Implementation of MIMO OFDM NOMA System using Iterative Algorithm

Anil S, Pappa M and Ramesh C
Dept of ECE, CMR Institute of technology, Bangalore, Karnataka, India
anls18vlsi@cmrit.ac.in, pappa.m@cmrit.ac.in, crameshm@gmail.com

Abstract: In this modern world, technology has improved a lot and wireless communications are much necessary. MIMO wireless technology is very much essential for providing increased connectivity and spectral efficiency combined with the reliability of advanced connectivity using what were previously considered as interference paths. The multiple access system is considered such that they provide the different methods in communication for multi-users. In this work, the iterative algorithm is used such that it helps in defining random array of signals and assigning the phase to the given measured amplitude. Different types of multiple access systems such as Non-Orthogonal multiple access (NOMA), Orthogonal multiple access (OMA) and Adaptive Orthogonal multiple access (AOMA) which are used to analyze transmission of multiple data stream over power domain in the presence of AWGN and Rayleigh channel. The data transmitted over the channel may vary due to some interference on its path. The signal strength is calculated in the receiver using the fading channel and the other noises that gets added in the channel. MATLAB software tool is used for simulation and the performance analysis in terms of average sum value i.e. the signal strength with respect to SNR for all the above mentioned multiple access techniques is compared. The simulation results clearly exhibits that NOMA outperforms the other two cases and is one of the promising technology for fifth generation wireless communications.

Keywords: MIMO, OMA, NOMA, AOMA, Iterative algorithm

1. Introduction
In the past several years, the way people communicate with each other has been revolutionized by mobile communication that adds mobility to the loop. A lot has been accomplished in a very short time on the wireless journey. Wireless access technology has advanced through leaps and bounds and is close to the fifth generation (5G). In the past, wireless access technology has pursued a number of progressive routes in an extremely mobile setting aimed at efficiency and performance. Today, MIMO technology is a key component of many modern wireless communication technologies including Long Term Evolution (LTE) and WiMAX. MIMO communications systems benefit significantly from spectral performance, power and energy efficiency compared to standard SISO Systems. In wireless propagation, whenever changes in amplitude and phase of radio waves occur, mobile stations transmit these changes through fragments of information. Amplitude or phase can vary conclusively on the receiver side of the mobile applications systems. This leads to deterioration in the system performance and affects the QoS parameters, because the accuracy of the standardized or instantaneous estimated...
channel has a strong impact on the performance of the receiver. So to improve accuracy of the received signal, channel estimation technique is introduced. Radio stations in mobile communication systems are often the most obsolete or fading channels because of the multi path propagation, due to which inter symbol interference (ISI) mixes with the received signal. To remove the ISI from the signal, many types of acquisition techniques or detection algorithms are used in conjunction with the receiver. These detectors or acquisition techniques should have the prior knowledge on channel impulse response (CIR) which can be provided by separate channel estimator. The channel estimation is based on a known sequence of different bits of specific and repeated transmissions throughout the transmission burst. This enables the channel estimator to estimate CIR (i.e.) channel impulse response from the known transmitted bits for each burst separately and from the corresponding received samples of the signal. The channel estimation category or classification is shown in Fig 1. They are Training based estimations, Blind channel estimations and semi-blind channel estimations.

![Figure 1. Types of Channel Estimation](image)

Along with the data symbols, the training based estimation is performed through the arrangement of pilots either in block type or the comb type. In Block type arrangement of pilots, one symbol full of pilot subcarriers is transmitted in a synchronous format by aligning in time and transmitting it periodically. This type of estimation is used for slow fading channel. In comb type arrangement of pilot estimation, the pilots are inserted to the OFDM symbols with a periodic frequency bins.

2. Literature Survey

R.S.Ganesh, Dr J.Jayakumari, Akhila I.P[1] has discussed a technique for multiple input multiple output(MIMO) systems, using a set of pilot carriers in the presence of Rayleigh fading. The algorithms that is used for estimating the channel are the conventional Least Square (LS) and Minimum Mean Square (MMSE) estimation. By means of estimated Bit Error Rate (BER) and Mean Square Error(MSE), MIMO-OFDM system performance is analyzed.

