ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 3, May 2013

Space Diversity for Wireless Communication System– A Review

Niru Desai, G. D. Makawana

Abstract* - The fading effects of multipath signals in mobile communications are a problem that limits the data rate when transmitting between base station and terminal, and it also causes interruptions when the signal strength is low. The communication in fading environments can be improved by means of diversity techniques in mobile devices. There are many ways of achieving independent fading paths in a wireless system. One method is to use multiple transmit or receive antennas, an antenna array, where the elements of the array are separated enough in space. This type of diversity is known as space diversity. Space diversity has been can be classified into two categories: receive diversity and transmit diversity, depending on whether multiple antennas are used for reception or transmission. This review focuses on transmit diversity technique in the field of wireless communication. An use of multiple antennas at the transmitter side using space time code not require the channel state information at the transmitter side. For wireless communication systems has gained overwhelming interest during the last decade - both in academia and industry. Multiple antennas can be utilized in order to accomplish a diversity gain, thus enhancing the bit rate, the error performance, or the signal-to-noise-plus-interference ratio of wireless systems. The objective of this review is to provide non-specialists working in the general area of digital communications with a comprehensive overview of this exciting research field.

Keywords- **Multiple-antenna system, Space-time coding, Transmit diversity, Wireless communication system.**

I. INTRODUCTION

In modern communication systems information is transmitted over channels whose time-varying behavior causes severe fluctuations of the amplitude of the received signal. The fluctuations of the received power, known as *fading*, can be the result of several distinct phenomena that characterize wireless channels, such as multipath transmission, Doppler spread, and shadowing [1]. In general, fading manifests itself as distortion in the frequency domain and inter symbol interference at the receiver, in addition to the fluctuations of its amplitude. The simplest type of fading takes the form of time-varying channel gain which remains constant throughout the transmission of one symbol. This type of fading is termed appropriately *flat* fading. A large number of wireless communication systems, including all narrowband systems, experience fading of the above type. Fading greatly increases the bit-error rate (BER) of a particular signaling scheme. Furthermore, the error rates decrease algebraically with the average signal-to-noise ratio (SNR), a major deviation from the exponential decay of BER's in additive white Gaussian noise (AWGN) channels [14]. As the demand for inexpensive and reliable mobile communications has increased dramatically during the past few years, wireless channels have become the focus of an increasing effort for the development of efficient communication systems for fading channels. The communication in fading environments can be improved by means of diversity techniques using same information transmit using multiple times in wireless communication system. According to domain diversity can be classified in three way time, frequency, and space diversity. In this paper we focused only space diversity. Space diversity is called transmit diversity if multiple transmit antennas are used for transmission purpose and receive diversity if multiple receive antennas are used for receive purpose. In this paper we will primarily be dealing with schemes employing transmit diversity.

