Research Article Impact Factor: 0.621 ISSN: 2319-507X
Praveen Likhitkar, IJPRET, 2014; Volume 2 (9): 319-326 IJPRET

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

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DIVERSITY IN ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING; A SURVEY

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Accepted Date: 27/02/2014 ; Published Date: 01/05/2014

Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is method of encoding digital data on multiple carrier frequencies. OFDM has developed into a popular scheme for wide band digital communication, whether wireless or over copper wires, used in applications such as digital. Television and audio broadcasting, DSL broadband internet access, Wireless networks, and 4G mobile communication. Many Techniques had been proposed for diversity for OFDM.

Keywords: OFDM, Diversity Techniques, Multiple Carrier Frequency.

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How to Cite This Article:

Praveen Likhitkar, IJPRET, 2014; Volume 2 (9): 319-326

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INTRODUCTION

OFDM based transmission schemes suffer from the lack of built-in diversity. Therefore, it is necessary to introduce some kind of diversity, e.g., spatial diversity, to such a transmission

System in order to achieve high reliability and availability without using additional bandwidth. In contrast to spatial multiplexing techniques, where the main objective is to provide higher bit rates compared to a single-antenna system, spatial diversity techniques predominantly aim at an improved error performance. This is accomplished on the basis of a diversity gain and a coding gain. Indirectly, spatial diversity techniques can also be used to enhance bit rates, when employed in conjunction with an adaptive modulation/channel coding scheme. There are two types of spatial diversity, referred to as macroscopic and microscopic diversity. Macroscopic (large scale) diversity is associated with shadowing effects in wireless communication scenarios, due to major obstacles between transmitter and receiver (such as walls or large buildings). Macroscopic diversity can be gained if there are multiple transmit or receive antennas, that are spatially separated on a large scale. In this case, the probability that all links are simultaneously obstructed is smaller than that for a single link. Microscopic (small-scale) diversity is available in rich scattering environments with multipath fading. Microscopic diversity can be gained by employing multiple co-located antennas. Typically, antenna spacing of less than a wavelength are sufficient, in order to obtain links that fade more or less independently. Similar to macroscopic diversity, the diversity gains are due to the fact that the probabilities of all links being simultaneously in a deep fade decreases with the number of antennas used. A comprehensive survey of the value of spatial diversity for wireless communication systems can be found in [18].The idea to utilize macroscopic diversity in wireless communication systems is not new. Even more so, the use of multiple receive antennas for gaining microscopic diversity (diversity reception) has been well established since the 1950's.However, it took until the 1990's before transmit diversity techniques were developed [2].

2. DIVERSITY IN OFDM SYSTEMS:

A. 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 [07].

B. Transmit Diversity and Space-Time Codes:

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. An early beginning of transmit diversity schemes was made with two papers that independently proposed a simple technique called delay diversity [08], [09]. Another early publication on transmit diversity can be found, e.g.in [10].However, the value of transmit diversity was only recognized in 1998, when Alamouti proposed a simple technique for two transmit antennas [1]. In the same year, Tarokh, Seshadri, and Calderbank presented their space-time trellis codes (STTCs)[2],which are two-dimensional coding schemes for systems with multiple transmit antennas. While delay diversity and Alamouti's transmit diversity scheme provide solely a diversity gain (more precisely, full diversity with regard to the number of transmit and receive antennas), STTCs yield both a diversity gain and an additional coding gain. Within the scope of this survey, we will use the generic term space-time coding scheme for all transmitter-sided spatial diversity techniques, irrespective of the presence of any additional coding gain. The preprocessing of the redundant transmission signals is performed by the space-time encoder, which depends very much on the specific scheme under consideration. At the receiver, the corresponding detection/decoding process is carried out by the space-time de-coder. In the delay diversity scheme [08], [09], for example, identical signals are transmitted via the individual antennas, using different delays. This causes artificial ISI, which can be resolved at the receiver by means of standard equalization techniques available for single-antenna systems. In contrast to this, Alamouti's transmit diversity scheme [1] performs an orthogonal space-time transmission, which allows for ML detection at the receiver by means of simple linear processing. STTCs [2] may be interpreted as generalizations of trelliscoded modulation to multiple transmit antennas. Optimum decoding in the sense of MLSE can be performed using the Viterbi algorithm. On the basis of simulation results, it was shown in [2] that STTCs offer an excellent performance that is within 2-3 dB of the outage capacity limit. However, this performance comes at the expense of a comparatively high decoding complexity. Motivated by the simple receiver structure of [1], orthogonal space-time block codes (OSTBCs) were introduced in [12], which constitute a generalization of Alamouti's scheme to more than two transmit antennas.

OSTBCs are designed to achieve full diversity with regard to the number of transmit and receive antennas. In contrast to STTCs, OSTBCs do not offer any additional coding gain. STTCs and OSTBCs can be combined with different diversity reception techniques at the receiver side. For example, the performance of STTCs and OSTBCs combined with antenna (subset) selection techniques at the receiver was examined in [13] and [14], respectively.

