International Journal of Advance Engineering and Research Development (IJAERD)
Volume 1,Issue 5,May 2014, e-ISSN: 2348 - 4470 , print-ISSN:2348-6406

Adaptive Modulation for Space-Time Trellis Coded Multiple Input Multiple Output Systems with Imperfect Channel State Information

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Abstract—Here it is proposed a novel adaptive transmission scheme for space-time trellis coded multiple-input multiple-output beamforming systems with imperfect channel state information at the transmitter, of which the signal constellation, total transmit power (temporal power), and power allocation among eigenbeams (spatial power) are jointly adapted to maximize the average spectral efficiency, subject to a target bit-error-rate and an average power constraint. The power allocation over the spatial and temporal domains makes the traditional approach of partitioning the received signal-to-noise ratio (SNR) inapplicable to the above design problem. By introducing a new variable, called as effective signal-to-noise-to-modulation ratio (ESNMR), we derive a rate-selection policy by partitioning the range of the ESNMR with an optimal set of thresholds. A closed-form temporal power control policy and a simple spatial power allocation algorithm are also obtained. Numerical results demonstrate that the new adaptive transmission scheme yields a significant performance gain over existing adaptation systems.

Keywords: Adaptive modulation, space-time trellis coding (STTC), multiple-input multiple-output (MIMO), beamforming, imperfect CSI, power allocation.

I. INTRODUCTION

The increasing demand of high data rate services always looks for spectrally efficient communication systems under limited radio spectrum. Adaptive modulation (AM), as a powerful technique for improving spectral efficiency (SE), has attracted lots of research efforts for single-input single output (SISO) systems [1]–[5]. The channel state information (CSI) at the transmitter (CSIT) is crucial to the operation of AM, which may be obtained through a feedback channel. In practical systems, CSIT suffers from imperfection due to channel estimation errors, feedback delay, or quantization errors [6]. Imperfect CSI can adversely affect AM performance. Therefore, it should be taken into account explicitly in performing system design. Multiple-input multiple-output (MIMO) approach is another promising SE technique with diversity and coding benefits. Therefore, AM and MIMO can be combined to leverage both of their potentials. Among all the MIMO signaling schemes, orthogonal, space-time trellis coding (STTC) has been widely used due to its simplicity. Although STTC is a diversity-based scheme which aims at minimizing bit-error rate (BER) at fixed spectral efficiency, it can be combined with AM to achieve high spectral efficiency for a target BER. Actually, at low SNRs, STTC can yield higher spectral efficiency than spatial multiplexing scheme. In, the performance of a variable-power (in time) variable-rate STTC system is analyzed under imperfect CSI. However, none of the above systems consider the power allocation among transmit antennas. Without the spatial power allocation, these works can use received signal-to-noise ratio (SNR) to derive adaptation policies by partitioning the range of SNR, parallel to the previous SISO cases. It is well-known that the BER performance of STTC systems can be improved by spatial power allocation for fixed data rate transmission .Intuitively speaking, if we combine spatio-temporal power allocation with AM for STTC systems, the SE can be further increased for given target BER and average power constraint. However, this design problem is difficult and has not yet been solved. Making use of CSIT, the STTC has been combined with beamforming (BF) to provide robustness against imperfection in CSIT [6]. The outputs of the STTC, after being power loaded, are transmitted through the eigen-directions of the autocorrelation matrix of the spatial channel estimate. AM for STTC-BF systems has been investigated. In order to alleviate the difficulty incurred by spatio-temporal power allocation focuses on constant-power transmission, only adjusting the constellation size and spatial power allocation. Though the time domain freedom is put aside, the constant power AM-MIMO problem has been solved by trial and error: start with the largest constellation and calculate the expected BER with optimal spatial power allocation, then decrease the constellation size until the target BER is satisfied. However this constant-power approach restricts the system performance. In other words, the existing AM schemes for STTC or STTC -BF systems lack of an efficient design algorithm and do not fully utilize the degrees of freedom of spatial and temporal power adaptation, which results in performance inferiority. In this paper, we develop optimal AM schemes for STTC/ STTC -BF MIMO systems with joint spatiotemporal power allocation under imperfect CSI. The constellation size, total transmits power and spatial power allocation parameters are jointly optimized to maximize the average spectral efficiency (ASE), subject to a target BER and an average power constraint. The initial formulation seems to be complicated. However, by introducing a new variable, called as effective signal-to-noise-to-modulation ratio (ESNMR), we can modify the original problem as an inner-outer optimization problem resulting in an efficient solution. Employing this variable, we can derive a rate-selection policy by partitioning the range of the ESNMR with optimal thresholds. A closed form temporal power control policy and a simple spatial power allocation algorithm are also obtained. The complexity of the proposed variable-rate and variable-power adaptation algorithm is reduced to one-dimensional root-finding of a monotonic function.

