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A Review Paper on Space Time Scheme for MIMO System

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Abstract—Communication system with multiple transmitter and receiver architecture is called MIMO(Multiple input and multiple output). Capacity-wise, bit-rate wise and reliability –wise MIMO has many advantages as compared to the SISO(Single input and single output). MIMO can be classified in three different categories I.e. Spatial diversity, Spatial multiplexing and Beam Forming. Spatial multiplexing is used to get the higher data rate while spatial diversity is used to reduce the bit error rate. Here in this literature review paper authors are mainly focused on space time coding technique. In this paper various techniques channel coding, space time coding for frequency flat fading channels, MIMO, MIMO OFDM channel were discussed

Keywords— SISO(Single input single output), MIMO(Multiple input Multiple output), ML(Maximum Likelihood), STC (Space Time Coding)

I. INTRODUCTION

In a conventional SISO(Single input single output) system, transmission and reception is accomplished by single antenna. But in MIMO(Multiple input multiple output) more than one antenna is used at the both end for transmission as well as for reception. So many work has been done in the MIMO area as it is advantageous over SISO system in many ways. In so many area MIMO system outperform the SISO system.

Due to its various advantages MIMO system secure its place in current edge technology with offering compatibility with 3G[1][2],4G[3], Wimax and IEEE 802.11 standard[4].

Better capacity, High bit rate, small bit error rate are some of the advantages of the MIMO as compared to the SISO. Good spectral efficiency along with good throuhput for the same amount of tarnsmit power and bandwidth are some other advantages of MIMO over SISO[1][2]. In a broader sense MIMO can be classified in three different categories i.e. Spatial multiplexing, Space diversity and beam forming techniques[6][32]&[33].Beam forming technique is based on the smart antenna concept where forming beam size and width is set as per the reciever position and environment variation. Antenna, in this scheme,adaptive signal processing unit is integrated with the antenna which provide high output power to mobile user[4]. It also has the ability to compensate the environment variation between tarnsmitter and reciever.

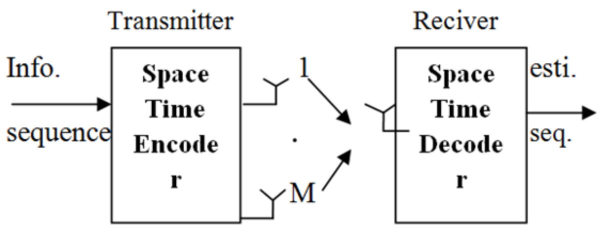

Figure 1 Basic Structure of Space time Coding

Spatial multiplexing technique, divide the input bit stream in N-number of sub-stream where N represent the total number of transmitting antenna. At the reciever side various combining scheme is used to collect the incoming signal[5]. This scheme increases the bit-transmission speed because it uses the parallel transmission[4].

In case of spatial diversity techniques, N-copies of the signal is generated and assigned to individual transmitting antenna[4]. This echeme reduces the signal fading effect to considerable level. It si because of the simultaneous transmission which improve the throughput and reduces the bit error rate considerably.

From the above discussion it is clear that higher data rate is achieved in spatial multiplexing case and small bit error rate is achieved in case of spatial diversity. Both the advantages can not be achieved simultaneously.

In order to improve the error rate performance, multiple antennas can be applied by transmitting the redundant signal having same sequence of information. This sequence of information is then transmitted on the multiple transmitted antenna with the help of two dimension coding in space and time which is called as space –time coding. Various combining techniques are used for combining these redundant signal at the receiver side[7]. Some of the combining techniques are MRC(Maximum ration combining)[30], EGC (Equal Gain Combining) and SD (Selection diversity). As compared to the single antenna transmission, parallel antenna transmission achieved better diversity and coding gain without degrading the bit rate.

Alamouti's transmit divert method [8] and space time trellis codes are some of the well known spatial diversity techniques [8]. In [9][10], an exhaustive servey was presented for spatial diversity. As per the [9], space time coding can be classified as STTC (Space time trellis code) &STBC(Space time block code). Space time block code

(STBC) is further classified as OSTBC(Orthogonal space time block code)& QSTBC(Quasi Orthogonal Space time block Code).

A. Space Time Code.

Space time coding is the combination of coding, modulation and signal processing for achieving transmit diversity. Almouti's transmit diversity scheme is mainly space time coding technique proposed in 1998. Transmit diversity scheme is used to achieve diversity or coding gain by sending same information to multiple transmit antenna. In the transmit diversity scheme, more than one antenna are required in at the transmitter side while the reciever antenna are optional as shown in the figure 1. Figure 1 represent the bsic structure of space time coding technique. Space time encoder basically encodes the stream of single information with the help of space and by using time at different times.

Due to above mentioned reason, it is called space time coding. Space time encoder pre-processed the redundant signal. At the reciever side, sapce time decoder is used for decoding purpose. The transmit diversity scheme was based on the delay diversity scheme proposed in the paper[11],[12]. Dely diversity is the simplest form of time diversity. In 1998 Space time trellis code (STTC) were invented.

Though delay diversity and time diversity scheme achieve diversity gain but STTC is able to achieve both diversity and coding gain. When identical signal are sent through the individual antenna then a problem of inter symbol intereference(ISI) occur which can be resolved

Using equalization techniques. Apart from this , in in paper [8] orthogonal space time transmission was proposed which provides ML detection at the reciever side.

Later on in paper [13], a STTC scheme is presented in which viterbi algorithm is used for decoding. According to this paper STTC performed excellent but the complexity of the decoding is very high in this case. In paper [14], orthogonal STBC was proposed. This scheme is just an extension of almouti's scheme. The main aim of developing the OSTBC's was to achieve full diversity but this scheme fail to achieve coding gain as comapred to the STTCs. In paper [15]&[16] antenna selection method at the reciever side is analyzed and examind.