II. TRANSMIT DIVERSITY AND SPACE TIME CODES

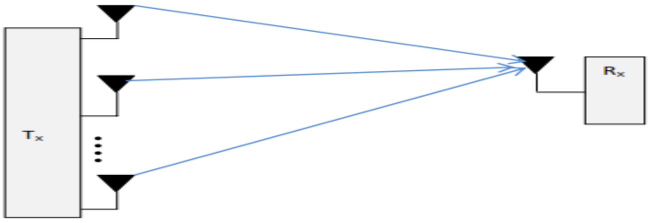

Fig.1 Transmit diversity configuration

Conventional single-antenna transmission techniques aiming at an optimal wireless system performance operate in the *time* domain and/or in the *frequency* domain. In particular, channel coding is typically employed, so as to overcome the detrimental effects of multipath fading. However, with regard to the ever-growing demands of wireless services, the time is now ripe for evolving the antenna part of the radio system. In fact, when utilizing multiple antennas, the previously unused *spatial* domain can be exploited. The great potential of using multiple antennas for wireless communications has only become apparent during the last decade. In particular, at the end of the 1990s multiple-antenna techniques were shown to provide a novel means to achieve both higher bit rates and smaller error rates. Transmit diversity are two type The main idea of transmit diversity is to provide a diversity and/or coding gain by sending redundant signals over multiple transmit antennas (in contrast to spatial multiplexing, where independent bit sequences are transmitted). To allow for coherent detection at the receiver, an adequate preprocessing of the signals is performed prior to transmission, typically without channel knowledge at the transmitter. With transmit diversity, multiple antennas are only required at the transmitter side, whereas multiple receive antennas are optional. However, they can be utilized to further improve performance. In cellular networks, for example, the predominant fraction of the overall data traffic typically occurs in the downlink. In order to enhance the crucial downlink it is therefore very attractive to employ transmit diversity techniques, because then multiple antennas are required only at the base station. With regard to cost, size, and weight of mobile terminals this is a major advantage over diversity reception techniques.

III. SMALLER ERROR RATES THROUGH SPACE DIVERSITY

Similar to channel coding, multiple antennas can also be used to improve the error rate of a system, by transmitting and/or receiving redundant signals representing the same information sequence. By means of two-dimensional coding in time and space, commonly referred to as space-time coding, the information sequence is spread out over multiple transmit antennas. At the receiver, an appropriate combining of the redundant signals has to be performed. Optionally, multiple receive antennas can be used, in order to further improve the error performance (diversity reception). The advantage over conventional channel coding is that redundancy can be accommodated in the spatial domain, rather than in the time domain. Correspondingly, a diversity gain and a coding gain can be achieved without lowering the effective bit rate compared to single-antenna transmission. Well-known spatial diversity techniques for systems with multiple transmit antennas are, for example, Alamouti's transmit diversity scheme [2] as well as space-time trellis codes [3] invented by Tarokh, Seshadri, and Calderbank. For systems, where multiple antennas are available only at the receiver, there are well-established linear diversity combining techniques dating back to the 1950's [4].

IV. DIVERSITY RECEPTION

Diversity reception techniques are applied in systems with a single transmit antenna and multiple receive antennas. They perform a (linear) combining of the individual received signals, in order to provide a microscopic diversity gain. In the case of frequency-flat fading, the optimum combining strategy in terms of maximizing the SNR at the combiner output is maximum ratio combining (MRC), which requires perfect channel knowledge at the receiver. Several suboptimal combining strategies have been proposed in the literature, such as equal gain combining (EGC), where the received signals are (co-phased and) added up, or selection diversity (SD), where the received signal with the maximum instantaneous SNR is selected (antenna selection), whereas all other received signals are discarded. All three combining techniques achieve full diversity with regard to the number of receive antennas. Optimal combining techniques for frequency-selective fading channels were, for example, considered in [5].

V. LITERATURE REVIEW

S. M. Alamouti [2] proposed a simple two branch diversity scheme. The diversity created by the transmitter utilizes space diversity and either time or frequency diversity. The Alamouti space-time coding scheme can achieve full spatial diversity gain (a gain of two for the 2×1 scheme and a gain of four for the 2×2 scheme). The scheme makes use of two transmitter antennas and one receiver antenna. Even then the proposed scheme provides the same diversity order as maximal-ratio receiver combining (MRRC) with one transmit antenna, and two receive antennas. The principles of this invention are applicable to arrangements with more than two antennas, (i.e. similarly it was proved) that the scheme can be generalized to two transmit antennas and M receive antennas, such that it may provide a diversity order of 2M. The most important advantage of the proposed scheme is that it does not require any bandwidth expansion or any feedback from the receiver to the transmitter. Additionally, the computational complexity of the proposed scheme is very much similar to MRRC.

Thus the reduction of the achieved rate that occurs because of the retransmission of the symbols at the second time slots is offset by the simultaneous increase of the rates since at each time slot two symbols are transmitted. Alamouti scheme BER versus Eb/No performance with coherent BPSK modulation. From the simulation result, it is very clear to see that Alamouti scheme has the same diversity as the two-branch maximal ratio combining (MRC). However, from that Almouti scheme performance is worse than the two-branch MRC by 3 dB and that is because the energy radiated from the single antenna in the MRC is the double of what radiates from each transmit antenna in the Alamouti scheme.

