Adaptive Selection of Antennas for Optimum Transmission using STBC

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Abstract: ***In this paper, we propose an optimum transmit structure using STBC instead of spatial modulation(SM) in a multiple-input multiple-output (MIMO) transmission technique. Based on transmission optimized spatial modulation (TOSM), selects the best transmit structure that minimizes the average bit error probability (ABEP). Unlike the traditional antenna selection methods, the proposed method relies on statistical channel state information (CSI) instead of instant CSI, and eigen value and feedback is needed for the optimal number of transmit antennas. The overhead for this, however, is negligible. In addition, TOSM has low computational complexity as the optimization problem is solved through a simple closed-form objective function with a single variable. Simulation results show that TOSM and STBC significantly improves the performance of various channel correlations. We propose a single radiofrequency (RF) chain base station (BS) based on TOSM, which achieves low hardware complexity and high energy efficiency. In comparison with multi-stream MIMO schemes, TOSM and STBC offers an energy saving of at least 56% in the continuous transmission mode, and 62% in the discontinuous transmission mode.***

Keywords: relay based communications, Space Time Block Code (STBC), channel correlation, transmit antenna selection, MIMO.

1. Introduction

The need to curtail the carbon footprint and the operation cost of wireless networks requires an overall energy reduction of base stations (BSs) in the region of two to three orders of magnitude . At the same time, a significant increase in spectrum efficiency from currently about 1.5 bit/s/Hz to at least 10 bit/s/Hz is required to cope with the exponentially increasing traffic loads. This challenges the design of multiple-input multiple-output (MIMO) systems associated with the BS. A typical long-term evolution (LTE) BS consists of radio-frequency (RF) chains, baseband interfaces, direct current to direct current (DC-DC) converters, cooling fans, etc. Each RF chain contains a power amplifier (PA), and PAs contribute around 65% of the entire energy consumption, i.e. more than two thirds of the energy is consumed in quiescent power. This drives research on minimizing the overall BS energy consumption instead of the energy required for the RF output stage only. As a result, power optimization of PAs has been studied. In cell discontinuous transmission (DTX) was proposed to enable the BSs to fall into a sleep mode when there is no data to convey, so that the overall energy consumption can be reduced. Based on that concept, another optimization method using on/off PAs was reported, and a similar work was conducted for MIMO orthogonal frequency division multiple access (OFDMA) systems. However, those studies have the following limitations:

1) They focus on the operation of RF chains, while modulation schemes are not considered;
2) The optimization is implemented within each individual RF chain;
3) The benefit is inversely proportional to the traffic load.

When the BS has to be operated in the active mode continuously, the above methods would fail to achieve any energy-saving gain. Therefore it is necessary to study energy reduction on a more comprehensive level, including not only hardware operations, but also modulation schemes.

While multi-stream MIMO schemes, such as vertical Bell Labs layered space-time (V-BLAST) and space-time block coding (STBC), offer high spectrum efficiency, unfortunately, they need multiple RF chains that heavily compromise the energy efficiency. Meanwhile, spatial modulation (SM) is a unique single-stream MIMO technique, where the bit stream is divided into blocks and each block is split into two parts:

1) The first part activates one antenna from the antenna array while the remaining antennas do not emit a signal;
2) The bits in the second part are modulated by a signal constellation diagram, and sent out through the activated antenna.

The use of a single active antenna makes SM a truly energy-efficient MIMO transmission technique, because only one RF chain is required, regardless of the number of transmit antennas used. At the same time, SM ensures spatial multiplexing gains as information is encoded in the antenna index. However, like all other MIMO schemes, SM suffers performance degradation caused by channel correlations. Trying to improve the performance of SM against channel variations, an adaptive method was proposed, where one candidate is selected from several optional SM structures. Although the performance of SM can be improved to some extent, this method has the following weakness:

1) It requires instant channel state information (CSI), and therefore it is not suitable for fast fading channels;
2) The relation between the adaptive selection and the channel correlation has not been exploited;
3) Despite using a simplified modulation order selection criterion, it still requires significant processing power.

