$$

$$\tilde{\sigma}_{t+1}^2 = \sigma_t^2 v_t/(1 - v_t)$$

- STEP 3: To achieve the final estimated value, convert the estimated value into imaginary form.

$$\hat{h}^{(ri)} = \begin{bmatrix}\hat{h}^{(r)} \\ \hat{h}^{(i)}\end{bmatrix} \qquad \bar{h} = \hat{h}^{(ri)} + i\hat{h}^{(ri)} \tag{4}$$

EXPERIMENTAL RESULTS

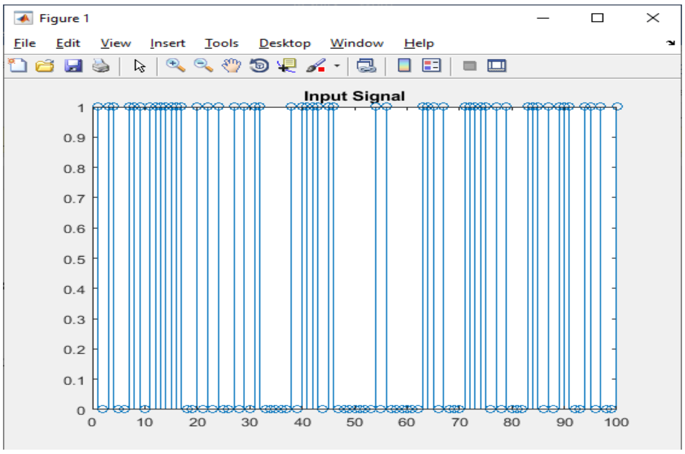

Figure 3: Input Data Signal.

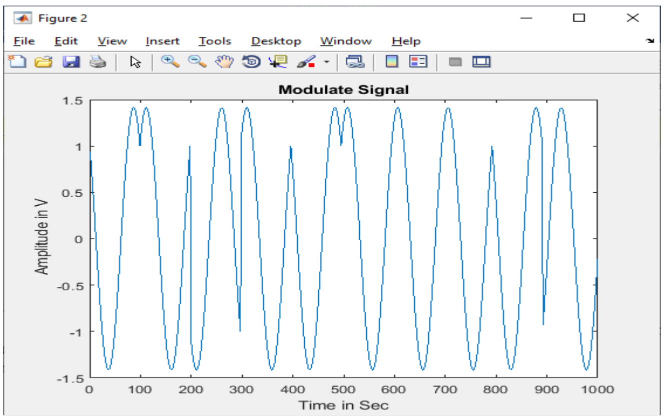

Figure 4: Modulated Signal.

The data signal created and given as input to transmit is shown in Figure 3. It's a binary signal that's also created at random. The output of a modulated signal is seen in Figure 4. QPSK modulated signal is the sum of inphase and quadrature signals.

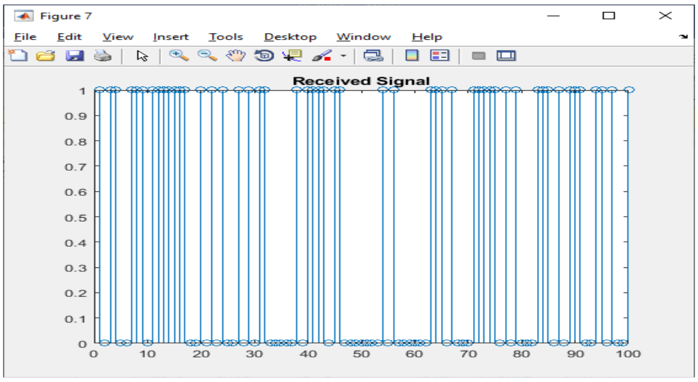

Figure 5: Received Signal.

The signal received at the receiver is shown in Figure 5. The receiving signal is decoded and demodulated to obtain this signal. The quadrature phase shift key is used for demodulation. It is the reversal of the procedures taken on the transmitting side.

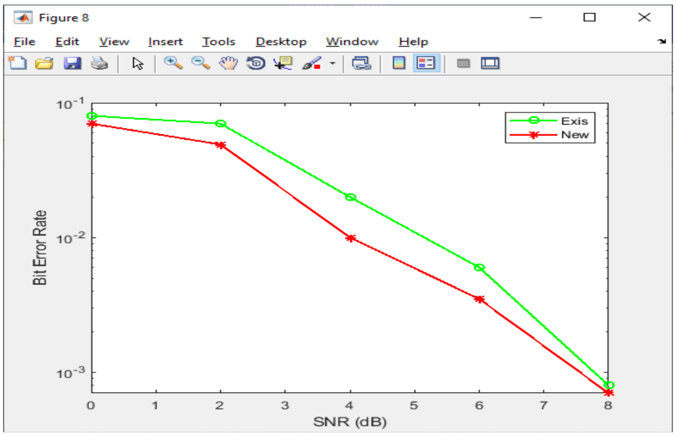

Figure 6: BER.

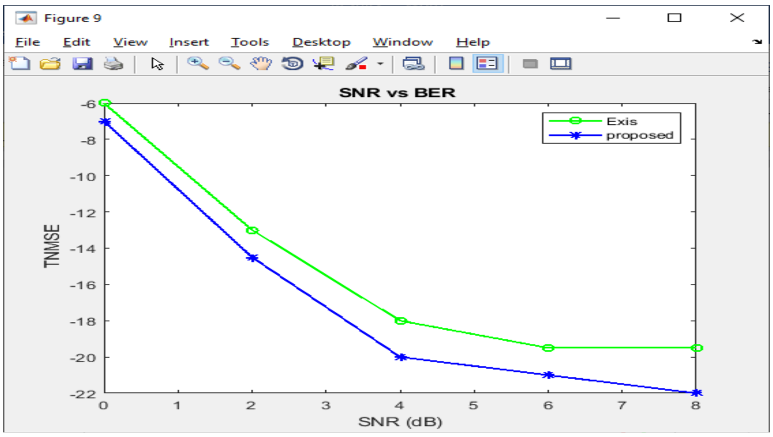

Figure 7: Performance Curve.

The bit error rate performance curves of the two algorithms are shown in Figure 6 under various SNR circumstances. The two have an inverse relationship. Figure 7 depicts the performance curves of the two algorithms under various SNR and TNMSE conditions (Time Normalized Mean Square Error). The graph depicts the HHMP vs. HHMP contrast (Hierarchical message passing and Hybrid message passing). It demonstrates that the proposed algorithm produces better results.

CONCLUSION

The proposed study aims to solve the uplink channel estimation problem for huge MIMO-OFDM systems using a new channel estimating method. Singular value decomposition is employed for precoding, followed by the VAMP approach for channel estimation. The proposed algorithm can effectively exploit the structured sparsity and temporal correlation of realistic channels to obtain high channel estimation accuracy, fast convergence speed, and low pilot overhead, and extra terms derived from variance constraints can improve the convergence stability and performance in the few pilot subcarrier cases, according to simulation results.

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