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Combined Array Processing to Suppress Interference for High Data Rate Wireless Communication

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Abstract

Space-time block code (STBC) designs for two-user MIMO X channels are used to accomplish full diversity while the inter-user interference is cancelled by the group of zero-forcing receivers of channel codes for better data speed and consistency for wireless environment. The use of multiple transmitters and receivers as an alternative to single one can help out to recover consistency without any consequence in the bandwidth expenditure. This paper promotes the reduction in encoding and decoding complexity by partitioning antennas at the transmitter into tiny groups, by means of individual space–time codes, to transmit information from every cluster of antennas. By the side of the receiver, an individual space–time code is decoded by a new linear processing technique that suppresses signals transmitted by other groups of antennas by treating them as interference. An easy receiver structure is derived to provide diversity and coding gain above uncoded systems. This mixture of array processing at the receiver and coding techniques for multiple transmit antennas can provide trustworthy and incredibly elevated data rate communication over narrowband wireless channels. A modification of this fundamental structure gives rise to a multilayered space–time architecture which generalizes and improves upon the layered space–time architecture proposed by Foschini.

Keywords: Space Time Block coding, MIMO, diversity, decoding complexity, combined array processing.

Introduction

Day by day, the demands for the capacity in wireless communication is increasing exponentially, thanks to the surge in the use of mobile telephone, Internet and multimedia services throughout the world. However, there is a limit on the available radio spectrum and a gargantuan increase in communication spectral efficiency is imperative for the capacity needs. Bandlimited wireless channels are essentially like narrow pipes, which do not allow rapid flow of data. Advances in coding concerning a single antenna link have reached a state where through the use of turbo and low density parity check codes, Shannon capacity limit is almost at reach. The present effort is thus partial towards the use of multiple antenna links. In fact it is now established that the capacity of a multichannel system is far superior to that of a single channel communication system. In fact, as long as the number of receive antennas is greater than equal to the number of transmit antennas, the capacity grows almost linearly with the number of transmit antennas, assuming ideal propagation.

The multiple-antennas at the transmitter and/or at the receiver in a wireless communication link open a new dimension in reliable communication, which can improve the system performance substantially. The idea behind MIMO is that the transmit antennas at one end and the receive antennas at the other end are ”connected and combined” in such a way that the quality (the bit error rate (BER), or the data rate) for each user is improved. The core idea in MIMO transmission is *space-time* signal processing in which signal processing in time is complemented by signal processing in the spatial dimension by using multiple, spatially distributed antennas at both link ends.

The use of antenna arrays at the transmitter and receiver to form a multi-input multi-output (MIMO) system has emerged as a powerful technique to improve the information rates and reliability of wireless links at low cost. High data rate wireless communication systems are becoming more and more desirable for universal personal.

Physical limitations on wireless channels present a fundamental technical challenge to reliable communication. Bandwidth limitations, propagation loss, time variance, noise, interference, and multipath fading make the wireless channel a narrow pipe that does not easily accommodate the flow of data. Further challenges come from power limitation as well as size and speed of devices in wireless portables.

Deploying multiple transmit antennas at both the base and remote stations increases the capacity of wireless channels [4], [12], and information theory provides measures of this increase.

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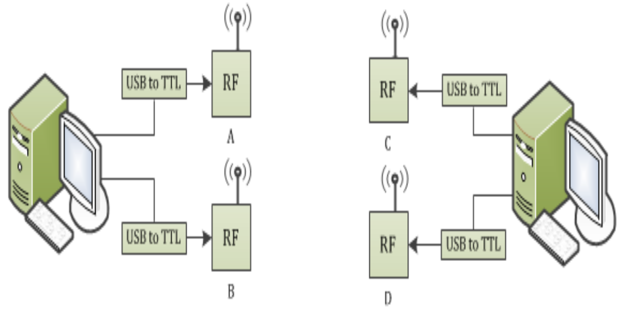
The standard approach to exploit this capacity is linear processing at the receiver [14] or extensions thereof [1]. Transmit diversity has been explored by Wittneben [15], and this proposal includes the delay diversity scheme of The space–time codes presented in [11] provide the best possible tradeoff between constellation size, data rate, diversity gain, and trellis complexity.