Arsla Khan, Soo Young Shin [2], has shown that, performance of typical NOMA systems in the presence of linear precoding techniques provides trade off with complexity. Actually Performance improves at the cost of slight increment in complexity.
Zhiguo Ding, Xianfu Lei, George K. Karagiannidis, Robert Schober, Jinhong Yuan, Vijay K. Bhargav [3], has discussed the extensive research aspects of NOMA, including innovations as well as their emerging applications.

Sergey D. Sosnin, Gang Xiong, and Yongjun Kwak[4], suggested that when iterative interference cancellation is used along with a reference signal in a data aided manner, improved channel estimation can be achieved. When interference cancellation is done using data aided signals in combination with the reference signal, it improves the overall link performance as well as improved channel estimation in NOMA receiver.

Muyiwa B. Balogun, Fambirai Takawira, Olutayo O. Oyerinde [5], has proposed that with the combination of Orthogonal Frequency Division Multiplexing (OFDM) and Non-Orthogonal Multiple Access (NOMA), spectral efficiency can be enhanced better. An efficient and improved algorithm namely weighted least square based iterative algorithm is proposed and implemented for the channel estimation in NOMA-OFDM systems. By using the improved weighted least square algorithm as the initialization step, an iterative linear minimum mean-square-error (LMMSE) algorithm is developed to estimate the channel. For MIMO OFDM NOMA systems, with the aid of imperfect successive interference cancellation (SIC), this algorithm is implemented for estimating the channel.

3. Multiple Access Systems
In wired or wireless channels, multiple numbers of users are serviced using multiplexing techniques or access methods. On the other hand Communication channels, whether they belong to the category of wireless spectrum segments or cable connections, are tend to be lavish and expensive. So in order to use the available bandwidth efficiently, service providers must allocate users over limited resources to make a profit. Sometimes sharing of these limited channels among many users is also enabled by the access methods to provide the economy of scale necessary for a successful communications business. As shown in figure 2, frequency division multiple access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA), orthogonal frequency division multiple access (OFDMA) and spatial division multiple access (SDMA) are the five different multiple access techniques. This paper concentrates on Orthogonal multiple access (OMA) and Non Orthogonal multiple access (NOMA). These multiple access has different types respectively and OMA is divided in to TDMA, FDMA, CDMA and OFDMA. The NOMA is divided into IDMA LDS, CDMA, Power domain NOMA and MUSA.
Orthogonal Multiple Access: The Orthogonal Multiple Access techniques have several different access technologies that are Time Division Multiplexing Access, Frequency Division Multiplexing Access and Code Division Multiplexing Access. None of these can meet the parameters which are better than the NOMA. These schemes are defined in a different ways; in TDMA the signals sent to the user are sent in non overlapping time slots. They need perfect timing synchronization. In FDMA the signals for each user is assigned to a subcarrier. The CDMA uses code to divide the user in the respective channel.

Power Domain NOMA: Power domain NOMA defines multiple user usage in the power domain and examines channel differences between multiplexed users. On the transmitter side the signals from different users are combined or superimposed and the outgoing signals are transmitted at the same frequency to the same users. On the recipient side, to obtain the desired signals, multi-user acquisition algorithms such as SIC(Successive Interference Cancellation) is used as shown in figure 3.
4. Iterative Algorithm

This algorithm explains the random array and it assigns phase to the measured amplitudes, thus it has a capability of generating the complex-valued spectrum at zeroth iterate. Let's consider the random array as and hence the complex valued spectrum can be given as $\mathbb{S}^0$ and hence the complex-valued spectrum given as $\mathbb{S}^0 = p_{\text{meas}} \exp(i\phi^0)$. A following sequence can be initiated as shown below: Inverse Fourier Transform is used on the function $\mathbb{S}^0$ to get the zero-th estimate in the group of longitudinal distribution $\mathbb{S}^0$. Impose the time domain constraints by applying information on the distribution. Calculating the FT of domain function, and get a subsequent estimate in the frequency domain $\mathbb{S}^1$ and calculate its phase $\phi^1 = \text{arg}(\mathbb{S}^1)$. Frequency domain iterative can be updated by imposing the frequency domain constraint $\mathbb{S}^1 = p_{\text{meas}} \exp(i\phi^1)$. The feature of iterative method is that, different solutions are obtained from the initial phases and these are not always correct sometimes they are distorted. There is a need in the selection and averaging the solutions given, because at end only one profile is required. There are different types of averaging:

Two step averaging: As shown in figure 4, here the first step would be averaging the Hilbert profile as reference and in second, new profile is being used as reference. The drawback here is we lose a lot of time to attain advantage in $X^2$.