C. Optimized STTCs and OSTBCs:

In [2], general design criteria were derived for STTCs that guarantee a maximum diversity advantage and allow for an optimization of the coding gain (both for high SNR values). These design criteria depend on the number of transmit and receive antennas as well as on the cardinality of the employed modulation scheme. Unfortunately, 'good' STTCs can not be constructed analytically, but have to be found by means of a computer search. An efficient design procedure for STTCs, which is based on simple lower and upper bounds on the coding gain, was presented in [15]. In [2], some examples of optimized STTCs were stated, for certain modulation schemes and certain numbers of transmit antennas.15 Further examples of optimized STTCs, sometimes based on (slightly) modified design criteria, can be found, e.g., in [15]-[17]. OSTBCs are based on the mathematical theory of (generalized) orthogonal designs, which dates back to the 1890s.Orthogonal designs are a special class of orthogonal matrices. In general, the use of OSTBCs causes a rate loss when compared to an uncoded single-antenna system. For the case of a real-valued modulation scheme, full-rate (and delay optimal) OSTBCs for systems with two to eight transmit antennas could be established in [12] (partly based on generalized orthogonal designs). Given a complex-valued modulation scheme, however, the only full-rate OSTBC is Alamouti's transmit diversity scheme [1] for two transmit antennas. In [12] it was shown that half-rate OSTBCs for complex-valued modulation schemes can be constructed for any number of transmit antennas. However, to find OSTBCs with higher rates (and moderate decoding delay) is, in general, not a trivial task. A systematic design method for high-rate OSTBCs was presented for complex-valued modulation schemes and arbitrary numbers of transmit antennas.

D. Other Families of Space-Time Codes:

Since the advent of STTCs and OSTBCs in 1998, various other families of space-time codes have been proposed in the literature. Similar to OSTBCs, square-matrix embeddable STBCs allow for ML detection at the receiver by means of (generalized) linear processing. A family of non-orthogonal full-rate linear STBCs, called diagonal algebraic STBCs, was constructed. Diagonal algebraic STBCs provide full transmit diversity and allow for efficient ML detection by means of the sphere decoding approach. Another non-orthogonal full-rate STBC for two transmit antennas, constructed based on number theory, For more than one receive antenna, this STBC provides an improved coding gain compared to Alamouti's transmit diversity scheme [1]., STBCs based on linear constellation precoding were proposed, which provide full rate and full diversity for any number of transmit antennas and perform superior to OSTBCs, a sphere decoding approach as well as suboptimal alternatives were used for decoding. Here the strict constraint of perfect orthogonality was relaxed in favor of a higher data rate. The resulting STBCs are therefore referred to as quasi-orthogonal STBCs. Due to the relaxed orthogonality constraint, however, quasi-orthogonal STBCs typically offer reduced diversity gains compared to OSTBCs. In particular, the parallel concatenation of two identical recursive STTCs was studied. Here the encoder structure was inspired by the original turbo code proposed by Berrou, Glavieux, and Thitimajshima in 1993.16 .Recursive STTCs are also well suited for a serial concatenation with an outer channel code (with iterative detection at the receiver).

E. Cooperative Diversity Schemes:

The concept of multiple-antenna systems can be transferred to so-called cooperative wireless networks, where multiple distributed transmitting or receiving nodes cooperate in terms of a joint transmission/reception strategy. In fact, cooperative wireless networks have recently gained considerable attention. On the one hand, cooperating network nodes build the basis of ad-hoc networks, which are envisioned for sensor networks, public safety communication networks, or tactical networks for military applications. On the other hand, cooperating nodes also promise benefits for hierarchical types of networks, such as cellular networks. Through cooperation, network nodes are able to share their antennas and can thus establish a virtual antenna array. By this means the cooperating nodes, possibly equipped with just a single antenna, can enjoy some of the benefits offered by conventional MIMO systems with co-located antennas. Examples include cooperative diversity schemes, where multiple network nodes share their transmit antennas by employing a distributed space-time-coding scheme. The design of efficient cooperative diversity schemes is currently a hot topic and poses many challenging problems calling for future work.

3. CONCLUSION:

This literature survey has offered a comprehensive overview of the diversity techniques for wireless communication systems, which has evolved rapidly, the CO-OFDM system achieves a diversity gain comparable to the conventional space-time-coded OFDM system, even when synchronization and channel estimation are taken into account. **S**pace diversity provides an attractive means for improving the performance of mobile radio systems. With space diversity, the signals from the receiving antennas can be combined to combat multipath fading of the desired signal and reduce the relative power of interfering signals. STTC &STBC methods considerably minimize multi-cell interference by jointly consuming the diversity gain and coding gain.

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