In this context, we propose STBC based adaptive antenna selection method for optimum transmission. Based on transmission optimized spatial modulation (TOSM) and STBC aims to select the best combination of these two constellation sizes, which minimizes the average bit error probability (ABEP). To avoid the prohibitive complexity caused by exhaustive search, a two-stage optimization strategy is proposed. The first step is to determine the optimal number of transmit antennas, and this is performed at the receiver. In the second step, the required number of antennas are selected at the transmitter. In addition to low computational complexity, TOSM needs very limited feedback because of three aspects: i) since it is based on statistical CSI and eigen value, the frequency of updating is relatively low; ii) STBC is used for creating the duplicate of the information signals; and iii) feedback is required only to inform the transmitter of the number of selected antennas, instead of the index of each selected antenna. The overall BS energy consumption is studied for TOSM. The DTX technique is combined with TOSM to further improve the energy efficiency. Compared with our preceding studies, the contributions in this paper are four-fold: i) a two-stage optimization method is proposed to balance the spatial modulation order with the signal modulation order in SM systems; ii) a complete derivation of a simplified ABEP bound for SM over generalized fading channels is presented; iii) a direct antenna selection method based on circle packing is proposed; and iv) the energy efficiency of TOSM in terms of the BS energy consumption is evaluated for both the continuous mode and the DTX mode

2. Existing System

Select The Specific Antenna From Antenna Array

1)Optimal Selection of the Number of Transmit Antennas

In this step, the minimization of the simplified ABEP with respect to N (or M) is implemented for a given scenario, which is comprised of the spectrum efficiency, the number of receive antennas, the SNR, the fading distribution, and the correlation coefficient. The term 1/ηs in (30) is a positive constant, hence it can be removed without affecting the optimization result. In addition, the difference between antennas is not considered in this step. As a result, BN and CN are replaced by BNt and CNt to avoid the dependence on the antenna dissimilarity

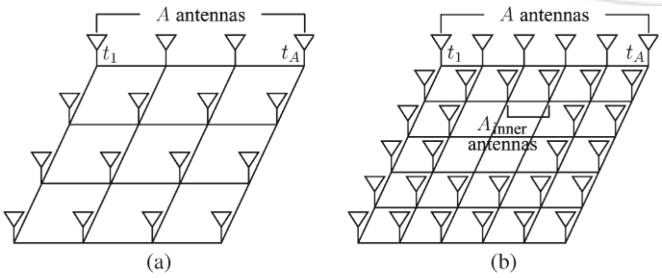

Figure 1: Examples of the transmit antenna array. (a) N_t= 16. (b) N_t= 32.

2)Direct Antenna Selection

The second step is to select a sub array of Nopt antennas from the size-Nt antenna array. The chosen subset should achieve the minimum ABEP of all subarrays with the same size. Since BN is irrelevant to the channel correlations, the problem is equivalent to finding the subarray with a minimum CN. Like the traditional transmit antenna selection (TAS) methods, this issue can be solved by an exhaustive search. However, this results in an unaffordable complexity for a large ηs. Taking ηs = 6 and Nopt = 16 as an example, the full search space is about 5× 1014, which is prohibitive for practical implementations. Here we propose a novel TAS method based on circle packing, which can directly determine the selection.

As the correlation coefficient ρti,tj is inversely proportional to the distance dti,tj, a rational solution is to maximize the minimum geometric distance between any pair of the chosen antennas. This is equivalent to the circle packing problem in mathematics which can be worked out numerically. Fig. 2 shows the circle packing solutions for various numbers of antennas, where the antennas are located at the circle centers. In the original problem, each circle must fit inside the square boundary. The problem at hand is slightly different where the circle centers are restricted to be inside the boundary,