U V. Tarokh, A. Naguib, N. Seshadri, and A. R. Calderbank [6] described a space-time code that is applicable for high data rate wireless communications. Generally it is well known that space-time coding is a bandwidth and power efficient method of communication over fading channels that realizes the remunerations of multiple transmit antennas. Precise codes have been constructed using design criteria consequent for quasi-static flat Rayleigh or Rician fading, where channel state information is accessible at the receiver. It is apparent that the reasonableness of space- time codes will be significantly improved if the derived design criteria continue to be applicable in the absence of perfect channel state information. It is even more enviable that the design criteria not be disproportionately sensitive to frequency selectivity and to the doppler spread. They presented a theoretical study of these issues beginning with the effect of channel estimation error. They also assumed that the channel estimator extracts fade coefficients at the receiver and for constellations with constant energy, it is proved that in the absence of perfect channel state information, the design criteria for space-time codes is still valid. They also derived the maximum-likelihood detection metric in the presence of channel estimation errors. They studied the effect of multiple paths on the performance of space-time codes for a slow changing Rayleigh channel. It is proved that the presence of multiple paths does not decrease the diversity order guaranteed by the design criteria used to construct the space- time codes.

V. Tarokh, H. Jafarkhani, and A. R. Calderbank, [7] A new paradigm for communication was introduced by Tarokh . They introduced a space-time block coding, a new paradigm for communication over Rayleigh scheme. Fading channels using multiple transmit antennas. Data is encoded with the aid of a space-time block code and the encoded data is divide into “n” streams which are concurrently transmitted using “n” transmit antennas. The received signal at each receive antenna is a linear superposition of the “n” transmitted signals disconcerted by noise. Maximum likelihood decoding was accomplished in an uncomplicated means through decoupling of the signals transmitted from different antennas rather than joint detection. The approach focuses on achieving the maximum diversity order for a provided number of transmit and receive antennas subject to the limitation of having a simple decoding algorithm. The space-time block code is constructed using the classical mathematical framework of orthogonal designs. Consequently, a generalization of orthogonal designs is shown to afford space time block codes for both real and complex constellations for any number of transmit antennas as the code constructed in the above way exist only for a few sporadic values of “n”. These codes realize the greatest possible transmission rate for any number of transmit antennas using any uninformed real constellation such as Pulse Amplitude Modulation (PAM). The best tradeoff between the decoding delay and the number of transmit antennas was also computed and they showed that many of the codes presented here are optimal in this sense as well.

For arbitrary complex constellations and for the specific cases n=2, 3 and 4 , we have provided space-time block codes that achieve, respectively, all, 3/4 , and 3/4 of the maximum possible transmission rate.

V. Tarokh, A. Naguib, N. Seshadri, and A. R. Calderbank[8 [8] in this put forth a practical way to illustrate that the information capacity of wireless communication systems can be increased dramatically by employing multiple transmit and receive antennas. An effective approach to increasing data rate over wireless channels is to employ space-time coding techniques suitable to multiple transmit antennas. These space-time codes initiate sequential and spatial correlation into signals transmitted from different antennas, so as to provide diversity at the receiver, and coding gain over an uncoded system. Their proposed approach noticeably reduced encoding and decoding complexity. This was achieved 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. A novel linear processing which is capable of suppressing the signals transmitted by other group of antennas by treating them as interference was employed at the receive antenna to decode an individual space-time code. The simple receiver structure provides the diversity and the coding gain over uncoded system. This combination of array processing at the receiver and coding techniques for multiple transmit antennas can offer steadfast and very high data rate communication over narrowband wireless channels. A modification of this fundamental configuration gives rise to a multilayered space-time structural design that both generalizes and improves upon the layered space-time architecture. This multilayered space–time coded architecture. Each frame consists of 130 transmissions from each transmit antenna. It is assumed that the channel matrix is perfectly known at the receiver. They presented a new method 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.

