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Effective Measurement of MIMO-Space Time Block Coding With Different Hybrid Technology

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Abstract: MIMO systems provide a number of advantages over single-antenna-to-single-antenna communication. Sensitivity to fading is reduced by the spatial diversity provided by multiple spatial paths. Under certain environmental conditions, the power requirements associated with high spectral-efficiency communication can be significantly reduced by avoiding the compressive region of the information-theoretic capacity bound. Here, spectral efficiency is defined as the total number of information bits per second per Hertz transmitted from one array to the other. The wireless communication devices must have very high spectrum efficiency and the capacity of overcoming the channel fading in the environment of multi-path channel. In wireless telecommunications, multipath is the propagation phenomenon that results in radio signals' reaching the receiving antenna by two or more paths.

Keywords: Frequency selective fading, ISI, MIMO, OFDM, Spatial Multiplexing.

I. INTRODUCTION

Wireless communication involves the transfer of data without the use of wires. The earliest uses of wireless technology were very limited and data transferred was minimal, hence the available spectrum was sufficient. Communication technology is growing day by day, and system devices are reducing in size as well as being capable of increased processing power. With the growth in wireless communication, customers are demanding more improved and attractive applications, due to which there is a need for improvement in capacity of the available wireless spectrum. Many major technologies have been developed to meet user requirements. 4G/WiMAX technology will provide high data rate and capacity.

Designing the future wireless system with multiple input and output is emerging in a high rate. Multiple Transmit and receive antenna are now widely used to form Multiple Input Multiple Output (MIMO) system used in wireless communications offers various benefits such as higher capacity (bits/s/Hz) through spatial multiplexing scheme and better transmission quality (Bit Error Rate, outage) through transmit diversity scheme(Space Time Block Coding). [4].

The wireless communication devices must have very high spectrum efficiency and the capacity of overcoming the channel fading in the environment of multi-path channel. In wireless telecommunications, multipath is the propagation phenomenon that results in radio signals' reaching the receiving antenna by two or more paths. Causes of multipath include atmospheric ducting, ionosphere reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings. The effects of multipath include constructive and destructive interference, and phase shifting of the signal. Since the shape of the signal conveys the information being transmitted, the receiver will make mistakes when demodulating the signal's information. If the delays caused by multipath are great enough, bit errors in the packet will occur. The receiver won't be able to distinguish the symbols and interpret the corresponding bits correctly. This leads to an error in the symbol decoding. It is very difficult to match these requirements using the traditional modulation technique including MIMO & Orthogonal Frequency Division Multiplexing (OFDM); however the hybrid MIMO-OFDM system can meet these requirements [1].

Hybridization of MIMO-OFDM system is a combination of MIMO and OFDM technologies. MIMO is an antenna technology which uses multiple antennas at both the receiver and transmitter side. OFDM is the one of the best digital modulation techniques which splits the signal into several narrow band channels to obtain spectral efficiency. Some of the

features of 4G technologies are supporting multimedia, video streaming, internet and other broadband services.
MIMO systems take advantage of the multiple signals to improve the quality and reliability of the transmitted information signal as the information in wireless channels is mainly affected by multipath fading. Multipath results in the multiple copies of the transmitted information at the receiver with some delays. OFDM uses the spectrum very efficiently by overlapping the sub carriers. It increases the data rate, reduces the ISI (Inter Symbol Interference) and utilizes the spectrum very effectively which is required for transmission of video and other multimedia messages. [1, 13, 15].

II. MIMO SYSTEM MODEL

MIMO which is short for Multiple Input Multiple Output uses multiple antennas at the same time in the transmitter and receiver of the communication system and it can increase the transmission rates by using the random fading and multi-path propagation. Its key technology is space-time signal processing, that is, it processes the signal by using several time domain and space domain. The MIMO technology is a very effective method of increasing the capacity of the channel and system. We suppose that the number of the transmitting antennas is M_T, transmitted signal is $s_j(t)$,j=1,…,M_T,
the number of the receiving antennas is M_T, received signal is $y_i(t)$,i=1,…,M_R, then the relation between the transmitted signal and received signal is written as:

$$y_i\,(t)=\sum_{i=1}^{M_R} h_{i,i}\,(t) * s_i\,(t) + n_i\,(t), \quad i=0, 1\ldots,M_R \qquad (1)$$

