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Combination of Alamouti Code and Beamforming Technologies via Dual-Polarized Antenna Array Systems

by
Xin Su and Rongzhi Gu

College of Internet of Things (IOT) Engineering, Hohai University, Changzhou, 213022, China.
Email: leosu8622@163.com, muqianchuan@gmail.com

Abstract

Generally, space-time block coding (STBC) and beamforming (BF) gains cannot be obtained simultaneously because the former performs well under a low correlated MIMO channel, and the latter works eiciently in an environment with high correlation. However, array systems with antenna polarization have the potential to achieve gains with both techniques simultaneously because the cross-branch links in the system are usually uncorrelated. he cross-array links, on the other hand, can be highly correlated by setting the array element space equal to, or less than, a half-wavelength. This paper proposes a scheme to explore STBC and BF simultaneously via a dual-polarized uniform linear array (DPULA) system. The proposed scheme was veried under a polarized MIMO (PMIMO) channel model, and therewith, the simulation results confirmed the validity of our proposed scheme.

Keywords: STBC, Beamforming, Antenna Polarization, MIMO, Correlation

Xin Su received B.E. degree in Computer Engineering from Kunming University of Science and Technology, China, in 2008. He received his M.E. in computer engineering from Chosun University, Korea, in 2010. In 2015, he received his Ph.D. degree in the Program in IT & Media Convergence Studies, Inha University, Korea. He is currently with the College of Internet of Things Engineering, Hohai University, China. His research interests include 3GPP LTE(-A) systems, MIMO beamforming, antenna pattern and polarization–based MIMO systems, wireless backhaul solutions, and mobile ad-hoc networks.

1. Introduction

- In 5G communication networks, antenna polarization is an effective resource to be exploited for space-limited devices to support a large network payload because it has the advantages of enhancing channel capacity and reducing the required antenna space via the principle of polarization diversity and multiplexing [1]-[6]. MIMO technologies, such as space-time diversity, multiplexing, and array processing could be applied with the polarization principle to enhance the MIMO system performance. Therefore, many research articles and projects have been dedicating to the topic of antenna polarization. On the other hand, there is less research articles have focused on achieving gains of STBC and BF simultaneously via the MIMO systems. George et al. uses the numerical methodology to verify system performance when the STBC and transmit BF (TxBF) are combined [7], where the numerical derivation is based on the characteristic of orthogonal STBC code-word. However, the designing of optimal STBC used for practical implementation is not achieved by reference [7], especially when a large number of transmit antennae are employed. If it requires a comparison with reference [7], at least the STBC code-word as well as the decoding method should be provided clearly.

- In this paper, we suggest a robust MIMO architecture to realize the STBC and BF gains simultaneously via dual-polarized antenna array systems. The polarized antenna braches are categorized into two groups that adjust two orthogonal beams to guarantee the BF gain, while the Alamouti code is applied additionally at orthogonally co-located branches of each array element to accommodate the space-time diversity gain [8]. The remaining part of this paper is organized as follows. Section II describes the dual-polarized antenna array systems along with the characteristics of polarized channels, and Section III provides the proposed MIMO architecture. In Section VI, the simulation results are demonstrated and discussed, and at last, the conclusions are confirmed in Section V.

2. Dual-polarized Antenna Array System

- Fig.1 provides an example of an orthogonal dual-polarized antenna array system in array and branch multiple antennae configuration. According to Fig. 1, there are two orthogonally co-located antenna branches at each transmitter (Tx) or receiver (Rx) ports. Via uniformly aligning the polarized antenna ports (array elements) at Tx and Rx, a dual-polarized antenna array system is given that indicates the antenna polarization is realized at both array and branch levels.