Vahid Tarokh, Hamid Jafarkhani, and A. Robert Calderbank[9]

The performance of space–time block codes which provided a new standard for transmission over Rayleigh fading channels using multiple transmit antennas was documented by in [9]. They considered a wireless communication system with “n” antennas at the base station and “m” antennas at the remote. The main purpose of their paper is to estimate the performance of the space–time block codes constructed them in their earlier work and to provide the details of the encoding and decoding procedures. They assumed that transmission at the base-band employs a signal constellation. Maximum likelihood decoding of any space–time block code can be achieved using only linear processing at the receiver. Figure 2 shows the system block diagram of space-time coding.

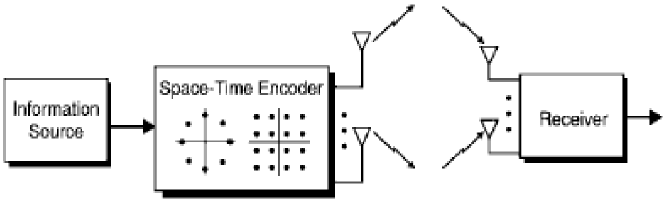

Fig 2. System block diagram of STC Scheme

The information source is encoded using a space–time block code, and the constellation symbols are transmitted from different antennas. The receiver estimates the transmitted bits by using the signals of the received antennas. Their experimental results revealed the fact that considerable gains can be achieved by increasing the number of transmit antennas with very little decoding complexity. The transmission using two transmit antennas employs the 8PSK constellation and the code G_2. For three and four transmit antennas, the 16-QAM constellation and the codes H_3 and H_4, respectively, are used. Since H_3 and H_4 are rate 3/4 codes, the total transmission rate in each case is 3 bits/s/Hz. It is seen that at the bit error rate of 10^{-5} the rate 3/4 16-QAM code gives H_4 about 7 dB gain over the use of an 8-PSK G_2 code.

I. Emre Telatar **[10]** investigated the use of multiple transmitting and/or receiving antennas for single user communications over the additive Gaussian channel with and without fading. Formulas for the capacities and error exponents of such channels were also derived and evaluated the computation procedures for those formulas in [10]. Additionally, the paper also revealed the potential gains of such multi-antenna systems over single-antenna systems is rather large under independence assumptions for the fades and noises at different receiving antennas. A single user Gaussian channel with multiple transmitting and/or receiving antennas has been taken into account for deriving the formulas and the computation procedures. The use of multiple antennas will significantly augment the attainable rates on fading channels if the channel parameters can be estimated at the receiver and if the path gains between different antenna pairs behave independently.

G. J. Foschini, and M. J. Gans[11] presented a paper that was greatly motivated by the need for fundamental understanding of ultimate limits of bandwidth efficient delivery of higher bit-rates in digital wireless communications and to also begin to look into how these limits might be approached. They examined the development of multi-element array (MEA) technology, which is processing the spatial dimension to improve wireless capacities in certain applications. The case where the channel characteristics is not available at the transmitter but the receiver tracks the characteristic which is subject to Rayleigh fading has been explored in their presented paper. The capacity offered by MEA technology was revealed by fixing the over all transmitted power. They investigated the case of independent Rayleigh faded paths between antenna elements and find that with high probability extraordinary capacity is available. Standard approaches such as selection and optimum combining are seen to be incomplete when compared to what will eventually be possible. New codecs need to be invented to comprehend a robust portion of the great capacity promised.

With MEAs, the scaling is almost like n more bit/cycle for every 3 db increase in of SNR to illustrate how great this capacity is, even for small n , take the cases n=2, 4, and 16 at an average received SNR of 21 db.