Space–time codes [11] combine signal processing at the receiver with coding techniques appropriate to multiple transmit antennas, and this approach provides significant gain over [10] and [15]. To reduce encoding and decoding complexity by partitioning antennas at the transmitter into small groups, and using individual space–time codes, called the component codes, to transmit information from each group of antennas. At the receiver, an individual space–time code is decoded by a novel linear processing technique that suppresses signals transmitted by other groups of antennas by treating them as interference. A simple receiver structure is derived that provides diversity and coding gain over uncoded systems. This combination of array processing at the receiver and coding techniques for multiple transmit antennas can provide reliable and very high data rate communication over narrowband wireless channels. A refinement of this basic structure gives rise to a multilayered space–time architecture that both generalizes and improves upon the layered space–time architecture proposed by Foschini. A combination of space–time coding at the transmitter and array processing at the receiver which achieves high data rates.

The Communication Model

We model a wireless communication system with antennas at the base and *m* antennas at the mobile station. Data is encoded using a channel code. The encoded data goes through a serial-to-parallel converter and is divided into n streams of data. Each stream of data is used as the input to a pulse shaper. The output of each shaper is then modulated. At each time slot *t* the output of modulator *i* is a signal C^i_t that is transmitted using transmit antenna (Tx antenna) *i* for $1\leq i \leq n$. We emphasize that the *n* signals are transmitted simultaneously each from a different transmit antenna and that all these signals have the same transmission period *T* . The signal at each receive antenna is a noisy superposition of the *n* transmitted signals corrupted by Rayleigh or Rician fading (see Fig. 1).



At the receiver, the demodulator computes a decision statistic based on the signals received at each receive antenna $1\leq j \leq m$. The signal r^j_t received by antenna *j* at time *t* is given by

$$r_t^j = \sum_{i=1}^{n} \alpha_{ij}\, c_t^i + n_t^j \qquad (1)$$

The coefficient $\alpha_{i\,j}$ is the path gain from transmit antenna toreceive antenna *j* and n_t^i is the noise for the channel between transmit antennas and receive antenna *j* at time *t*. The path gains $\alpha_{i\,j}$ are modeled as samples of independent complex Gaussian random variables with mean zero and variance 0.5 per dimension. This is equivalent to the assumption that signals transmitted from different antennas undergo independent Rayleigh fades. The noise quantities η_t^j ,$j = 1...m$,t= 1,2,..,l are samples of independent complex Gaussian random variable with mean zero and variance $N_0/2$ per dimension. We further assume that are constant during a frame and vary from one frame to another (quasi-static fading). For any vector *x*, let x^T denote the transpose of *x* . We can now write (1) in the vector form given by

$r_t = \Omega_{ct} + \eta_t$
where $c_t = (c_t^1, c_t^2, \ldots, c_t^n)^T$

$r_t = (r_t^1, r_t^2, \ldots, r_t^m)^T$

$\eta_t = (\eta_t^1, \eta_t^2, \ldots, \eta_t^m)^T$

and

$$\Omega = \begin{pmatrix} \propto_{1,1} & \propto_{2,1} \cdots\cdots & \propto_{n,1} \\ \propto_{1,2} & \propto_{2,2} \cdots\cdots & \propto_{n,2} \\ \propto_{1,m} & \propto_{2,m} \cdots\cdots & \propto_{n,m} \end{pmatrix}$$

Maximum Ratio Combining

There are various techniques used to combine the signals from multiple diversity branches. In Maximum Ratio combining each signal branch is multiplied by a weight factor that is proportional to the signal amplitude. That is, branches with strong signal are further amplified, while weak signals are attenuated. In general,

1)The signals from each channel are added together,
2)The gain of each channel is made proportional to the rms signal level and inversely proportional to the mean square noise level in that channel.
3)Different proportionality constants are used for each channel.

Maximal-ratio combining is the optimum combiner for independent AWGN channels. Maximum ratio combining is a linear combining method, where various signal inputs are individually weighted and added together to get an output signal. A block diagram of a maximum ratio combining diversity is shown in Fig. 4.