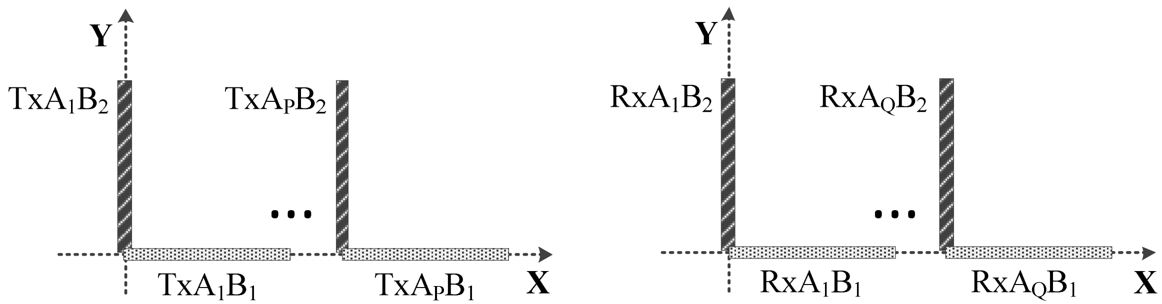

Fig.1. Orthogonal dual-polarized antenna array system.

- Channel Correlations in Polarized Antenna Array System
  - ✓ Correlation coefficient between the cross-array links is inversely proportional to the array element spacing due to the array aliasing effect.
  - ✓ Correlation coefficient between the cross-branch links is low.
  - ✓ Then, both high-correlated channels and low-correlated channels exist simultaneously in the system.

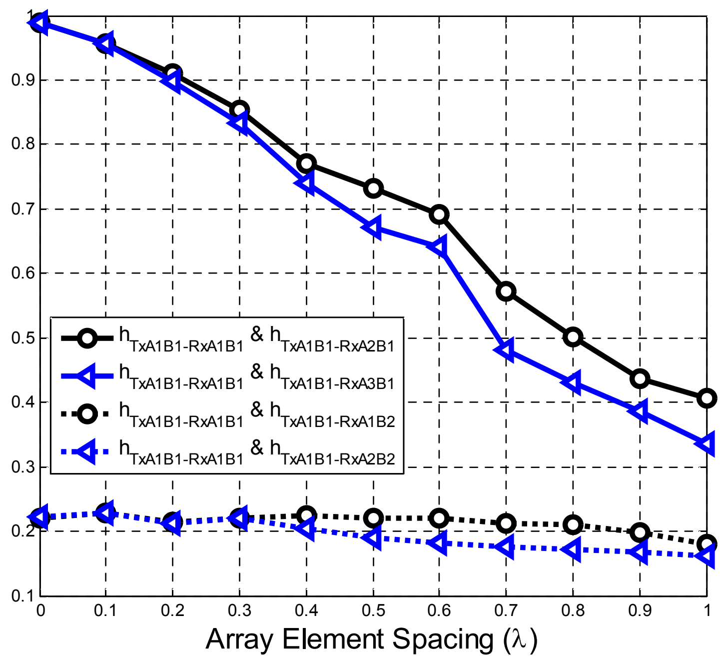

Fig.2. Correlation coefficient versus Rx array element spacing.

3. The Proposed MIMO Architecture to Accommodate Alamouti Code and Beamforming Technologies

- Incorporate Alamouti Code and Beamforming Technology Simultaneously
  - ✓ Via orthogonal dual-polarized antenna array systems.
    - ➢ Guaranteeing the system performance when the channel condition is bad.
      - TxBF weights: zero-forcing BF criterion
      - RxBF weights: MMSE criterion

