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Space Time block Codes :An Orthogonal Structured Codes for Wireless Fading Environment

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Abstract

ISpace time block codes are the orthogonal codes design with an objective to reduce the interference in the fading environment.In mimo systems where there are multiple antenna at the transmitter side there will be a high probability of interference amongst the signal when all the users transmit the data simultaneously thus space time block codes provide an effective solution in such scenario with its orthogonal structure design which minimises the interference and thus make the receiver to easily demodulate the incoming arriving signal at the respective receiving antenna and thus detection of signal at the receiver will become quite simple with much reduced complexity.In this research paper various equalization techniques at transmitter and receiver are presented which aims to reduce the ISI ,other source nterferences and thus reduce BER(bit error rate)which is a measure of performance of various communicating system The organization of paper is as follows section1introduces the reader to space time block codes.section 2 give an overview of channel models .section3 provides space time block coding with different schemes,section 4 represents system models.section 5 depicts different diversity techniques to combat fading.section 6 provide an insight of equlization techniques at transmitter .section 7 famialarize with equalization techniques at the receiver transmitter. Simulation results shows ber analysis of defferent techniques and confirm sphere decoder is an optimum decoder with much reduced complexity.

General Terms: Intersymbolic interference reduction and complexity reduction technique in Rayleigh fading environment.

Keywords: ISI(intersymbolic interference),STBC(space time block codes) BER(bit error rate) SD(sphere decoder),MMSE(minimum ean square)ZF(zero forcing)ML(maximum liklihood) Rayleigh distribution Gaussian distribution.

Introduction

The task is quite challenging to design codes which are well suitable for wireless environment at the same time provide high data rate transmission.Space time block codes are well suited in wireless environment with mimo systems.space time block codes are useful as they provide spatial diversity which help to reduce the complexity of the receiver .the performance are measured in terms of bit error rate and Eb/No(which is normalised SNR equivalent to figure of merit in analog communication.MIMO systems provide improved data rate ,coverage cellular capaciuty along with link reliability ,when combined with STBC provide a superb combinatition to increase spatial diversity in which redundancy is added in space (by seperation between the antenna)

which provide an effective measure to combat fading without increasing effective power or bandwidth,thus the consequent saving of radio spectrum space.

Channel Models

Space time block codes has attracted our much attention in the past few years due to its open loop architecture(do not require feedback informtion of receiver to at be transmitted transmitter Models are made with the intetion that they will represent a concept more clearly .channel models are made which describe the wireless channel more elaborately.few as such models are

(a)AWGN:additive white gaussian noise model provide a simplestic view about the communicating channel which take noise into consideration but not the fading..the channel output (Y)is given by Y=x+n where x is the channel input and n is additive whitegaussian noise with zero mean .

(b)Rayleigh fading model:to model a communication channel more realistically in a wirelless communicatinfg environment we can use rayleigh

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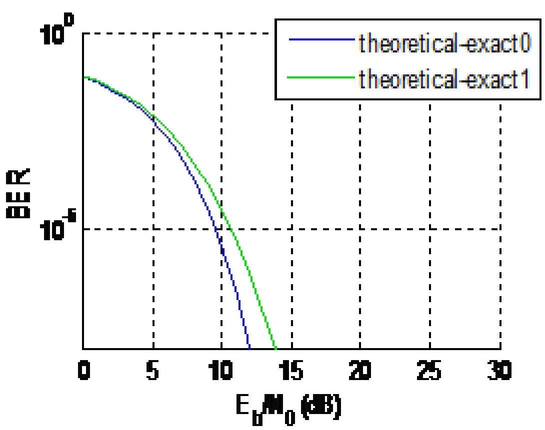
fading modelThis model take fading also into account which occurs due to multipath propogating environment. Mathe matically at time t the output y(t) would be denoted asY(t)=X(t)H(t)+n(t) here h(t) denotes signal attenuation factor due to wireless communicating environment.

c) Independent Quasi static flat rayleigh fading model:here due to multipathe propogation signal from various arrives at the transmitter thus the sum of signal at each antenna element will have gaussian distribution and amplitude of such gaussian distributed channel is rayleigh distributed.multipath signal arriving at each antenna will have TOA(time of arrival)<symbol rate which guarantees flat fading.the channel conditions remain static ie does not change with interval of framne will change independently between the frame which depicts Quasi static fading,the spacing between antenna element are such enough so that fading at each antenna element is different from the another which shows independent or spatially uncorrelated fading.



Ber curve of AWGN channel model(theoretical - exact0)and rayleigh fading model(theoritical-exact 1)at SNR of 30db. Simulated in matlab (R-2010a).there is a little difference in perfiormance curve between thye too rayleigh fading model takes fadding also under consideration.