Where, $h_{i,j}(t)$ denotes the channel impulse response between the transmitting antenna of number j and the receiving antenna of number i. The channel of the MIMO system can be expressed by a matrix:

$$H\,(t) = \begin{bmatrix} h_{1,1}\,(t)\, h_{1,2}\,(t) & \cdots & h_{1,M_R}\,(t) \\ \vdots & \ddots & \vdots \\ h_{M_R,1}\,(t)\, h_{M_R,2}(t) & \cdots & h_{M_R M_T}\,(t) \end{bmatrix} \qquad (2)$$

The receiver with multi-antenna can separate and decode the data stream by using advanced space-time coding, and get the best processing method. In particular, because the N sub-streams are sent to the channel at the same time and each transmitted signal occupies the same frequency band, the bandwidth is not increased. If the channels are independent, the MIMO system can create a number of parallel space channels. It is sure to increase the data rate by using these channels to transmit information independently. For a MIMO system with N transmitting antennas and M receiving antennas, it is assumed that the channel is independent Rayleigh fading channel and N, M are very large, then the channel capacity C is

$$C= \min\,(M, N)\;\; B \log_2\,(\beta/2) \qquad (3)$$

Where, B is the signal bandwidth, β is the average signal-to- noise of the transmitter, min(M, N) is the smaller of M and N. The above formula shows that the maximum capacity of the system will increase linearly with the raise of the minimal number of antennas when the power and bandwidth are fixed. MIMO technology can improve immensely the capacity of wireless communication system and the channel reliability, as well as reduce the error rate. [2, 3, 5]

The structure of MIMO system is shown in the figure1,

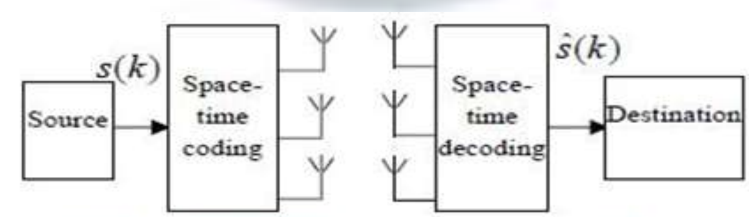

Fig. 1: MIMO system structure

III. OFDM SYSTEM MODEL

OFDM which is short for Orthogonal Frequency Division Modulation is a multi-carrier modulation technology. The principle of OFDM is to divide a single high-data-rate stream into a number of lower rate streams that are transmitted simultaneously over some narrower sub-channels. Hence it is not only a modulation (frequency modulation) technique, but also a multiplexing (frequency-division multiplexing) technique. Before we mathematically describe the transmitter-channel-receiver structure of OFDM systems, a couple of graphical intuitions will make it much easier to understand how OFDM works. OFDM starts with the ―O‖, i.e., orthogonal. That orthogonality differ OFDM from conventional FDM (frequency-division multiplexing) and is the source where all the advantages of OFDM come from. The difference between OFDM and conventional FDM is illustrated in Figure2. [13, 15]

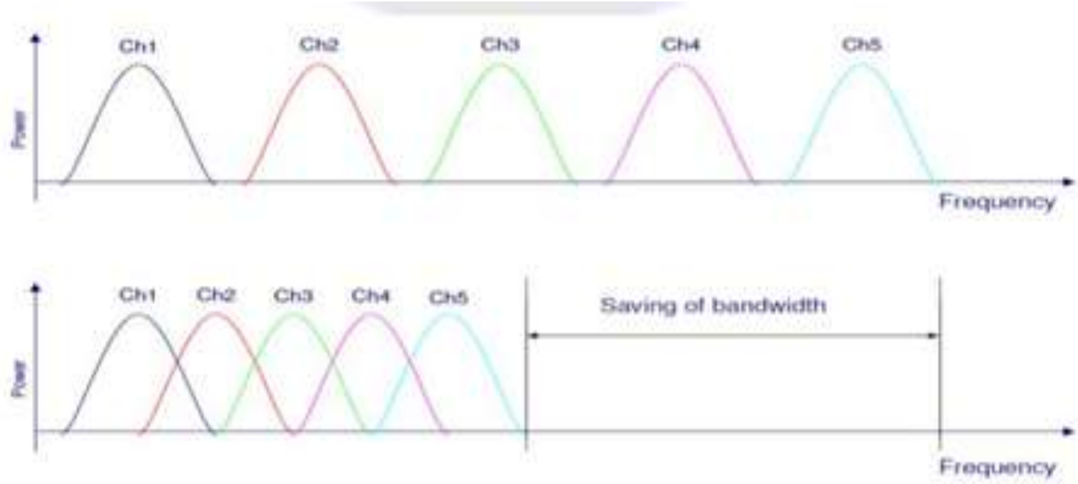

Fig. 2: Comparison between conventional FDM and OFDM

It can be seen from figure 2, in order to implement the conventional parallel data transmission by FDM, a guard band must be introduced between the different carriers to eliminate the inter-channel interference. This leads to an inefficient use of the rare and expensive spectrum resource. Hence it stimulated the searching for an FDM scheme with overlapping multicarrier modulation in the mid of 1960s. To realize the overlapping multicarrier technique, however we need to get rid of the ICI, which means that we need perfect orthogonality between the different modulated carriers.