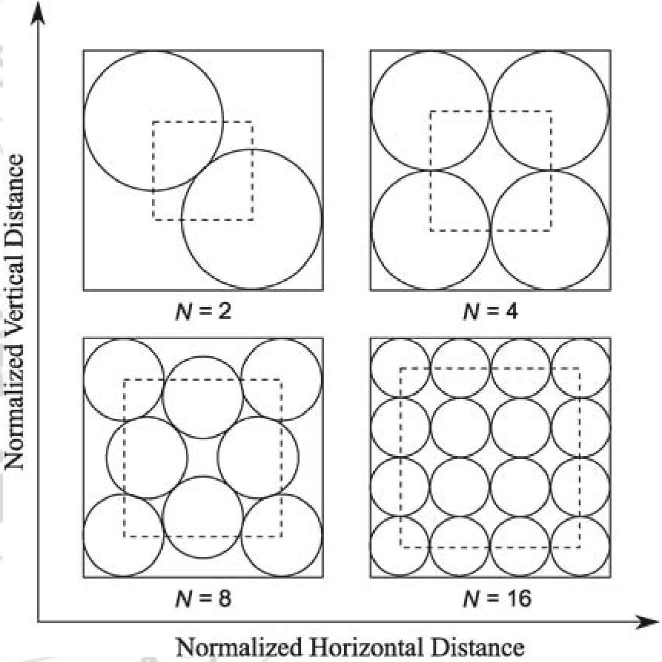

Figure 2: Examples of circle packing problems.

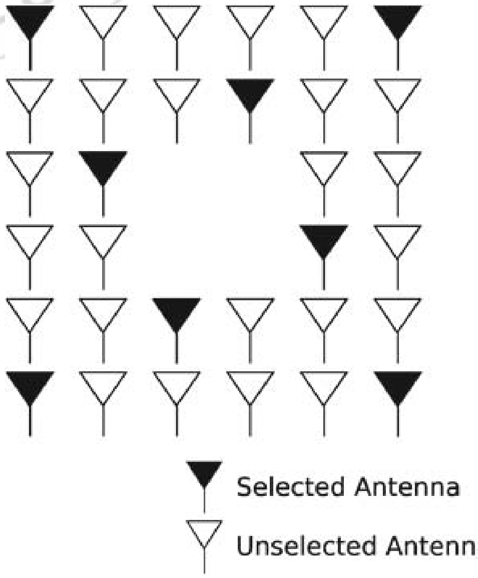

Figure 3: RCP for selecting 8 out of 32 antennas

And in Fig. 2 this is shown by dashed lines. It is worth noting that this solution requires fully flexible positions. Thus, we refer to it as ideal circle packing (ICP). However, the antenna positions are fixed in practice, and the sub array cannot be perfectly allocated by ICP. Instead, a realistic circle packing (RCP) is developed by selecting those antennas closest to the ideal positions. In Fig. 3 , an RCP solution is demonstrated for the case of Nt = 32 and N = 8. As can be observed, the selection presents a similarity to the solution for N = 8 in Fig. 2. With an increase of Nt, the RCP solution becomes closer to ICP as the antenna array supplies a larger flexibility in positions

3. Literature Survey

1) M. Di Renzo, H. Haas, and P. M. Grant, "Spatial modulation for multiple antenna wireless systems: A survey," IEEE Commun. Mag., vol. 49 , no. 12, pp. 182–191, Dec. 2011.
    - Transmission technique
    - Improve spatial efficiency.
2) H.-Q. Lai and K. J. R. Liu, "Space-time network coding," IEEE Trans. Signal Process., vol. 59, no. 4, pp. 1706–1718, Apr. 2011
    - improve communication reliability
    - Signal transmission in TDMA manner cause large transmission delay
    - Transmission from two or more node using FDMA and CDMA are associated with the issue of imperfect frequency and timing synchronization
    - STNC scheme is proposed to achieve full diversity with low transmission delay
    - STNC provide spatial diversity with only(N+R) time slots
3) Kai Yang and, Nan Yang "Space-Time Network Coding With Transmit Antenna Selection and Maximal-Ratio Combining", IEEE Trans. Commun. , VOL. 14, NO. 4, APRIL 2015
    - STNC scheme for cooperative communication to overcome the problem of imperfect synchronization
    - Local area network

4. Proposed System

Using adaptive selection of antenna for optimum transmission in spatial modulation have some limitations. The main limitation is interference. To avoid these limitations, use different enhancement methods. They are,

- Eigen and channel state information based antenna selection
- Space time block code used instead of spatial modulation
- Adaptive filter can be used to avoid interferences

Transmitted signal's quality can be identify using channel state information and Eigen values. Using channel state information and Eigen based antenna selection to get the accurate value or good signals. This method is used for selecting the best antenna for transmission