Liang Li, Sergiy A. Vorobyov, Alex B. Gershman [12] They was proposed new scheme for increase the BER performance of transmit diversity using transmit antenna selection technique. Performance of multiple-antenna communication systems is known to critically depend on the amount of channel state information (CSI) available at the transmitter. In this scheme use the low rate feedback for exploiting the channel state information at the transmitter. In the low-rate CSI feedback case, an important problem is what kind of information should be submitted to the transmitter in each feedback cycle and what is the optimal transmission strategy in this case. In this paper, they address this problem in the transmit diversity or multiple-input single-output (MISO) case by analytically comparing the bit error rate (BER) performance of different low-rate feedback based transmitter strategies involving various combinations of transmit antenna selection, Alamouti's space time coding, and adaptive power allocation.

Jack H. Winters [13] In this paper consider transmitting delayed copies of the information-bearing signal on each antenna in order to obtain a diversity gain at the receiver. They study the ability of transmit diversity to provide diversity benefit to a receiver in a Rayleigh fading environment. With transmit diversity, multiple antennas transmit delayed versions of a signal to create frequency-selective fading at a single antenna at the receiver, which uses equalization to obtain diversity gain against fading. They use Monte Carlo simulation to study transmit diversity for the case of independent Rayleigh fading from each transmit antenna to the receive antenna and maximum likelihood sequence estimation for equalization at the receiver. There results show that transmit diversity with M transmit antennas provides a diversity gain within 0.1 dB of that with M receive antennas for any number of antennas. Thus, they are obtain the same diversity benefit at the remotes and base stations using multiple base-station antennas only. Specifically, there results for 2–30 antennas show that transmit diversity can achieve diversity gains within 0.1 dB of receive diversity.

Chiang-Yu Chen, Aydin Sezgin, John M. Cioffi, Arogyaswami Paulraj [13] They presents outage probability analysis and a practical algorithm for antenna selection in multiple-input multiple-output wireless communication systems employing space-time block codes (STBC). They was first, to minimize the outage probability in these systems, a satisfactory antenna selection criterion for an STBC is to maximize the channel Frobenius norm. They analyze that the more receive antennas are selected, the better the performance. However, the performance of transmit antenna selection heavily depends on how fast the channel changes. When the channel changes slowly, since STBC averages the channel gains of the selected transmit antennas, selecting more transmit antennas causes lower coding gain and thus higher outage probability.

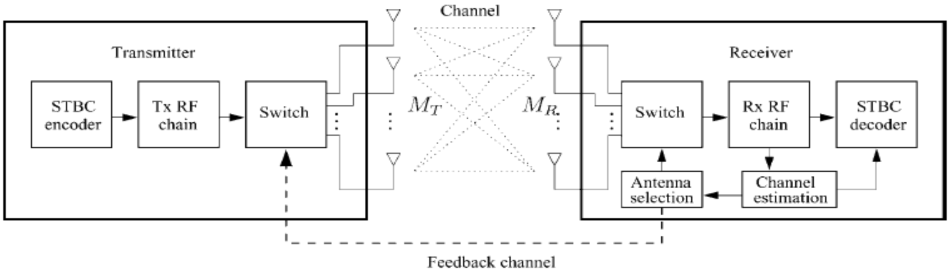

Fig 3 STBC system with antenna selection

When the channel is fast changing, they shown analytically that the system can no longer provide transmit selection diversity in the high SNR regime. Since the transmit diversity can be still provided by using STBC, the best STBC scheme varies with SNR. Although the outage analysis helps determine the STBC scheme, finding the optimal antenna subsets with maximum channel Frobenius norm for each fading state is still a challenging problem. This is because solving the problem optimally requires an exhaustive search with exponentially growing complexity. When the numbers of antennas are large, the problem becomes intractable. They was reduce the complexity, this problem is formulated as a quadratically constrained quadratic programming (QCQP) problem. Despite the fact that the problem is non convex, a Semi definite relaxation of QCQP enables the problem to be solved approximately in polynomial time. And there simulation results indicate that the loss of semi definite relaxation to optimal selection is negligible.

