Beamforming and OFDM in MIMO Technology

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Abstract: In remote systems multipath is a concern. It triggered the fading as remote signal travel through different paths and interacted with each other when entering Rx. Beamforming is one of the techniques to receive the signal with high link quality.
Orthogonal Frequency Division (OFDM), this technique has been used in many wireline and wireless networks. This paper discusses the essence of wireless technologies OFDM and Beamforming, and provides a description of the combination Beamforming-OFDM

Keywords : Beamforming, Transmit Beamforming, OFDM.MIMO.

1.   Introduction

Multipath effects can be mitigated by pre-processing the wireless signal at Tx using known beamforming method to increase the robustness and throughput of the links. IEEE 802.11n refers to the amount of MIMO techniques used by various antennas to improve performance in multipath environments. One such technique is Beamforming Transmission (TxBF). Tx BF is an elective feature in IEEE 802.11n, but industry demand for unique features is growing in various wireless applications. The Wi-Fi Alliance has registered beamforming as features as possible in 11n certification programme. These methods significantly enhance the robustness and efficiency of linkages.

OFDM is multi-carrier technique accepted by several wireless communication standards. A system of multicarrier communication with orthogonal sub-carriers is known as Orthogonal Frequency Division Multiplex (OFDM) system. The word "orthogonal" displays that there is specific mathematic relationship between the carriers' frequencies of system. The OFDM basic principle is to splitting high data rate sequences into numeral of sequences with low-rate that consecutively transferred over a no. of subcarriers. As symbol interval is increased for parallel subcarriers of low rate, the comparative amount of time dispersion caused by multipath delay spread get reduced. Inter-symbol interference (ISI) is also get removed almost completely on beginning of every symbol of OFDM with guard interval. The symbol of OFDM extended cyclically in guard interval so as to exclude ICI. Thus, a selective channel of high frequency is get changed into huge set of flat fading, narrowband channels and non-frequency selective[2].

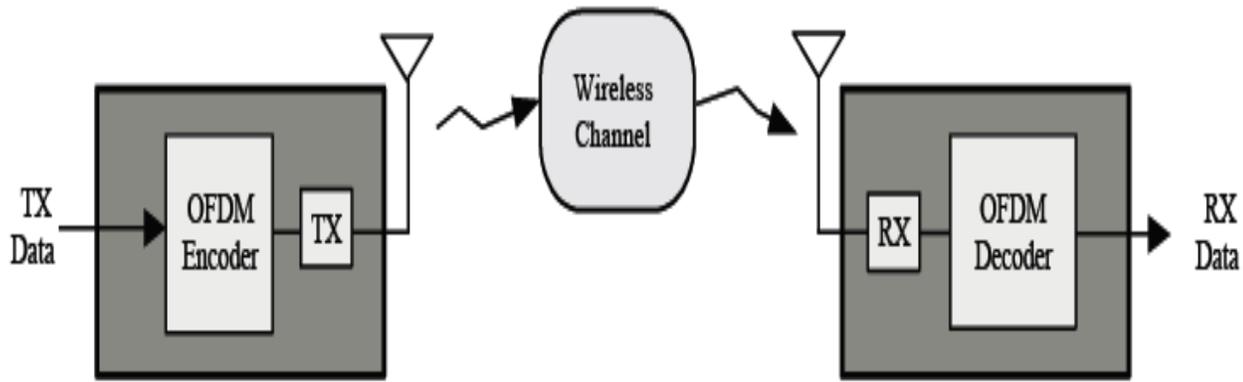Fig.1 shows the beamforming pattern of one transmit and one receive antenna.

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Figure 1: System of single antenna at transmitter and receiver.