OFDM converts the high-speed serial data stream to low-speed parallel string which can be transmitted in N sub-channels. Then, the technology modulates them by N sub-carriers which are orthogonal with each other. Lastly, the N modulated singles are sent together. The destination receives them with relevant subcarrier, and restores the original high-speed data by parallel/serial conversion.

Suppose that T is the width of the OFDM symbols, N is the number of sub-channels, fc is the carrier frequency of sub-carrier of number 0, d_i (i=0,1,…,N-1) is the data symbol allocated to each sub-channel,

(4) $$rect(t) = \begin{cases} 1, |t| \leq T/2 \\ 0, otherwise \end{cases}$$

Then, the OFDM symbols can be expressed easily, and the equivalent complex baseband notation is

$$s(t) = \sum_{i=0}^{N-1} d_i rect\left(t - t_s - \frac{T}{2}\right) \exp\left(j2\pi \frac{i}{T}(t - t_s)\right) \qquad (5)$$

$t_s \leq t \leq t_s + T$ s(t)=0 $t < t_s \wedge t > t + t_s$

For the system with larger N, the equivalent complex baseband signal can be achieved with inverse discrete Fourier transform method. We make t_s=0 and ignore the rectangular function, and the sample rate is T/N, so that

(6) $$s_k = s\left(\frac{kT}{N}\right) = \sum_{i=0}^{N-1} d_i exp\left(j\frac{2\pi ik}{N}\right)(0 \leq k \leq N-1)$$

It can be seen that s_k can be equivalent to IDFT operations of d_i. Simply, in order to restore the original symbol d_i, the receiver carries out the inverse transform. According to the above analysis, we can see that the modulation and demodulation of the system can be replaced by IDFT/DFT. By the N-point IDFT operation, the frequency domain symbol d_i is transformed to time domain symbol s_k. After radio frequency carrier modulation, the symbol is sent to wireless channel. Each of output data s_k of IDFT is the superposition of all sub-carrier signal.

The system structure is as Figure 3. The Insertion of the protection interval can eliminate the inter-symbol interference. Usually, the protection interval should be larger than the largest multi-path delay length, so, the code interferences can be prevented. [6, 7, 8, 9, 10]

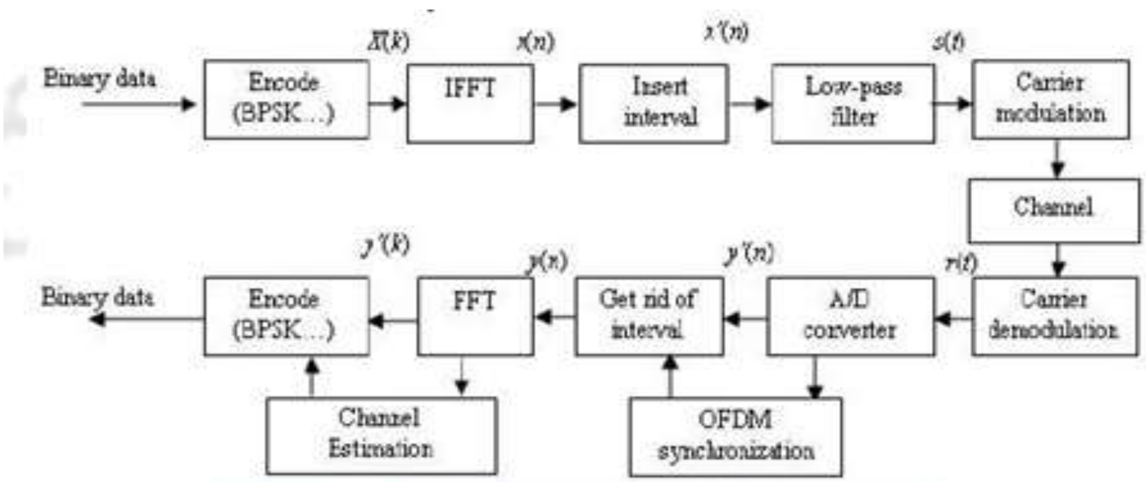

Fig. 3: OFDM system structure

IV. MOTIVATION TO ADOPT MIMO-OFDM

Traditionally, multiple antennas (at one side of the wireless link) have been used to perform interference cancellation and to realize diversity and array gain through coherent combining. The use of multiple antennas at both sides of the link (MIMO) offers an additional fundamental gain — spatial multiplexing gain, which results in increased spectral efficiency. A brief review of the gains available in a MIMO system and the benefits of OFDM technology is given in the following. [12, 13, 14, 15]