B. Optimized Space Time Trellis Code (STTC)

STTC was the first space time coding proposed[13]. Decoding capability of this scheme is very good but its complexity increases with the increase in transmission rate. As compared to other encoding scheme, this scheme gurantee maximum diversity. The design of this scheme depends on the transmit antenna, receive antenna and modulation scheme.

In paper [17], a prallel concatenation of two similar STTC was presented while in paper[18], super orthogonal STTC alnog with the super quasi orthogonal STTC was described.

C Optimized space time block code (STBC)

Decoding complexity of STTC led to the evaluation of the STBC and the alamouti's technique was the first STBC scheme[8]. Structure and simplicity of the alamouti's scheme mahe it an standard for both W-CDMA and CDMA-2000[2]. In alamouti's STBC, two transmit antenna and Nr receive antenna are used which achieve the maximum diversity order of 2Nr[8].

Orthogonal space time code is one of the variants of the space time code which not only provide less computational complexity but also require multiple antenna only at the base station. It provides full diversity by supressing slow fading with the help of multiple antenna at the base station. Orthogonal space time block code causes a rate loss as compared to the uncoded version of the single antenna system. Full rate OSTBC was proposed in paper [14] which uses two to eight transmit antenna. This paper also explined that the Half rate OSTBC can be designed for complex valued modulation scheme. An exahustive system design for high rate OSTBC were presented in paper [19] for complex modulation scheme with any arbitrary method of transmit antenna.

One of the advantage of the oSTBC is its decoder simplicity. In paper [20][21] other varinats of OSTBC can be found.

In paper [22], square matrix embeddable STBCs was proposed which also includes the ML detection phase. This method reveals that coding rate falls exponentially with the number of transmit antenna. In paper [23], Diagonal algebraic STBCs was presented. This approcah also deliver full diversity and apply sphere decoding scheme for ML detection. One of the disadvantage of the ML detector is that its complexity grows exponentially with the increase ij number of antenna and number of bit per symbol used in modulation scheme. Sphere decoding is employed for reducing this type of complexity. Sphere decoding was also employed in the STBCs scheme presented in [23]. This scheme uses linera constellation predecoding.

D. MIMO & MIMO-OFDM cahnnel with ISI

Intersymbol interference is a type of distortion in a signal which occur in wireless communication. In this type of distortion, one symbole interefere with the other symbol. This is undesirable as it distort the signal to that level that it become difficult for the reciever to exatrct the correct symbol from the received bit. It is due to the fact of multipath propagation along with the non-linear frequency response of the channel. In the presense of ISI,OSTBC loses its orthogonality[25].

There three different way of designing the soace time coding scheme for MIMO channel with ISI. The first approach is to design space time code for the channel without ISI and mitigate the effect of the ISI at the receiver side using equalization techniques. Second approach is to design the Space time code with OFDM (Orthogonal Frequency division Multiplexing). Third approach is to develop the existing scheme of STBCs to suit for ISI channel.

MIMO-OFDM system offeres a frequency domain approach. In this scheme inverse fourier transform is used at the tarnsmitter and fourier is used at the recevier side which make this system very simple to implement. The davantage of using OFDM is that it convert the frequency selective channel in to a set of parallel flat fading sub-channel which reduce the demodulation complexity and equalization overhead at the receiver side. It is because of this OFDM modulation sceme is so popular. One of the main advantage of the OFDM over single carrier modulation scheme is that it has the ability to cope up with the severe cahnnel condition like attenuation, intereference and cahnnel fading caused by the multipath phenomenon without employing the equalization techniques.

Apart from applying space time coding to the MIMO-OFDM,two dimensional coding(Space, Frequency) or three dimensional coding (Space, frequency, Time) can also be performed. Length of space-frequency codeword is of the size of one OFDM code while Space-time codeword can span up to two or more OFDM symbol. Decosing delay in SF-OFDM is smaller but channel varian is faster than the ST-OFDM. SF-OFDM provides large diversity gain as compared to the space-time code. In paper [26] and [27], space-frequency codes were propsoed and presented.

In this paper space frequency codes were designed for STBCs and STTCs. In paper [28],[29] space-time – frequency codes were presented along with the performance and design criterion. Sapce-time-frequenct(STF) codes provides low complexity.

E. Closed loop MIMO system

All of the above mentioned methods are designed with open loop system. In open loop system, Feedforward information sent by the transmitter is used by the receiver such as pilot symbol to estimate the channel response. In this type of system no feedback information is sent by the receiver to the transmitter. Due to above mentioned reason this type of system is called the open loop system. So from this discussion it is clear that on open loop system, only receiver has the Channel state information(CSI) which does not sent by the receiver to the transmitter. Channel state information contain the channel gain and phase information of the system.

On the other hand in closed loop system, a feedback of CSI is sent by the receiver to the transmitter so that transmitter adapt itsself to the channel characteristics during the next transmission.EO-STBC(Extended Orthogonal STBCs) is one of the popular closed loop system which was proposed in thye paper[31]. On of the drawback of the complex space time block code for more than two transmit antenna is that it does not achieve full arte in MIMO. Method proposed in paper [31] was able to overcome this problem and achieve the higher rate as compared to the other STBCs.

II. CONCLUSION

In this literature survey paper, authors have tried to give a comprehensive survey report on space time block code for multiple antenna system in wireless communication. Topics like Space time codes, Channel coding, MIMO architecture, MIMO OFDM channel with ISI and closed loop MIMO system have been studied. Lots of paper have been published and presented in this field, some other areas like co-operative diversity, closed loop MIMO system need to be explored for giving further direction to this work.

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