Figure 2 applies beamforming to one transmit source to establish two encoded streams for two transmitters. Both streams move to the Rx inside a multitrack system. The recipient analyses the combined streams in order to recover the initial source being sent. It is believed that channel coefficients are understood at the Tx, essentially beamforming enables the transmitter to phase the 2 signals such that the signal is optimally connected at the input to the receiver, thereby preventing any signal cancelation that may occur in a random path. [2].
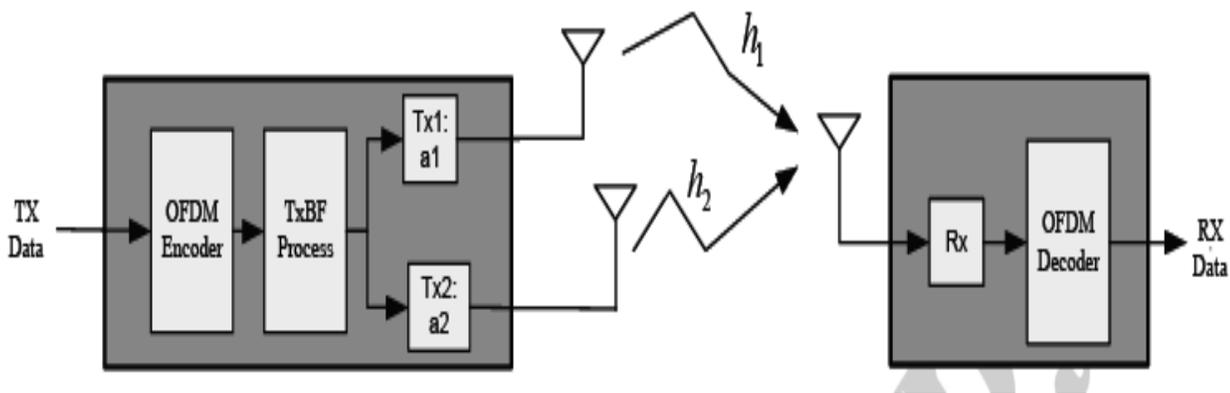

Figure 2. System of 2 Tx Beamformer with 1R beamformee receiver.

Fig.3 shows the mutile antenna in the input side and the multiple antenna at the receivers= side with proper beamforming and orthogonality.
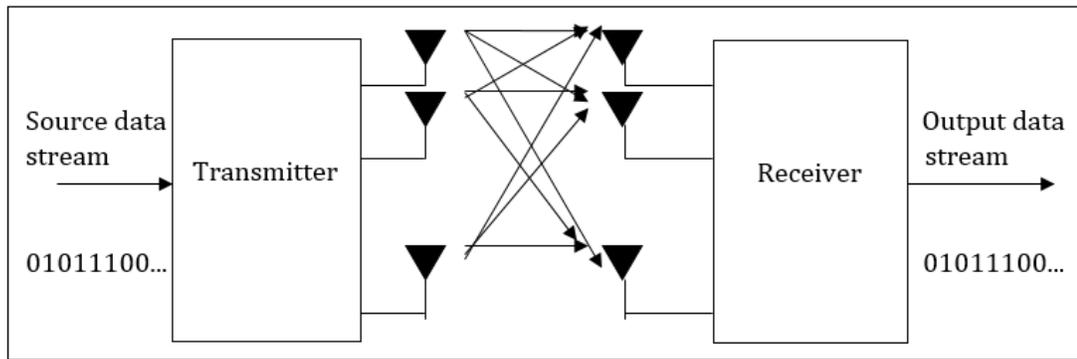
Figure 3. Block Diagram of MIMO System

2. Transmit Beamforming

On the Rx antenna, the received signal is,

$$y = [h_1 \quad h_2]\begin{pmatrix} x \\ x \end{pmatrix} + n = (h_1 \quad h_2)x + n$$

Where y, is the obtained signal, hi are the channel coefficients shown from the ith transmission antenna, x is the broadcast symbol and n is the Rx antenna noise. Once transmitting beamforming is introduced, we subtract the symbol from each transmit antenna with complex number equal to the channel's inverse step in order to ensure whether the receiver's signals are constructively incorporated. The signal obtained can be described as:

$$y = [h_1 \quad h_2]\begin{pmatrix} e^{-j\emptyset_1} \\ e^{-j\emptyset_2} \end{pmatrix} x + n$$

and the channel coefficients further expressed as:

$$h_1 = e^{-j\emptyset_1}|h_1|$$
$$h_2 = e^{-j\emptyset_2}|h_2|$$

To apply beamforming to this basic system, shown in Fig.2., set the 2 beamforming parameters $a_1 = e^{j\emptyset_1}$ and $a_2 = e^{j\emptyset_2}$ .Then the signal which is beamformed arriving at the receiver is:

$$y = (|h_1| + |h_2|)x + n$$

Notice that the powerful channel coefficients applied in-phase, such that several route effects can be utilized to an benefit, essentially increases the power of the obtained signal. Considering the equalization of zero-forcing (ZF), we will split the obtained symbol y by the current efficient channel,i.e.,