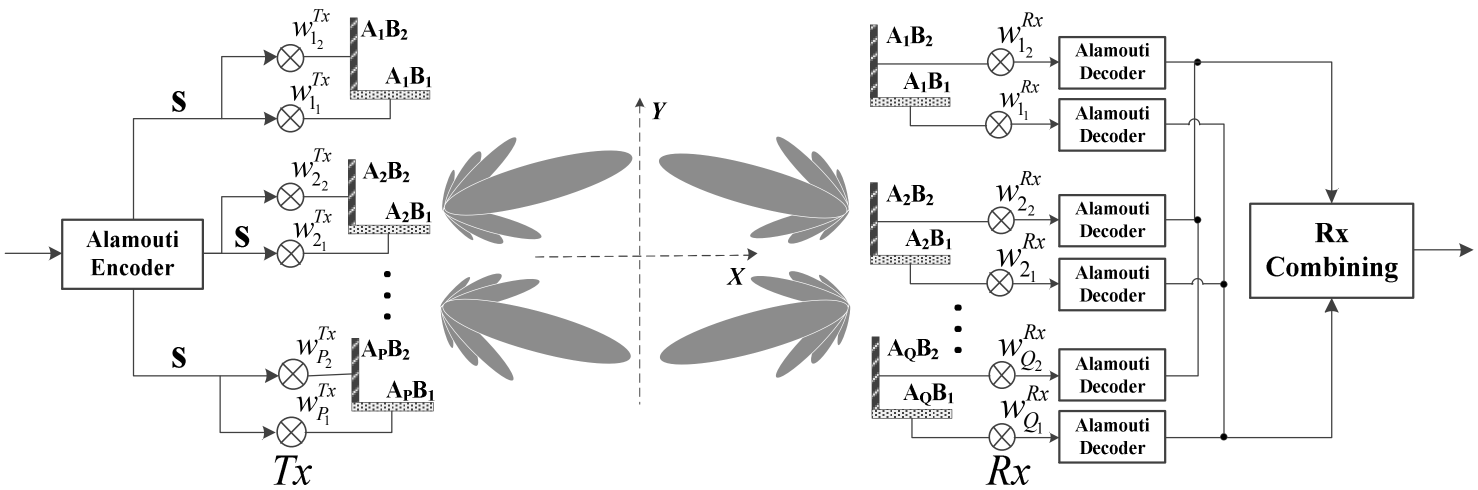

Fig.3. The proposed MIMO transceiver to accommodate Alamouti code and beamforming technologies simultaneously.

4. Performance Verification of the Proposed MIMO Transceiver

- In this section, we verify the proposed MIMO transceiver by computer simulations, where Table 1 gives all the parameters details. Of special note, the percentage of training sequence used for RxBF is 10%.

Table 1. Simulation parameter settings

SYSTEM PARAMETER	**Value**
Carrier frequency	1.8 GHz
System bandwidth	10 MHz
Number of symbols in one packet	100
Number of pilots in one packet	10
Modulation	QPSK
MIMO configuration	4 array elements * 2 branches at Tx; 2 array elements * 2 branches at Rx
Array spacing	Half wavelength
BF schemes	Zero-forcing BF at Tx; MMSE BF at Rx
Antenna type	Half wavelength dipole

- As we mentioned before, there is less research articles have focused on achieving gains of STBC and BF simultaneously via a MIMO system. If it requires a comparison with existing schemes, at least the STBC code-word as well as the decoding method should be provided clearly by existing schemes. Consequently, we only compare four transmission cases in this paper to verify our proposal under the polarized channel model in [5]. These four case are dual-polarized antenna array system without MIMO schemes, dual-polarized antenna array system with STBC, dual-polarized antenna array system with STBC and TxBF, and dual-polarized antenna array system with STBC TxBF and RxBF. Fig.4 illustrates the simulated packet-error-rate (PER) for these four transmission cases, where the first case has the worst performance because there is no space-time coding and BF gain achieved. Via employing the Alamouti code, about 3 dB of signal-to-noise ratio (SNR) gain at the target PER of 10^{-3} can be achieved. Additionally, compared with the second transmission case, about 1 dB SNR gain at target PER is obtained by the third transmission case when the TxBF is applied.

- At last, compared with the third transmission case, 1.2 dB SNR gain at the target PER is yielded by using the MMSE RxBF via the fourth transmission case due to the amount of error fed into the STBC decoding process is further reduced. According to the link-level simulation results, we can confirm that the proposed MIMO transceiver is efficient to incorporate STBC and BF MIMO schemes to boost system performance. Fig.5 provides the simulated throughput curves for these four transmission cases. Based on Fig.5, we notice that the fourth transmission case can achieve the highest throughput of 14.4 Mbps at Eb/N0 of 5 dB, while only 14 Mbps, 13.3 Mbps, and 12.4 Mbps for the third, the second, and the first transmission cases. Again, the validity of our proposed scheme is proved.