![Two step Averaging in Iterative Algorithm](image)

Figure 4. Two step Averaging in Iterative Algorithm

Averaging is a simple technique where weight can be considered as correlation coefficient and uniform averaging also works similar in principle. The linear sampling is used here for reconstruction methods.

5. Methodology

Multiple-input Multiple-output is an antenna technology used in the transmission and reception of more data or signals in multiple paths for wireless radio communication. There can be various MIMO configurations $2\times 2$, $4\times 4$ etc. Pre-coding, spatial multiplexing and diversity coding are the three important categories of MIMO Systems. In MIMO-OFDM systems, channel estimation plays a crucial or vital part in analyzing the performance of the system. To support pre-coding and scheduling, channel state information (CSI) is measured. During its transmission noise gets added as unwanted signal and interfere the desired signal as shown in figure 5. Two channel conditions namely AWGN and Rayleigh are considered here.
In presence of AWGN Channel the output is calculated as
\[ y(m) = x(m) + w(m) \]  
(1)

Where \( y(m) \) is the output, \( x(m) \) is the input, and \( w(m) \) is the noise.

In presence of Rayleigh fading channel, the output is calculated as
\[ y(m) = h(m)x(m) + w(m) \]  
(2)

Where \( h(m) \) denotes the fading process.

The multiple access system considered here is NOMA, OMA and AOMA. As shown in the figure 6 the user 1 transmits the signal they note a transmission power when they do so. The AWGN with zero mean and variance is used. With help of the SIC the base station decodes the signal of user 1 and user 2 in two stages. The user 2 signal is treated first by considering the user 1 as the noise. In next stage the receiver subtracts the decoded signal from the received signal and decodes the user 1. As the signal starts propagating the decay of the signal also starts. We know that signal strength becomes weak if the distance between the antennas increases. There will also be a phase delay in a signal because it is a wireless channel that is called as echo signal.

Figure 5: MIMO Principle

Figure 6. Multiple access scheme for two user scenario (a) NOMA (b) OMA [7]
Here the channel estimation is done with and without NOMA with respect to MIMO. TDMA scheme with fixed and adaptive form for the OMA (without NOMA) is implemented. In NOMA the Power Control is used to reduce the interference of the channel as shown in figure 7. In this case SIC (successive interference cancellation) is used for the interference cancellation.

**Figure 7.** Channel Estimation with and without NOMA

The channel estimation of a MIMO is done through three methods they are NOMA, OMA and AMOA. The parameters such as SNR, and power factors and the time synchronization are initialized. The loss of signals such as fading loss, group loss and Rayleigh gain is calculated. These all losses are calculated together for the given threshold values. They are calculated with respect to the SNR values and also for different users. The calculated Gaussian $g^{th}$ values are compared with the fading losses; if fading loss is high then the signal strength is calculated and will be given it as the output. If the $g^{th}$ values are high then we calculate the different SNR to different users again as shown in figure 8.
Figure 8: Flow Chart

- Initialize the optional parameters
- Repeat for different SNR
- Repeat for different Users
- While fading loss $> g_{th}$
  - Identify signal strength from TDMA
    - Fixed OMA
  - Identify signal strength from TDMA
    - Adaptive OMA
  - Identify signal strength from NOMA
    - Power Domain NOMA

Output
An OFDM based NOMA scheme with two users is considered, where the users transmit signals $S_k(m), k \in K = \{1,2\}$ on subcarrier $m \in \{1, \ldots, M\}$. In order to minimize or remove completely the multiuser interference on each subcarrier, two users are considered here. SNR is calculated as:

$$SNR = \frac{P}{N_0}$$  \hspace{1cm} (3)

Where $P$ is the transmit power and $N_0$ is the noise added due to the channel.