II. SYSTEM DESCRIPTION

We consider a wireless multi-antenna communication system with N_t transmit antennas and N_r receive antennas operating over a AWGN (Additive White Gaussian Noise) channel as depicted in Fig.1. The adaptive modulator in the system employs either QPSK (quadrature phase shift keying)or QAM (Quadrature Amplitude Modulation).The space-time encoder, which is represented by an $N_t \times T$ STTC transmission code word matrix , is used to encode K data symbols into an N_t-dimensional vector sequence of T time slots with code rate $r = K/T$. The STTC vector sequence is then sent along the N_t eigen-directions of the autocorrelation matrix of the spatial channel estimate at the transmitter with power allocation in space and time. The channel is represented by an $N_r \times N_t$ matrix $\mathbf{H} =\{h_{ij}\}$, where h_{ij} denotes the channel gain from the jth transmit antenna to the ith receive antenna. It is assumed that h_{ij} remains constant over a STTC frame and varies from frame to frame, and $\{h_{ij}\}$ are modeled as independent identically distributed (i.i.d.) complex Gaussian random variables (r.v.s) with zero-mean and variance 0.5 per dimension. At the transmitter, only an imperfect channel estimate $\hat{\mathbf{H}}$ is available for the current frame, modeled as $\hat{\mathbf{H}} = \mathbf{H}+\mathbf{E}$, where $\mathbf{E}$ is the channel error matrix independent of $\mathbf{H}$. The elements of $\mathbf{E}$ are assumed to be i.i.d. complex Gaussian r.v.s with zero mean and variance σ_e^2 Adaptive modulation i.e. QAM/PSK is used.STTC (Space-Time-Trellis-Coding) and STBC (Space Time Block Code) is used. Both temporal and spatial power allocation is considered. Beam-Forming weights are computed. Space-Time decoding is performed at the receiver (corresponding to whether trellis coding or block coding is used at the transmitter). Carrier demodulation is performed. Parallel data is converted to serial data. Serial data at the input and output of the system is compared for plotting different graphs

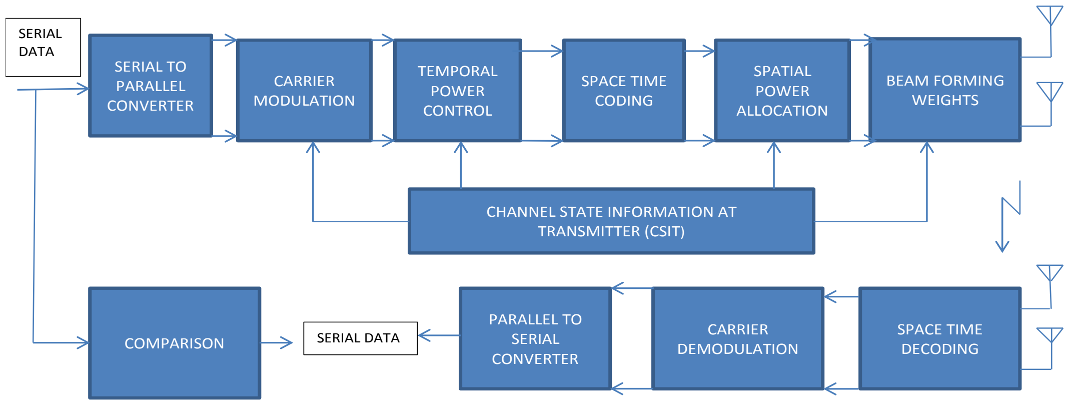

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Fig. 1 System diagram

III. RESULTS

The simulation results obtained are shown below.Figure-2 shows variation of throughput with respect to SNR. Figure-3 shows variation of ASE with respect to SNR. Figure-4 shows variation of BER with respect to SNR. Figure-5 shows variation of Channel capacity with respect to SNR.