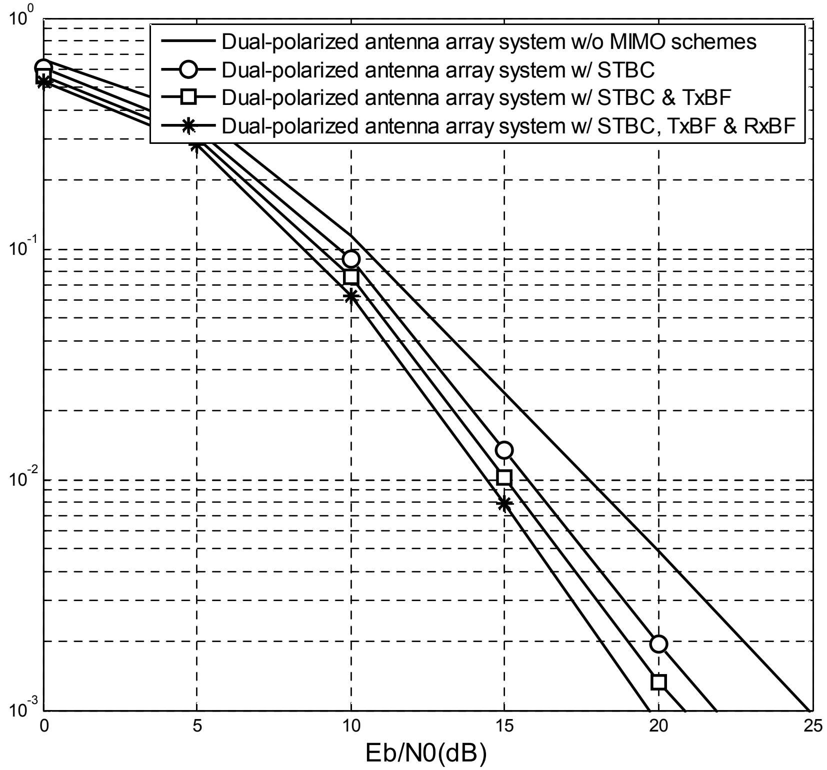

Fig.4. Packet error rate results

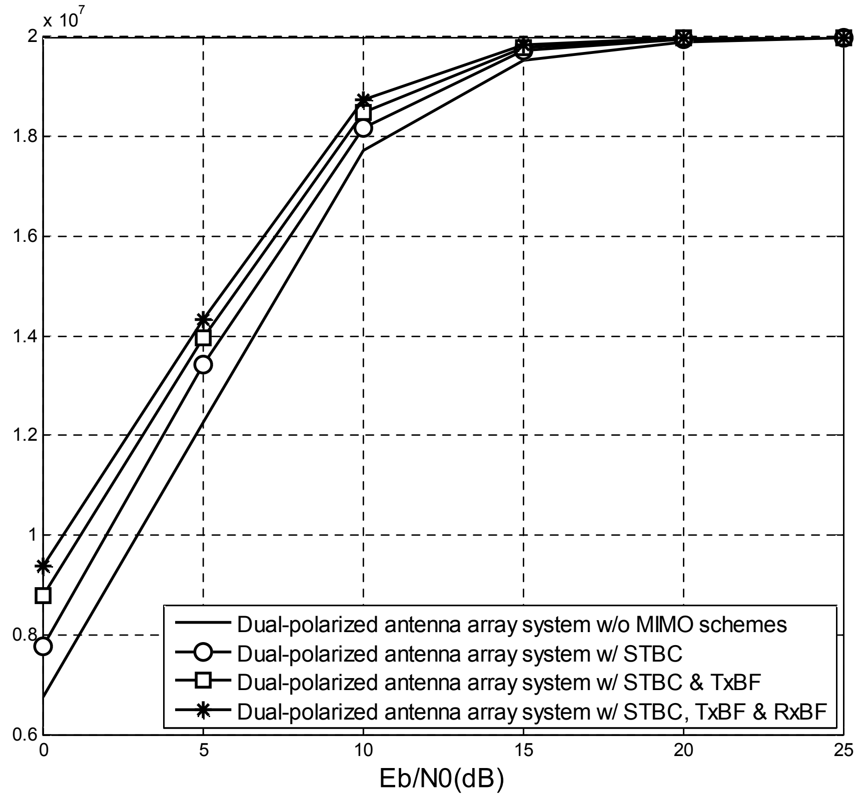

Fig.5. Throughput results

5. Conclusions

- In this paper, we propose a MIMO transceiver to incorporate the STBC and BF gains simultaneously. The polarized antenna branches are divided into two groups with each group generating and steering a signal beam. Alamouti code is employed at each array element in addition to accommodate the space-time gain. According to the simulation results, the efficiency of our proposal is confirmed and validated.

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