In terms of decibels, it is mentioned as,

$$SNR_{dB} = 10 \log_{10} \left( \frac{P}{N_0} \right)$$  \hspace{1cm} (4)

SNR Variation with respect to time in terms of $t_{step} = 0.1 \text{ seconds}$ is used in the calculation. It is considered in terms of $t_{step}$: $t_{step} : 1 - t_{step}$. Here the path loss factor is -3.76 and the Gaussian value is

$$g^{th} = \left( \frac{35}{38} \right)^{PL}$$  \hspace{1cm} (5)

The phase is calculated in terms of variations with respect to time and it is denoted as $0: p_{step}: 1$

Uniformly Generated signal is represented by the following equations:

$$a = \text{rand}(1,1)$$  \hspace{1cm} (6)

$$a = x = \sqrt{a} \ast \frac{3}{2}$$  \hspace{1cm} (7)

Random signal is represented by

$$b = \text{rand}(1,1)$$  \hspace{1cm} (8)

Signal transmitted is $signal_{Tx} = \left( a \ast b \ast \left( \frac{3}{2} \right) \ast \text{signal} \right)$

Fading Loss and Group Loss is calculated by,

$$P_{loss} = [\text{norm}(a,b)]^{PL \text{ factor}}$$  \hspace{1cm} (9)

$$g_{Loss} = P_{loss} + \left( \frac{\log_{\text{normal}}}{P_{Loss} + m \log_2} \right)$$  \hspace{1cm} (10)

Where $\log_{\text{normal}} = 10^{\text{rand}+0.8}$

To calculate the overall loss, Rayleigh gain is required and it is calculated using

$$R_{gain} = abs \left( \frac{(\text{rand} + i \text{rand})^2}{2} \right)$$  \hspace{1cm} (11)

Combined or Overall loss is calculated using

$$G_{all} = g_{Loss} \ast R_{gain}$$  \hspace{1cm} (12)

5.1 Channel estimation without NOMA

The MIMO-OFDM was introduced for the next generation communication that is the 4G connection using TDMA. The use of TDMA will over-come some challenges which faced by the CDMA, they are limited performance and complexity in detection of multiuser. Here we show different numerical calculations or simulation results for the Adaptive TDMA and Fixed TDMA. The NOMA-OFDM
scheme has two user transmitting signals $S_1(m), x_i \in X = \{1, 2\}$ on subcarrier $m \in \{1, \ldots, M\}$. These two users are used to reduce completely or minimize the multiuser interference (MUI) on subcarrier used each and also help in reducing the complexity. To separate the superimposed signals of various users, successive interference cancellation technique (SCI) is proposed.

Power ‘$PL$’ is assigned to the user ‘$x_i$’ based on the distance from the base station, hence the signals from the $x_i$ users on subcarrier $m$. They can be represented as $X^n_{x_i}(m) = \sqrt{PL_{x_i}(m)S^n_{x_i}(m)}$.

The Fixed TDMA is calculated with respect to the strength of signal and the noise in it:

$$OMA = \log_2\left(1 + G_{all} \cdot P_{sum}\right)/2$$ (13)

The adaptive TDMA as considered to be having multiple noises which are produced in transmission of a signal given as: $g_1 \cdot g_2$

Phase shift also calculated as $p_{1v} = P_{sum} \cdot PS_v$

Then the Adaptive OMA in TDMA is given as:

$$rate_1 = t_{temp}$$ (14)

$$rate_2 = \left(1 - t_{temp}\right) \cdot \log_2\left(\frac{1 + p_{max}}{(1 - t_{max}) \cdot G(2)}\right)$$ (15)

$$AOMA(snr_{tx}) = AOMA(snr_{tx}) + \sum(rate_1 + rate_2)$$ (16)

5.2 Channel Estimation with NOMA

The NOMA OFDM is also given by the power tool through the power control technique and SIC. The noise or interference cancellation in the given NOMA is done by strengthening the channel by power control method. Hence when we increase the signal strength as required it can travel to longer distance and also without much disturbance and interference, the signal will reach its destination.