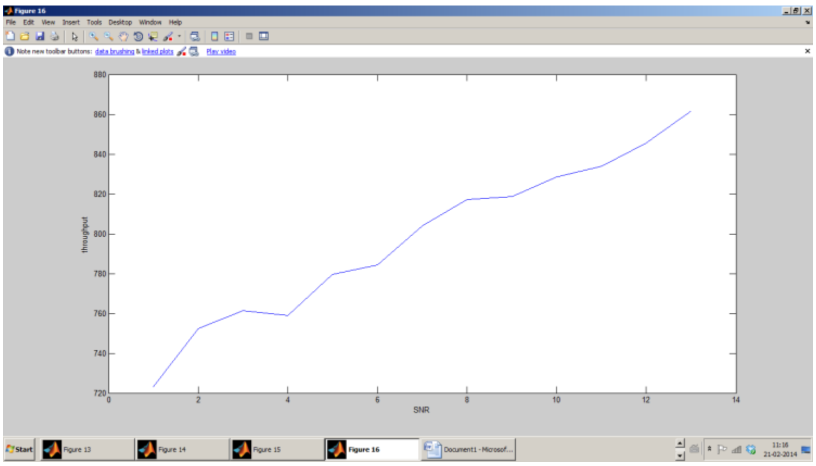

Figure-2 throughput vs. SNR

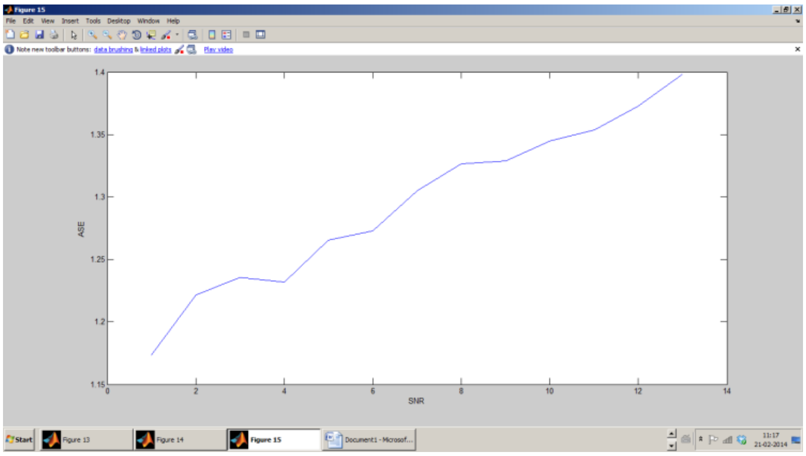

Figure-3 ASE vs. SNR

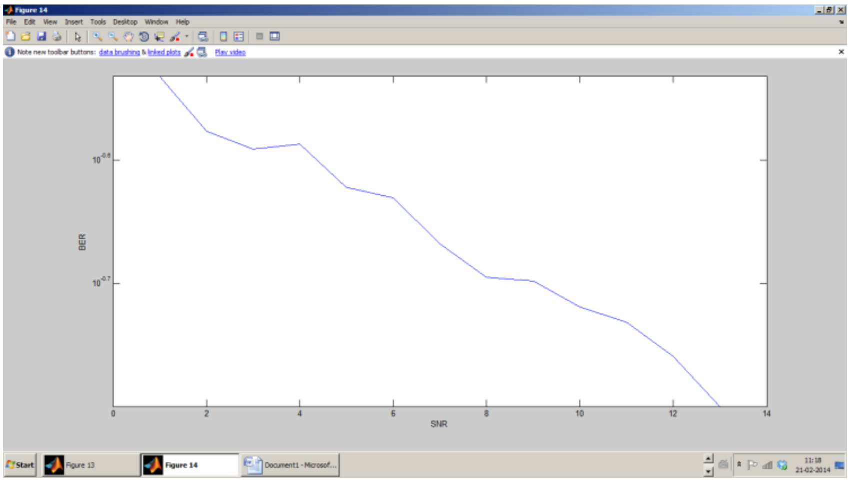

Figure-4 BER vs. SNR

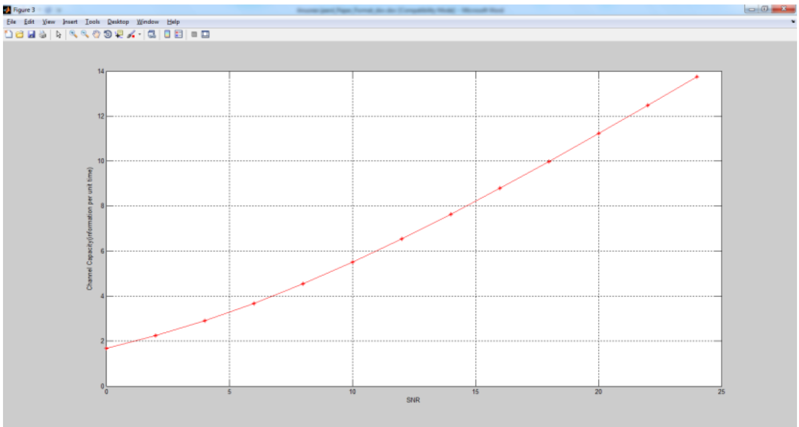

Figure-5. Channel capacity vs. SNR

IV. CONCLUSION

In this paper, we have proposed the joint rate and spatiotemporal power adaptation scheme for STTC / STTC -BF MIMO systems with imperfect CSIT. The proposed transmitter optimally adjusts the signal constellation, temporal power, and spatial power allocation to maximize the average spectral efficiency, subject to a target bit-error-rate and an average power constraint. By introducing a new variable, the so called ESNMR, we have obtained the rate-selection policy by partitioning the range of the ESNMR with optimal thresholds. A closed-form temporal power control policy and a simple spatial power allocation algorithm have also been obtained. Compared to adaptive systems with restricted freedoms on power adaptation, our adaptation scheme significantly improves the ASE. The additional peak power constraint can be incorporated into the proposed scheme. The simulation results show that the ASE of the scheme with an additional peak power constraint may be reduced in the low SNR region.

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