5. Simulation Results

A. Accuracy of the Simplified ABEP

In Fig. 4, the simplified ABEP expression of STBC is verified against simulation results. To present an extensive comparison, several scenarios are considered by varying the shape factor, the number of receive antennas, the spectrum efficiency and E_b/N_0. A unit spread controlling factor is assumed. For a certain scenario, the BER curve of SM is shown as a function of the average correlation degree. As can be seen, in general, the theoretical curves match the simulation results well. Since the simplified ABEP is an approximation of the ABEP upper bound, we expect some deviations especially at high channel correlations. Despite this, the simplified ABEP is still very close to the simulation results.

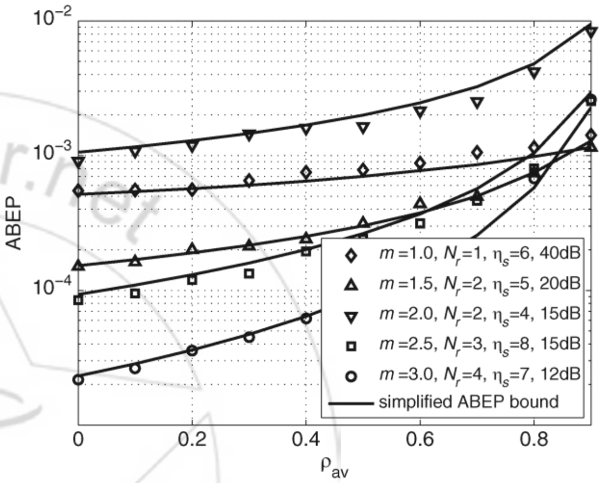

Figure 4: The simplified ABEP bound of STBC versus simulations.

B. Optimality of the Look-up Table

The following outcomes are observed: i) given a certain η_s and N_r, the optimal N decreases as ρ_{av} increases. In other words, it is better to use STBC instead of SM with fewer transmit antennas at high channel correlations; ii) if $N_r = 1$, the best choice regresses to a single transmit antenna scheme for an extremely high ρ_{av}; iii) when N_r is increased, STBC is suitable for more cases of (η_s,ρ_{av}), and the optimal number of transmit antennas becomes larger; and iv) for a certain N_r and ρ_{av}, the best selection of M maintains a constant when η_s is large enough.

In practice, N_r and η_s are usually fixed for a BS. As a result, the only parameter that needs to be determined is the correlation coefficient, which can be obtained through the structured correlation estimator. Using $\eta_s = 6$ and $N_r = 2$, for example, Fig. 5 shows the simulation results of various fixed-SM schemes at $E_b/N_0 = 25$ dB. As shown, SM using $N = 16$ outperforms $N = 8$ when ρ_{av} is below 0.5. However, the opposite result happens for $0.6 \leq \rho_{av} \leq 0.9$. At an extremely high correlation of $\rho_{av} = 1$, two transmit-antenna SM achieves the lowest BER.

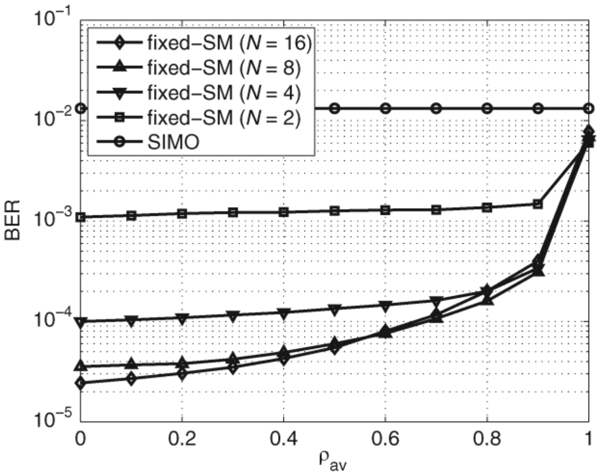

Figure 5: BER performance of fixed-SM schemes over c.i.d. Rayleigh fading

C.BER Performance of Direct Antenna Selection

The BER performance of the proposed RCP approach is evaluated against two baseline schemes: i) the exhaustive search (ES); and ii) the worst case where the neighbouring antennas are selected. We refer to this scheme as worst selection (WS) in the sequel.