- Step 1:

Identifying Power control parameters, as $P_1$ from user 1 and $P_2$ from user 2,

$$P_1 = P_{sum} + P_s$$ (17)

$$P_2 = P_{sum} - p_{1v}$$ (18)

- Step 2:

Finding maximum relative rate of amplitude:

$$rate_{i1} = \log_2\left(1 + \frac{(g_1 + P_s)}{(g_2 + P_2 + N_0)}\right)$$ (19)
Where $N_0$ is average noise

$$\text{rate12} = \log_2 \left( 1 + \frac{g_2}{N_0} \right)$$  \hspace{1cm} (20)

Multiplying equation (19) and (20) we have:

$$\text{Relative Rate 1} = \text{rate11} \times \text{rate12}$$  \hspace{1cm} (21)

Hence for the other user also we calculate the rate21 and rate22 in same as above by taking:

$$\text{rate21} = \log_2 \left( 1 + \frac{g_1}{N_0} \right)$$  \hspace{1cm} (22)

$$\text{rate22} = \log_2 \left( 1 + \frac{(g_2+p_2)}{(g_1+p_1+N_0)} \right)$$  \hspace{1cm} (23)

Multiplying equation (22) and (23) we have:

$$\text{Relative rate 2} = \text{rate21} \times \text{rate22}$$  \hspace{1cm} (24)

- Step 3

NOMA based output signal is calculated based on relative power $R_{1\text{max}}$ and $R_{2\text{max}}$.

*If* $R_{1\text{max}} > R_{2\text{max}}$ NOMA signal depends on Relative Rate 1 or else depends on Relative Rate 2.

### 6. Simulation Results and Discussion

The proposed iterative algorithm is utilized to investigate and analyze the performance of MIMO OFDM systems channel estimation with and without NOMA. SNR ratio variation rate of 5 db is used for the simulation of average sum rate of OMA, AMOA and NOMA.

| SNR in terms of dB | Average Sum Rate |
|--------------------|------------------|
|                    | Without NOMA | With NOMA |
|                    | OMA          | AOMA      | NOMA    |
| 0                   | 0.2482       | 0.2753    | 0.2864  |
| 5                   | 0.4688       | 0.5213    | 0.5511  |
| 10                  | 0.8387       | 0.9280    | 1.0027  |
| 15                  | 1.3972       | 1.5299    | 1.6921  |
| 20                  | 2.1826       | 2.3535    | 2.6643  |

Table 1. Average sum value (strength of signal) with respect to SNR in db
The impact of SNR with average sum-rate using OMA, AOMA and NOMA is shown above in Table 1 and Figure 9. As per the results it is obvious that the MIMO OFDM Systems better in presence of NOMA than without NOMA. Simulations are even plotted in terms of Logarithmic values versus SNR in Table 2 and Figure 10.

**Figure 9:** Average sum rate versus SNR

Table 2: Logarithmic values of Average sum value (strength of signal) with respect to SNR in db

| SNR in terms of dB | Average Sum Rate |
|-------------------|-----------------|
|                   | Without NOMA    | With NOMA       |
|                   | Log OMA         | Log AOMA        | Log NOMA        |
| 0                 | -0.29616        | -0.2160         | -0.1985         |
| 5                 | -0.1334         | -0.0640         | -0.0270         |
| 10                | -0.1282         | -0.0285         | -0.0570         |
| 15                | -0.3171         | -0.1956         | -0.0750         |
| 20                | -1.7031         | -1.5737         | -1.3868         |
Figure 10: Logarithmic Average sum rate versus SNR

7. Conclusion

In this paper channel estimation problem for OFDM based NOMA system using Iterative algorithm has been presented. Here two users using single antenna are illustrated for transmission of a carrier data. There are various transmissions when we consider MIMO. With estimated channels at the base station, we derived sum rates that are achievable with OMA, AOMA and NOMA. The average sum of a signal is estimated to move in a channel. Simulations results are presented for estimated channel with NOMA and without NOMA and by comparing both, we can conclude that with NOMA higher number of signals can be transmitted at a time which is also described as MIMO-NOMA. The results show that the iterative technique ensures enhanced efficiency and overall system performance. Since NOMA and OMA finds extensive applications in many sectors and also used in the internet generations, this proposed work achieves considerable improvement in signal transmission.

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