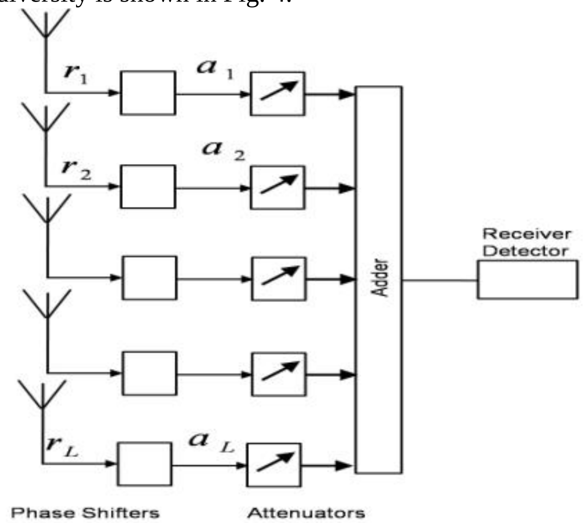


Fig. 4: block diagram of a maximum ratio combining diversity

Zero Forcing Detection Tequnique

Spatially multiplexed MIMO systems can transmit data at a higher data at a higher speed than MIMO system using antenna diversity techniques . spatial demultiplexing using antenna detection at the receiver side is a challenging task for SM MIMO systems .Consinder the $N_R \times N_T$ MIMO system in fig .Let H denote a channel matrix with it (j,i)th entry h_{ji} for the channel gain between the ith transmit antenna and the corresponding received signals are represented by

$$x = [x_1, x_2, \ldots\ldots x_{N_T}]^T$$ and

$$y = [y_1, y_2, \ldots\ldots\ldots y_{N_R}]^T$$,respectively

,where xi and yj denote the transmit signal from the ith transmit antenna and received signal at the jth receive antenna ,respectively .Let zj denote the white Gaussian noise with a variance at jth receive antenna and $h_i$denote the ith column vector of the channel matrix H.Now the $N_R \times N_T$ MIMO system is represented as

$$y = H_x + z$$
$$= h_1 x_1 + h_2 x_2 + \ldots\ldots + h_{N_T} x_{N_T} + z$$

Where $$z = [z_1, z_2, \ldots\ldots z_{N_R}]^T$$

Linear Signal Detection Method

Linear signal detection method treats all transmitted signals as interferences except for the desired stream from the target transmit antenna. Therefore ,interference signals from other transmit antennas are minimized or nullified in the course of detecting the desired from each antenna the effect of the channel is inverted by a weight matrix W such that

$$\tilde{x} = [\tilde{x}_1 \tilde{x}_2 \ldots\ldots \tilde{x}_{N_T}]^T = W_y$$
$$\tilde{x}_{ML} = \arg\min_{x \in C^{N_T}} \|y - H_x\|^2$$
$$\|y - H_x\|^2$$

The standard linear detection methods include the zero-forcing (ZF)technique and the minimum mean square error (MMSE) technique.

ZF Signal Detector

Zero forcing technique nullifies the interference by following weight matrix

$$W_{ZF} = (H^H H)^{-1} H^H$$

Where (.)H = Hermiton transpose operation (inverts the effect of channel)

$$\tilde{x}_{ZF} = W_{ZF} y$$

$$= x + (H^H H)^{-1} H^H z$$
$$= x + \tilde{z}_{ZF}$$

Where $\tilde{z}_{ZF} = W_{ZF} z = (H^H H)^{-1} H^{-1} H^H z$

Error performance is directly connected to the power of $\tilde{z}_{ZF}$ (i.e., $\|\tilde{z}_{ZF}\|_2^2$)

$$\|\tilde{z}_{ZF}\|_2^2 = \left\|(H^H H)^{-1} H^H z\right\|^2$$

$$= \left\| \left(V \sum{}^{2} V^{H} \right)^{-1} V \Sigma U^{H} z \right\|^{2}$$

$$= \left\| V \Sigma^{-1} U^{H} z \right\|^{2}$$

Conclusion

By implementing the proposed scheme of signal processing, namely group interference suppression method. This method was combined with space–time coding giving rise to combined array processing and space–time coding. Very high rates at reasonable complexity and signal-to-noise ratios can be achieved using this method

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