Fig. 6 and Fig. 7 present the BER performance of RCP for η_s = 4 and 5, respectively. Due to the intractable complexity of ES, the results when $\eta_s > 5$ are not presented. In addition, the antenna area is assumed to be the same to ensure a fair comparison for different η_s. Therefore, ρ_s is used instead of ρ_{av}. As shown, the RCP scheme achieves almost the same performance as ES with a gap of less than 0.3 dB. Furthermore, the negligible difference between RCP and ES is barely affected by the channel correlations, whereas the performance of WS becomes much worse as the correlation increases. To achieve the same BER value of 1×10^{-4} in the case of selecting 8 out of 32 antennas, in comparison with WS, RCP obtains an energy saving of 1.1 dB and 2.0 dB at ρ_s = 0.1 and 0.9, respectively.

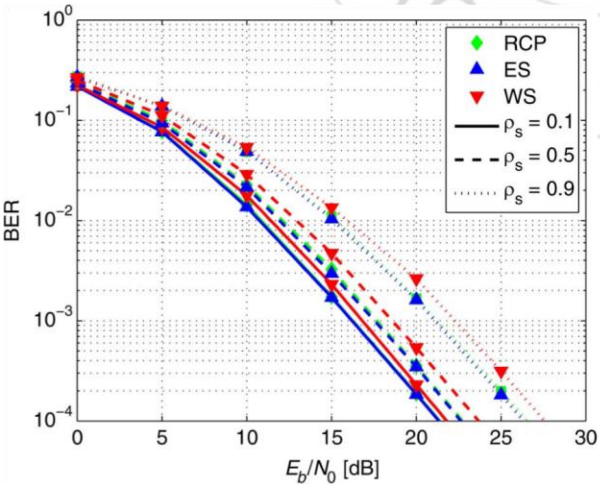

Figure 6: BER performance of RCP for $N_t = 16$ and $N = 8$

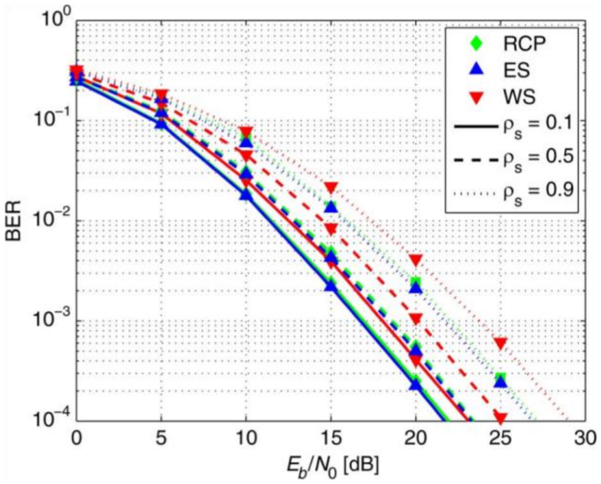

Figure 7: BER performance of RCP for $N_t = 32$ and $N = 8$

D.BER Performance of TOSM

The complexity of the MIMO system depends on the number of RF chains rather than the total number of transmit antennas. Despite the requirement of large antennas at the transmitter, TOSM needs only one RF chain. For this reason, it is reasonable to compare our approach to fixed-SM schemes with the same η_s. Based on the obtained optimal N, we evaluate the BER performance of TOSM. Assuming $N_r = 2$ and E_b/N_0 = 25 dB, Figs. 8–10 show the BER results against the channel correlation for η_s = 4, 5 and 6, respectively. The case of $N = 1$ is referred to as single-input multiple-output (SIMO).