$$\hat{y} = \frac{y}{(|h_1|+|h_2|)} = x + \frac{n}{(|h_1|+|h_2|)} \ .$$

3.   OFDM generation

To produce OFDM well the link among all carriers need to prudently control to keep the normality of the carriers. For this purpose, OFDM is created by 1st chooses the spectrum needed, based on data input, & modulation system used. Individual carrier to create is allocated certain data to transfer. The require phase & ampl of carrier is then be calculated based on scheme of modulation. The necessary spectrum is then changed back to signal in time domain using an IFT. In maximum applications, an IFFT is used. The IFFT does the conversion efficiently, and gives easy way of confirming that carrier signal produced are orthogonal. The FFT transforms a cyclic signal of time domain into corresponding spectrum of frequency. That is ended by finding of correspondent waveform, produced by amount of components that are orthogonal sinusoidal. The phase & amplitude of the sinusoidal modules signify the spectrum of frequency of signal in time domain. The IFFT accomplishes back method, altering spectrum (phase &amplitude of every component) into signal of time domain. The orthogonal carriers needed for the signal of OFDM could be simply generated by setting phase & amplitude of every data point, then carrying out IFFT.

4.   Orthogonality

A system's spectral efficiency is well described in frequency domain by the transferred bit rate. The differences between two subcarriers are necessary in a multi-carrier transmission in order to provide a bandwidth-efficient network. Because there is more space between the subcarriers, a higher bandwidth would be needed to transmit a signal at the same rate and thus the spectral efficiency is lower. As can be seen in Fig. 5, avoiding overlapping subcarriers removes inter-channel interference at the expense of inefficiency in the bandwidth.
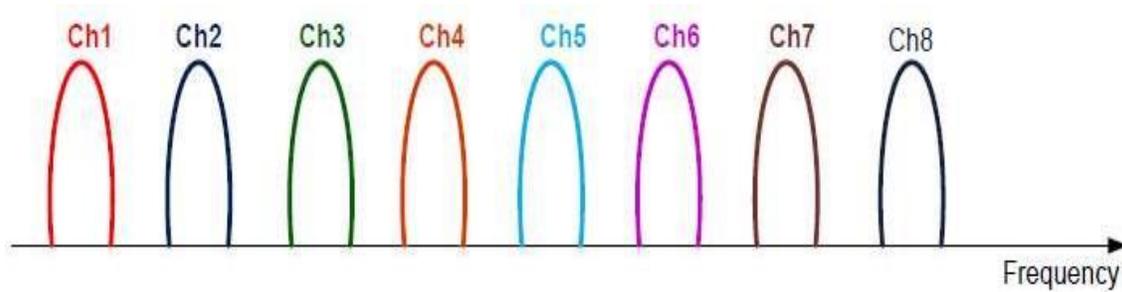
Fig. 5: Conventional Multicarrier Technique

To overcome the inefficiency of the bandwidth, OFDM was introduced where the center of a subcarrier is located in such a way that it reaches the nullity of the neighboring subcarrier as shown in Figure 1-6, saving nearly 50 percent of the bandwidth by making subcarrier overlap.

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Fig. 6 Orthogonal Multicarrier Modulation Technique

5.   Cyclic Prefix

In terrestrial systems the addition of cyclic prefix (CP) between two successive OFDM symbols shown in Fig.7 is used to reduce the effect of multipath channel delay spread. To simplify the

synchronization, before the data stream, a copy of the last end of the transmitted OFDM symbols is inserted, afterwards the IFFT operation. The length of the CP is adjustable and must be set to maintain an effective bandwidth system.
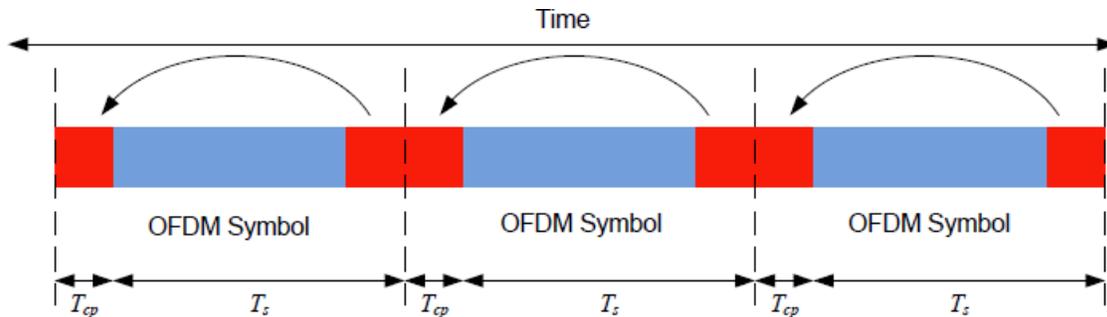

Fig. 7 Temporal Representation of OFDM Symbols

Let *D* denote the set of symbols at last of symbol of OFDM where *Ns* is complete no. of subcarriers. The interval of the CP depends on 4 factors:

1. **Channel length:** To validate a complete equalization, the length of the channel, L, should be less than the length of CP, D, that is, D > L.