VI. CONCLUSIONS & FUTURE SCOPE OF WORK

This literature survey has offered a comprehensive overview of the field of transmit diversity techniques for wireless communication systems, which has evolved rapidly during the last ten years. Conventional methods single-antenna transmission techniques aiming at an optimal wireless system performance operate in the *time* domain and/or in the *frequency* domain so consume extra bandwidth. In particular, channel coding is typically employed, so as to overcome the detrimental effects of multipath fading. Using space time coding technique exploit the transmit diversity without require channel state information at the transmitter and also improve the Bit-Error-Rate performance over conventional uncoded single antenna system. And future direction combine space time coding or space diversity with spatial multiplexing and beam forming improve, however, in order to achieve a good overall performance.

REFERENCES

[1] T. S. Rappaport, Wireless Communications, 2nd Edition, Prentice Hall, 2002.

[2] S. M. Alamouti, “A simple transmit diversity technique for wireless communications,” IEEE J. Select. Areas Commun., vol. 16, no. 8, pp. 1451–1458, Oct. 1998.

[3] V. Tarokh, N. Seshadri, and A. R. Calder bank, “Space-time codes for high data rate wireless communication: Performance criterion and code construction,” IEEE Trans. Inform. Theory, vol. 44, no. 2, pp. 744–765, Mar. 1998.

[4] D. G. Brennan, “Linear diversity combining techniques,” Proc. IRE, vol. 47, pp. 1075–1102, June 1959, Reprint: Proc. IEEE, vol. 91, no. 2, pp. 331-356, Feb. 2003.

[5] P. Balaban and J. Salz, “Optimum diversity combining and equalization in digital data transmission with applications to cellular mobile radio – Part I: Theoretical considerations; Part II: Numerical results,” IEEE Trans. Commun., vol. 40, no. 5, pp. 885–894, 895–907, May 1992.

[6] V. Tarokh, A. Naguib, N. Seshadri, and A. R. Calderbank, “Space-time codes for high data rate wireless communication: performance criteria in the presence of channel estimation errors, mobility, and multiple paths,” IEEE Transactions on Communications, vol. 47, no. 2, pp. 199-207, Feb 1999.

[7] V. Tarokh, H. Jafarkhani, and A. R. Calderbank, “Space-time block codes from orthogonal designs,” IEEE Transactions on Information Theory, vol. 45, no. 5, pp. 1456-1467, 1999.

[8] V. Tarokh, A. Naguib, N. Seshadri, and A. R. Calderbank, “Combined array processing and space-time coding,” IEEE Transactions on Information Theory, vol. 45, no. 4, pp. 1121-1128, May 1999.

[9] Vahid Tarokh, Hamid Jafarkhani, and A. Robert Calderbank, “Space–Time Block Coding for Wireless Communications: Performance Results,” IEEE Journal on Selected Areas in Communications, vol. 17, no. 3, pp. 451-460, 1999.

[10] I. Emre Telatar, “On a Capacity of Multi-Antenna Gaussian Channels,” Technical Report AT&T Bell Laboratories, 1995.

[11] G. J. Foschini, and M. J. Gans, “On Limits of Wireless Communications in a Fading Environment when Using Multiple Antennas,” An International Journal on Wireless Personal Communications, vol. 6, no. 3, pp. 311-335, 1998.

[12] Liang Li, Sergiy A. Vorobyov, Alex B. Gershman,” Transmit Antenna Selection Based Strategies in MISO Communication Systems with Low-Rate Channel State Feedback”, IEEE Transactions On Wireless Communications, vol. 8, no. 4, pp.-1660-1666, April 2009.

[13] Jack H. Winters,” The Diversity Gain of Transmit Diversity in Wireless Systems with Rayleigh Fading”, IEEE Transactions On Vehicular Technology, Vol. 47, No. 1, pp 119-123, 1998.

[14] J. G. Proakis, Digital Communications. New York: McGraw-Hill, 1989.

[15] Chiang-Yu Chen, Aydin Sezgin, John M. Cioffi, Arogyaswami Paulraj,” Antenna Selection in Space-Time Block Coded Systems: Performance Analysis and Low-Complexity Algorithm”, IEEE Transactions On Signal Processing, vol. 56, no. 7, July 2008, pp.-3303-3314.