A. Spatial multiplexing

This yields a linear capacity increase, compared to systems with a single antenna at one or both sides of the link, at no additional power or bandwidth expenditure. The receiver exploits differences in the spatial signatures induced by the MIMO channel onto the multiplexed data streams to separate the different signals, thereby realizing a capacity gain.

B. Diversity

It leads to improved link reliability by rendering the channel ―less fading‖ and by increasing the robustness to co-channel interference. Diversity gain is obtained by transmitting the data signal over multiple (ideally) independently fading dimensions in time, frequency, and space and by performing proper combining in the receiver. Spatial (i.e., antenna) diversity is particularly attractive when compared to time or frequency diversity, as it does not incur expenditure in transmission time or bandwidth, respectively. Space-time coding [5] realizes spatial diversity gain in systems with multiple transmit antennas without requiring channel knowledge at the transmitter.

C. Array gain

It can be realized both at the transmitter and the receiver. It requires channel knowledge for coherent combining and results in an increase in average receive signal-to-noise ratio (SNR) and hence improved coverage.

D. Fading

The wireless channel is a multipath propagation channel. Multipath in the radio channel causes rapid fluctuation of signal amplitude, called small scale fading or simply fading. Fading is caused by destructive interference of two or more versions of the transmitted signal arriving at the receiver at slightly different times with different amplitudes and phases. Delayed signals are the result of reflections/scatterings from terrain features such as trees, hills, or mountains or objects such as people, vehicles or buildings. Fading can be classified as frequency-flat and frequency-selective. If the signal bandwidth is lesser than the Coherence bandwidth, the fading is known as frequency-flat. If signal bandwidth is greater than the Coherence bandwidth of the channel, the fading is frequency-selective. MIMO mitigates the effect of flat fading but not the frequency selective fading but by using the OFDM modulation in congestion with the MIMO, frequency selective fading can be converted to flat fading by using N subcarriers in the OFDM technology which makes the signal bandwidth lesser than the coherence bandwidth.

E. ISI

Inter symbol interference (ISI) is a form of distortion of signal in which one symbol interferes with subsequent symbols. This is an unwanted phenomenon as the previous symbols have similar effect as noise, thus making the communication less reliable. ISI arises because of the imperfections in the overall frequency response of the system. The presence of ISI in the system, however, introduces errors in the decision device at the receiver output. Therefore, in the design of transmitting and receiving filters, the objective is to minimize the effects of ISI, and thereby deliver the digital data to its destination with the smallest error rate possible. To deliver the signal error free a guard interval can be used between the signals but this reduces the resource bandwidth. Hence by using OFDM modulation we can remove the ISI by having cyclic prefix. At the decoder it can be removed. While using OFDM one has to take care of subcarriers, normally the size of FFT/IFFT and subcarriers depends on frequency of the spectrum

V. ADOPTION OF HYBRIDIZATION TECHNOLOGY MIMO-OFDM

The version of this template is V2. Most of the formatting instructions in this document have been compiled by MIMO can be used with any modulation or access technique. Today, most digital radio systems use Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA), or Orthogonal Frequency Division Multiplexing (OFDM). Time division systems transmit bits over a narrowband channel, using time slots to segregate bits for different users or purposes. Code division systems transmit bits over a wideband (spread spectrum) channel, using codes to segregate bits for different users or purposes. OFDM is also a wideband system, but unlike CDMA which spreads the signal continuously over the entire channel, OFDM employs multiple, discrete, lower data rate sub-channels. MIMO can be used with any modulation or access technique. However, research shows that implementation is much simpler, particularly at high data rates for MIMO-OFDM.