2. **Performance of System:** Since the CP shows a redundancy of the end of the OFDM symbol, the spectrum efficiency is reduced and Ns/(Ns+D) is given. Ns would need to be infinity, in order to achieve spectral efficiency close to 1.

3. **Complexity:** The FFT processes are rendered on Ns block size, hence the Ns value can not be indefinitely increased in order to provide a feasible method. In such instances, there needs to be a trade-off between complexity and spectral efficiency. The value of Ns is usually selected equals 4D, giving a spectral efficiency of 25 percent.

4. **Channel type:** To get the convolution's circularity, the channel needs to stay constant throughout the transmission of a single OFDM symbol. In these instances, the system's diversity cannot be increased even though Ns grow. The selection of Ns therefore depends on the form of channel (channel diversity, slow or quick fading).

6.   Advantages of OFDM

➢ OFDM is also an effective BW modulation technique because the parallel subcarriers overlap but are orthogonal without interfering with each other.

➢   Each subcarrier could be modulated using different M-PSK or M-QAM modulation techniques depending on the system's need.

➢ OFDM tends to be a very effective modulation technique for systems operating under selective frequency channels.

➢ OFDM has comparatively large PAPRs that appear to decrease the power efficiency of RF amplifiers.

7.   MIMO-OFDM with Beamforming MODEL

OFDM converts the selective frequency channel into a wide range of individual
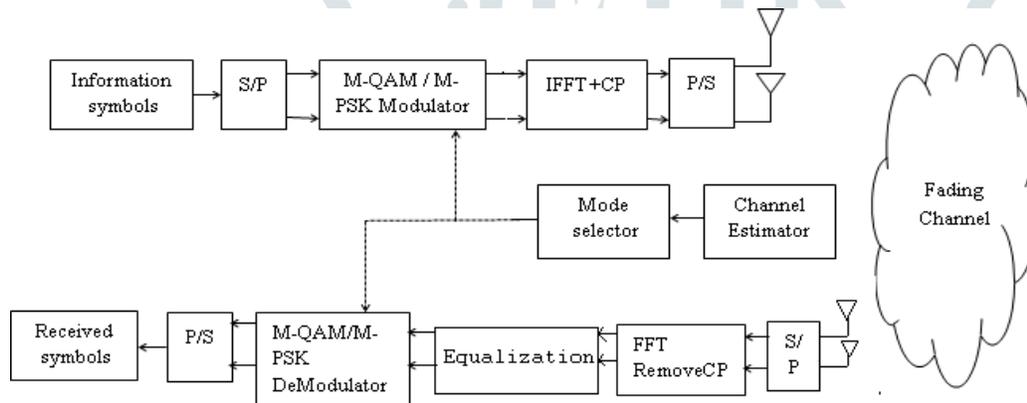

Fig. 8 MIMO-OFDM with Beamforming Model

Non-selective narrowband frequency channels appropriate for MIMO systems requiring non-selective frequency characteristics on each channel when the transmission rate is higher and necessary to render the entire frequency selective channel. That is why MIMO engages OFDM, referred to as MIMO-OFDM, capable of achieving greater spectral efficiency. The acquisition of multiple antenna elements at Tx for spatial transmission, however, resulted in the superposition of various transmitted signals at Rx skewed by identical multi-path channels and made the reception of signals very difficult. This put real test on the project system basically offering true spectral efficiency information. If there is channel with selective frequency, then the received signal is deformed by ISI, which led to difficult identification of transmitted signals. OFDM had emerged as the most effective way of removing ISI[3-5].