Different coding techniques of STBC

Ortoginal STBc scheme was firstly proposed by ALmouti it can acheive full rate full diversity but applicable for only two transmitting antenna only . Code matrix is as follows

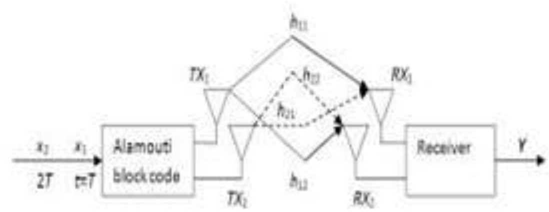
$$G_2 = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix}.$$

$$G_2 = \begin{matrix} t_1 \\ t_2 \end{matrix} \left\{ \overbrace{\begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix}}^{Tx_1 \quad Tx_2} \right.$$

ged.

$$(s_1, -s_2^*).(s_2, s_1^*) = s_1 s_2^* + (-s_2^*)(s_1) = 0$$

Thus the above equation proved the orthogonality of space time block codes).here Tx_1 . Here it reveals the transmitting symbol from transmitting antenna one.and Tx_2 transmitting from second antenna 2.here h_{11} represent path from transmitting antenna 1 to receiving antenna 1 and h_{22} represents pathe from transmitting antenna 2 to receiving antenna 2.and t_1 and t_2 are the time time slots respectively.



Space time block codes has attracted our much attention in the past few years due to its open loop architecture(do not require feedback informtion of receiver to at be transmitted here data symbols are encoded in space as well as in time domain to acquire the features of both shemes then the incomuing data is converted from serial to parrel (as parrel transmission increses its speed of data transmission and indirectly the speed of execution) which in turn increases the speed of data transfer (that is the data rate) which is the no of bits transmitted persecond that is the performance quality measuring parametre.Then this data is applied to interleaver which ensuress independent fading amongst data streams meaningfully have different fading thus they will be all uncorelated then these are applied to modulator they provide the digital modulation(QPSK,QAM etc) of the incoming data and then transmit these encoded data symbol simultaneously by multiple antenna elements suprisingly over the same band of frequency without inducing interference amongst the signals.at the

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receiver reverse operation could be performend to obtain the desired data symbol.

$$\text{time-slots} \downarrow \overset{\text{transmit antennas} \rightarrow}{\begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1n_T} \\ s_{21} & s_{22} & \cdots & s_{2n_T} \\ \vdots & \vdots & & \vdots \\ s_{T1} & s_{T2} & \cdots & s_{Tn_T} \end{bmatrix}}$$

Mimo channel matrix

Here rows represents time slots and columns the antenna element.for example s11 denotes in first time slot s11 (data element) is transmitted from transmitting antenna 1 ans so on.

In mimo wirless systems fewers terms are worth noting :multiplexing gain which describe the spectral effecency of the system.wheras diversity gain describes the reliability of the link Diversity gain when used in conjuction array gain provides us the coverage area,cochannel interference reduction techniquee provide us the cellular capacity.

System Model

Channel coding can be done with block codes or convolutional codes, error detection(ED) ,error correction (EC) ,automatic repeat it increases the reliability of the systemrequest(ARQ) forward error correcting codes(FEC). Channel coding when combined with interleaving provide an effective measurto give time diversity.

Diversity Techniques to Combat Fading

In wireess envirnment the transmitted signal travels from multiple path from transmitter to receiver due to interlacing objects present in the vicinity of the transmitter and receiver these propogating path have their own attenuation,phase shift,time of arrival,polarization which may even changes the phase of the incoming elctromagnetic wave.these incoming signal are coherently summed up at thee receiver constructive or destructive interference may take place .destructive interference may lead to reduced power level.This phenomenon is reffered to as fadding The concept of Deep fading occur s when combined signals are 180 degree out of phase almost. Fading is a undiserable phenomenon which may cause severse effect to the strength of signal.depending upon their size following phenomenon may seems to happen to the incoming elctromagnetic wave(EMW)

(a) Reflection:when an incoming electrmagnetic wave strikes an object whose size is much greater than signals wavelength such as wall etc then this coming elctromagnetic wave strikes at the boundry and changes its propogating direction.

(b) Refraction:When an incoming elctromagnetic wave travel from one medium to another ithere seems to diverted in its path due to different refracted indices of the medium.for example the propogation of wave from wall to air.

(c) Diffraction:when an incoming electromagnetic wave strikes an edge of an object whose size is much larger than its wavelength.for example in the outdoor environment the edges of the walls and in indoor invironment the edges of the furniture.

(d) Scattering:When an incoming electromagnetic wave hits at the object whose size is much smaller than signal wavelength then scattering occurs.example in the outdoor environment when wave strikes the rain drop whose size is much smaller than signal wavelength.

(e) Adjacent channel interference:which is a type of interference caused at the adjacent channels due to extra power from the transmiitting signal which produces the side lobes which interfere with the signal next to main signal.

(f) Co channel interference:co means same that means when working on the same channel or cell the interference occurs amongst the signals.

(g) Path loss:Which occurs when the signal transmitted power is loss when transmit from the transmitting antenna and in addition to it due to loss caused by propogation path.

(h) Shadowing:Which occurs when the obstacles present in the vicinity of the transmitter receiver path absorb power thus the provide which reaches at the receiver have rduced power level in it.When the objects fully absorb power the signal is said to be blocked.