Specifically, MIMO-OFDM signals can be processed using relatively straightforward matrix algebra. Moreover OFDM inherits the characteristics of multi-carrier parallel modulation and corresponding growth of symbol from the traditional MCM. It is very easy to achieve accurate symbol synchronization with the help of the guard interval or cyclic prefix, the sub-symbol interference of the data transmission in the wireless channel with serious multi-path delay can overcome effectively. Moreover, OFDM has another advantage that it has unique frequency domain block modulation and frequency domain channel equalization technology, and it can reduce the estimated calculation amount and the complexity of hardware design and enhance the utilization of the spectrum greatly. [2, 4, 6, 7, 8, 10]

VI. ARCHITECTURE OF MIMO-OFDM

Figure 4 shows a schematic of OFDM transmission over a SISO channel. OFDM extends directly to MIMO channels with the IFFT/FFT and CP operations being performed at each of transmit and receive antennas. The schematic of MIMO-STBC-OFDM is shown in Figure5. The signals are converted to corresponding symbols using STBC transmitter which creates a multiple antenna scheme. Orthogonal frequency division multiplexing technique, splits the data to be transmitted along the orthogonal narrowband carriers well spaced by frequency. The technique used for splitting the data is Inverse Fast Fourier Transform (IFFT) which incorporates the advantage of transmitting the data at a higher rate. The introduction of cyclic prefix (CP) in terms of guard interval consists of repetition of the last part of the symbol at the beginning of each symbol transmitted. This avoids interference between the various symbols and the carriers, if the CP interval is longer than the delay caused by the interferences of the channel. This improves the robustness of the technology used for the multipath transmission. The use of narrowband subcarrier is to get a channel which is constant for each sub-band. This avoids synchronization problems at the receiver side during the symbol transmission through the channel. In order to get high spectral efficient system, overlapping between the mutually orthogonal subcarrier is allowed. A MIMO system can improve the capacity by a factor of the minimum number of transmit and receive antennas for flat fading or narrow-band channels. For wideband transmission, it is natural to combine OFDM with space–time coding (STC) to deal with frequency selectivity of wireless channels and to obtain diversity and/or capacity gains. Therefore, MIMO-OFDM has widely been used in various wireless systems and standards. [15]

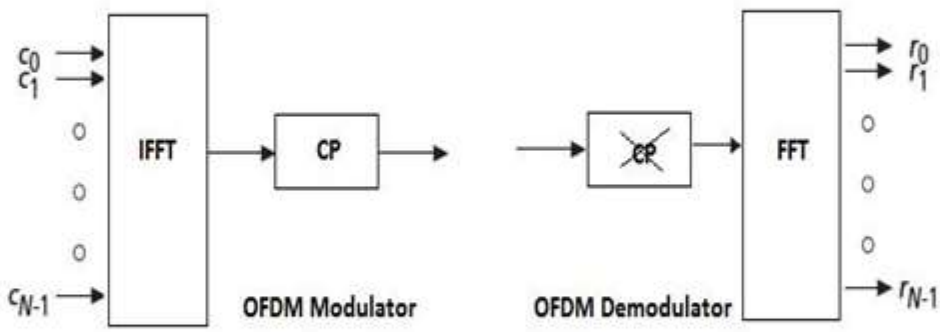

Fig. 4: Single antenna OFDM modulator and demodulator

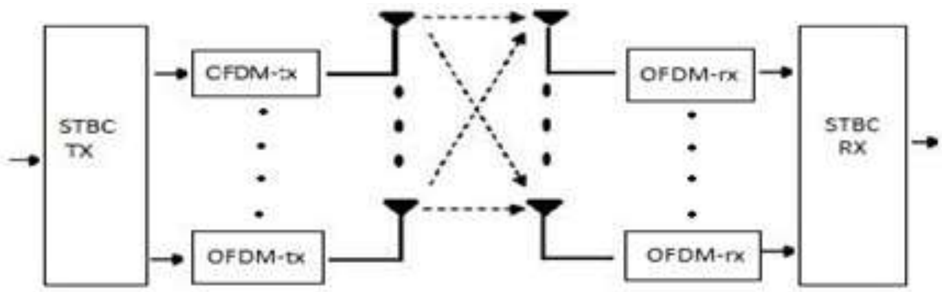

Fig. 5: MIMO-STBC-OFDM

CONCLUSION

MIMO-OFDM technology is more than the latest technical improvement for wireless networks. MIMO-OFDM is a major technology upgrade enabling demanding new applications with huge market potential and facilitating significant growth in existing applications. Hybridization framework reduces the frequency selective fading. Hence a novel idea has been proposed for the future wireless technologies and the adaptation of this hybridization technology increases the data rate, capacity, spectrum efficiency and decreases the bit error rate.

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