Description of model is given below:

a) Conversion from Serial to Parallel

The input stream of information in serial is organized into size of word necessary for broadcast, & moved to format of parallel.The data can then transferred parallel by allocating each one data word to single carrier in transmission.

b) Data Modulation

Data to transferred on every carrier is encoded differentially with earlier symbol, then plotted into format of PSK. As differential encoding required an inital phase reference further symbol is being added at beginning for it purpose. The data in every symbol is plotted to phase angle built on method of modulation.

c) Inverse Fourier Transform

 After mandatory spectrum worked out, an IFT is used to detect corresponding waveform of time.At beginning of each symbol ,guard period is then summed up.

d) Insertion of Guard Period

The guard period has 2 sections. Partial of time of guard period is 0 amplitude transmission. The another partial of guard period is symbol's cyclic extension to be transferred.This is to permit for timing of symbol to be simply recovered by envelope detection.However it is find that it is not require in any simulation as timing can be precisely determined samples position.

e) Mode of Channel

A channel is then employed for signal transfer. The model permits for the SNR, clipping of peak power & multipath to controlled. The S/N ratio set by addition of known quantity of white noise to transferred signal.

f) Multiple Antennas

Many Antennas (MIMO)are used on either Tx or Rx side to provide the improved efficiency with a smaller amount of interference.
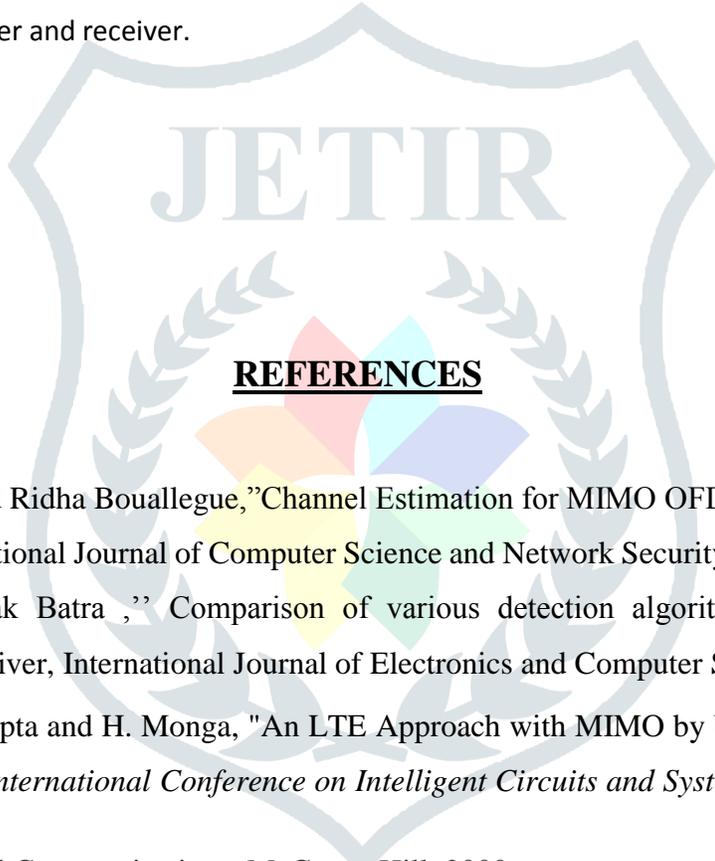
g) Receiver

The Rx mainly does opposite operation to Tx. The guard period get remove. FFT of every symbol took to find original transferred spectrum. The phase angle of every transmission carrier is assessed & changed back to data word by received phase demodulation. The data words are then combining back to same size of word as data in original.

8. Advantages of MIMO-OFDM

- ➢ Lesser amount of Interference.
- ➢ Diversity in gain.
- ➢ Data Capacity rises.
- ➢ Efficiency of power
- ➢ Gain in Bandwidth

9 Limitations of MIMO-OFDM

- ➢ Antenna space should be suitable depending on the type of channel.
- ➢ Complex transmitter and receiver.

REFERENCES

[1] Najoua Achoura and Ridha Bouallegue,"Channel Estimation for MIMO OFDM beamforming Systems", IJCSNS 106 International Journal of Computer Science and Network Security, VOL.8 No.3, March 2008

[2] Dhruv Malik,Deepak Batra ,'' Comparison of various detection algorithms in a MIMO wireless communication receiver, International Journal of Electronics and Computer Science Engineering.

[3] S. R. Chopra, A. Gupta and H. Monga, "An LTE Approach with MIMO by Using Suboptimal Selection of Antenna," *2018 International Conference on Intelligent Circuits and Systems (ICICS)*, Phagwara, pp. 167-172, 2018 .

[4] J. G. Proakis, Digital Communications. McGraw -Hill, 2000.