There are diversity techniques are available which are used to mitigate fading used commonly.:

(a)Time diversity: In time diversity also called temporaral diversity same signal is transmitted from all the antenna in different time slots with seperation between the slots will be greater than coherence time(frequency domain representation of coherence bandwidth) it is defined as the timeduration over which statae of the channel remain predicatable.therefore all the copies of same signal will undergoes independent fading .thus they could be easily summed up at the receiver by appropriate diversity combining techniques)

(b)Space diversity:This diversity scheme also called antenna diversity which uses multiple antenna ,when multiple antennas are used at transmitter it is called Transmitter diversity .when multiple ante nna are

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used at the receiver is called receiver diversity.here redundancy is added in space(spacing between the antenna element) therfore no extra bandwidth is nedded thus consiquent saving of spectrum space.
(C)Frequency diversity:
in this diversity scheme nformation symbols are send over different frequency carrierswhich much be seperated more than the coherence bandwidth of the channel so that they provide independent fading amongst the signal.

Equalization Techniques at the Transmitter

(a)Dirty paper coding:
To avoid interference in order to improve transmitter diversity these techniques are used. By this technique effecient data transmission is possible even when channel is subjected to some interference.This technique data before sending is precoded so that it can nulls out the interference caused by the channelthus we can get interference free data symbol without increasing the transmitted power .
(b)Thomilson harrishma precoding:this technique is also a tranmitter done equalization technique as in wireless communicating systems symbols transmit from transmitter to receiver via multiple path thus the there seems to reduce the transmitted signal in strength(fading)with some precoding
c)water filling algorithmn:in It is also considered as on/off algorithmn algoritmn used to overcome deep fading problem wwater filly algoritmn amplifiers in the communicating systems up to a certain power level provide us the compensating of the interference caused by the channel imparements .

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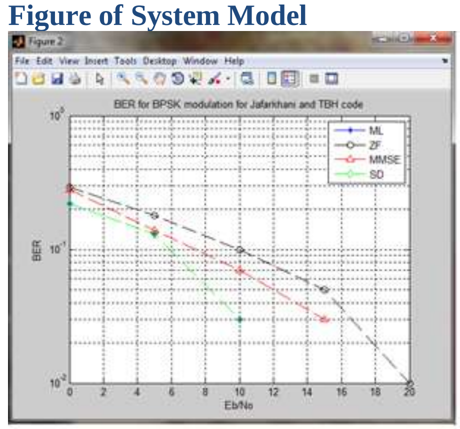
Equalization Techniques at the Receiver

(a) Vblast (vertical Bell Labs Layered Space Time):In this non linear equalization at the receiver the basic idea is to detect the most powerful signal then regenerates the signal from this user ,then this signal must be substracted by the received signal and further moves with this detction of second most powerful signal and so on,in this cumulative method the interference will reduce to greater extend.
(b)Zero forcing:this is a type of linear equalization it completely nulls out the interference coming from other antenna,in this type of equalizer the detection is done on each data streams independently.
(c)Minimum mean square error(MMSE):It minimises the mean square error between the transmitted data symbol and detected data symbol this type of receiver also belongs to the class of linear receiver whcich are totally basses on Minimum Mean Square Error Criterion
(d)Maximum liklihood receiver(ML):it is based on liklihood function which gives us an overview of the probability of chossing the most likely data sample from the data samples.they are optimally distributed ,have minimum variance and are well suited for large samples.in maximum liklihood estimator.it is optimum detector which aims to provide macximum diversity and lowest BERthese benifits comes at the most complex detectiuon .as the number of transmitting antenna increases the computational complexity increases exponentially.
(e)Sphere decoder:in sphere decoder all the posints which lies within the search radius are taken into consideration and ony those points are scanned.which reduces the computational complexity of the receiver with nearly same p[erformance like maximumliklihood detector.

Figure of System Model



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This ber anaysis comparrision simulation results reveals that SPHERE decoder is optimum decoder.

Table 1. Table of comparission between different receiving techniques

Serial no	ZF	MMSE	ML	SD
MERITS	Completely nulls out interfernce	It minimises total power of noise and ISI component	Optimum performance receiver	Reduces computational complexity by scanning ploints falls within a radius
DEMERITS	Additive noise may strongly increased	it does not usually eliminate ISI	Complexity increases exponentially as the no of transmitting antenna increasses	Points which falls outside the sphere are not taken into consideration.

Figures/Captions

The system model is as shown below

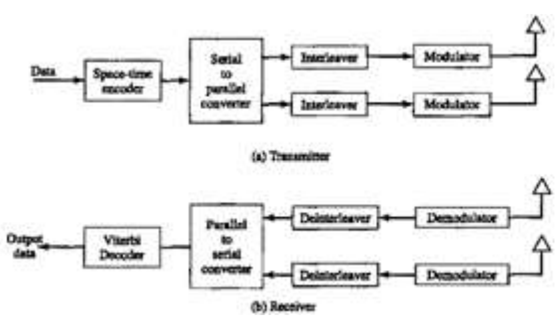

Fig 1: System model of MIMO

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