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Performance Analysis of STF Codes In MIMO-OFDM

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Abstract—
We consider the capacity of multiple-input–multiple output (MIMO) systems that use OFDM as the modulation format. We point out a basic equivalence between antennas and OFDM-tones. This similarity immediately allows us to essentially reuse all space-time codes designed for flat-fading channels in MIMO-OFDM systems operating in frequency-selective channels. An optimum code would thus code across all antennas and tones (as well as time) simultaneously. Since this can become very complex, we propose a method for grouping antennas and codes in such a way that the inherent diversity is retained, while the complexity is greatly reduced. Capacity computations between the full-complexity and the reduced-complexity systems illustrate this tradeoff.

Keywords—MIMO, OFDM, space-time coding, Space Time Frequency Block Codes (STFBC)

I INTRODUCTION

Swifter, higher, stronger —Motivated by the huge demands for fast and reliable communications over wireless channels, future broadband communication systems should provide swifter data processing (low-complexity), higher data rate, and stronger (robust) performance. In practice, however, the broadband channel is a typically non-line-of-sight n-channel and includes much impairment such as time selective and frequency-selective fading. To address these challenges, one promising solution is to combine two powerful technologies, namely, multiple-input multiple-output (MIMO) antennas and orthogonal frequency division multiplexing (OFDM) modulation. MIMO systems have been recently under active consideration because of their potential for achieving higher data rate and providing more reliable reception performance compared with traditional single-antenna systems for wireless communications. A space-time (ST) code is a bandwidth-efficient method that can improve the reliability of data transmission in MIMO systems. It encodes a data stream across different transmit antennas and time slots, so that multiple redundant copies of the data stream can be transmitted through independent fading channels. By doing so, more reliable detection can be obtained at the receiver.

As an example of MIMO applications, the IEEE 802.11n standard is still being discussed, but one Prototype can offer up to 250 Mb/s. This is more than five times the (theoretical maximum) speed of the existing IEEE 802.11g hardware. OFDM is based on the principle of frequency division multiplexing (FDM), but is utilized as a digital modulation scheme via DFT. The data stream that is to be transmitted is split into several parallel streams, typically dozens to thousands. By doing so, the wideband frequency selective channel is divided into a number of parallel narrowband sub channels, and each of the low rate data streams is transmitted over one sub channel. The major advantage of OFDM is its ability to cope with severe Channel conditions, for example, multipath fading and narrowband interference, without complicated equalization filters. In this article we attempt to provide an overview of ST coding, SF coding, and STF coding for MIMO-OFDM wireless systems, in particular focusing on recent work on high rate and full diversity ST/SF/STF code design.

Space-Time Block Codes

MIMO systems have been under high consideration since Alamouti introduced the well known STBC for two transmit and one receive antenna. STBC consists of data coded through space and time to improve the reliability of the transmission. Later, Tarokh introduced orthogonal space-time block coding which generalizes Alamouti's transmission scheme to an arbitrary number of transmit antennas and is able to achieve the full diversity promised by the multiple transmit and receive antennas. Like Alamouti scheme, these generalised codes have a very simple maximum likelihood decoding algorithm based only on linear processing at the receiver.

Alamouti's Space-Time Block Codes

Historically, the first STBC to provide full diversity with full rate matrix and simple decoding algorithm was proposed by Alamouti in. A block diagram of Alamouti STBC encoder can be found in Figure 2

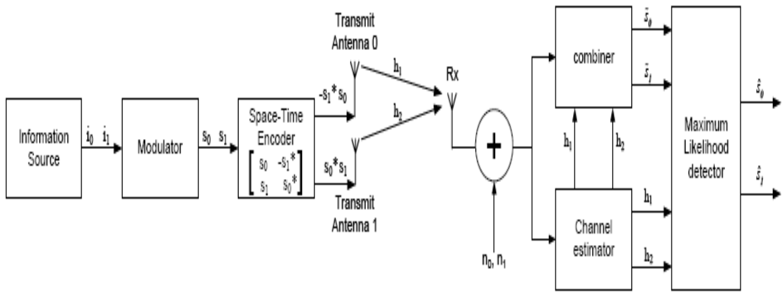


Figure 2: A Block diagram of alamauti's STBC

As it can be seen from Figure 2, M-ary modulated symbols s0 and s1 are passed through the STBC encoder and complex matrix S is generated such that symbols s0 and s1 are coded through space and time. Indeed, replicas of s0 and s1 for Alamouti coding are sent through two transmit antennas and over two time slots. Complex matrix S can be

$$S_2^c = \begin{bmatrix} s_0 & s_1 \\ -s_1^* & s_0^* \end{bmatrix}$$

where the superscript * represents the complex conjugate operation.

Here, the number of columns corresponds to the number of transmit antennas Mt and the number of rows to the number of time slots or number of symbols transmitted per antenna nt. It can be seen from the matrix in that at time t, s0 and s1 are sent simultaneously from antenna 1 and 2 respectively and at time t+T, where T is the symbol duration, is transmitted from antenna 1 and is simultaneously transmitted from antenna 2. Moreover, from, it can be seen that full diversity is accomplished as one symbol is transmitted from each antenna during each time slot. Finally, the rate (R) of STBC achieved by Alamouti's code defined as is full as the number of different symbols transmitted per antenna ns (here ns=2 because of the two symbols s0 and s1) divided by the number of time slots nt (here nt=2) is giving the full rate of one.

An interesting key feature of Alamouti's scheme is that the sequence transmitted from the different antennas are orthogonal since the matrix of S times the Hermitian matrix S is equal to the identity matrix such as:

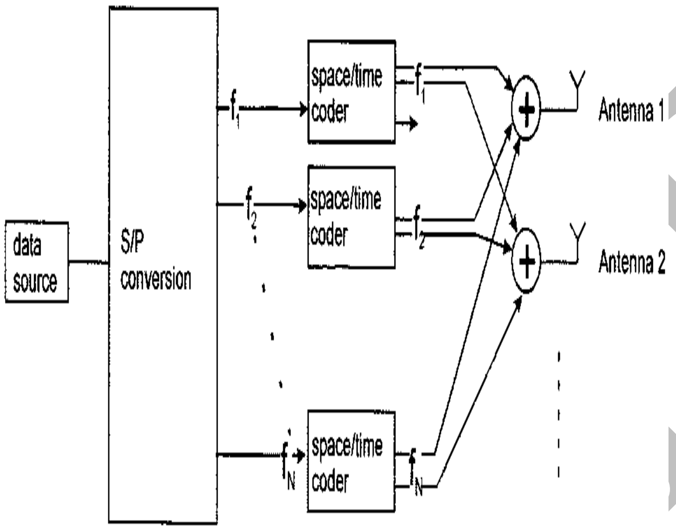
$$S_2^c . S_2^{cH} = \begin{bmatrix} s_0 & s_1 \\ -s_1^* & s_0^* \end{bmatrix} . \begin{bmatrix} s_0^* & -s_1 \\ s_1^* & s_0 \end{bmatrix}$$
$$= |s_0|^2 + |s_1|^2 \ I$$

where the superscript H represents the Hermitian matrix of S which is the transpose and conjugate of the matrix S and I is a 2x2 identity matrix.

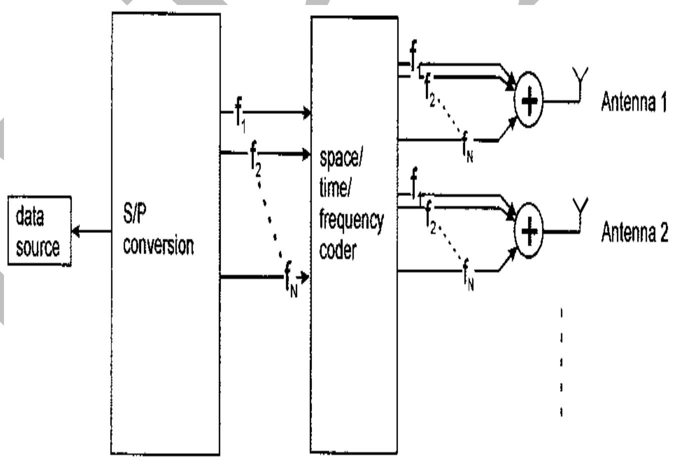
II ANTENNAS AND TONES—UNIFIED PERSPECTIVE

In a conventional OFDM system [see Fig. 1(a)], i.e., without exploitation of the frequency diversity, the data streams for the OFDM tones enter separate ST coders whose outputs are then forwarded to the different antennas. The tones at each antenna are inverse Fourier-transformed and the resulting time signal is up converted to the carrier frequency and transmitted across the mobile radio channel.

As coding across the tones is required to exploit the inherent frequency diversity in a time-dispersive channel. A full-complexity coder thus must use the symbols from all tones as input, and distribute them to all tones on all antennas jointly [Fig. 1(b)]. Assuming transmit antennas and tones, the size of the coder is thus .1 Systematic methods for designing these codes thus seem difficult to derive.2From the antennas, the signal is sent through the mobile radio Channel , which is assumed to be constant within one OFDM block. The fading of the signals at the different antenna elements



(a)



(b)

Fig. 1. System model for: (a) separate coding for each tone (upper figure) and
(b) joint space/time/frequence coding (lower figure).IFFT blocks not shown for simplicity. is assumed to be identically distributed, but not necessarily independent

III CONCLUSION

We have investigated STF codes for MIMO-OFDM. Startingfrom the premise that coding across the tones must be done ina systematic way, we have pointed out the basic mathematicalanalogy between antennas (or spatial eigen modes) and tones,and explained how this similarity allows to reuse the concepts of ST coding for space-time-frequency (STF) coding required for OFDM. We then proposed a reduced-complexity scheme that codes only across tones that are separated by about one coherence bandwidth. A logical next step would be to use real-world codes on that scheme and investigate performance with full- and reduced-complexity schemes.

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