The following trends are observed: i) fixed-SM with more antennas is not always better than those using fewer antennas. This signifies that the benefit does not simply come from employing more transmit antennas; ii) TOSM and STBC always performs better than fixed-SM schemes, which validates the optimization results; and iii) when η_s increases, TOSM and STBC employs more transmit antennas and performs much better than the fixed-SM with a small N. Specifically, STBC slightly outperforms fixed-SM with $N = 2$ at both low and high correlations for $\eta_s = 4$. However, for η_s = 5 and 6, STBC can always achieve a significant gain except when the channel correlation is extremely high. Similar, but less pronounced trends are noticed at lower SNRs. In Fig. 11, the BER performance of TOSM/ STBC is shown as a function of E_b/N_0 for η_s = 6. As can be seen, TOSM significantly outperforms the other schemes for all presented SNRs and various channel correlation degrees. When the channels are independent, i.e. $\rho_s = 0$, STBC saves energy in the regions of 0.8 dB, 8.7 dB, and 15.1 dB relative to SSK, fixed-SM with N = 2, and SIMO, respectively. As ρ_s increases, TOSM outperforms SSK more significantly. Conversely, fixedSM with $N = 2$ is only slightly affected by the channel correlation, and the advantage of TOSM is diminishing with an increase of ρ_s. However, the gain of TOSM over fixed-SM with $N = 2$ still exceeds 4 dB at ρ_s = 0.8.

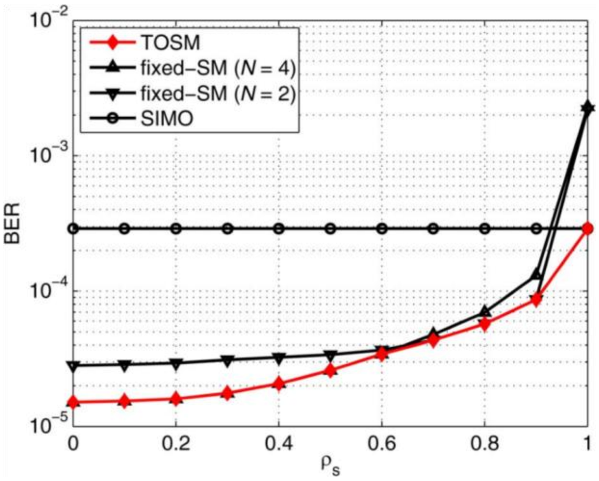

Figure 8: BER performance of TOSM/STBC against channel correlation for $\eta_s = 4$.

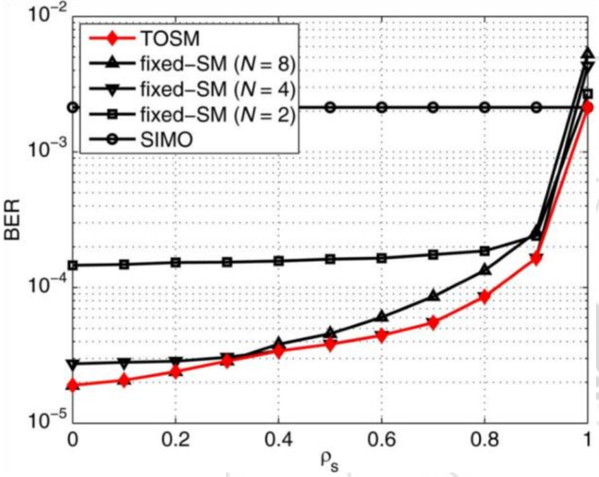

Figure 9: BER performance of TOSM/STBC against channel correlation for $\eta_s = 5$.

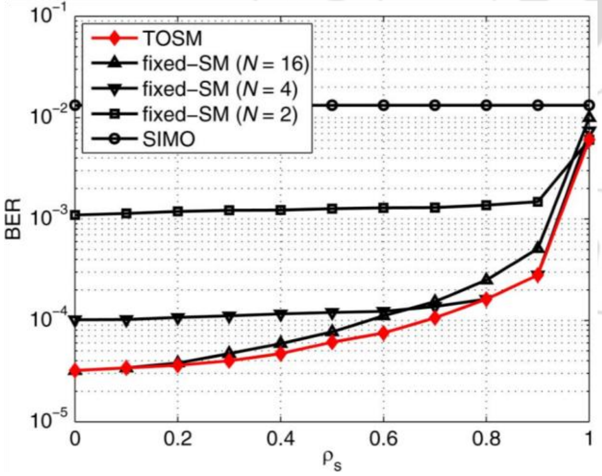

Figure 10: BER performance of TOSM /STBC against channel correlation for $\eta_s = 6$.

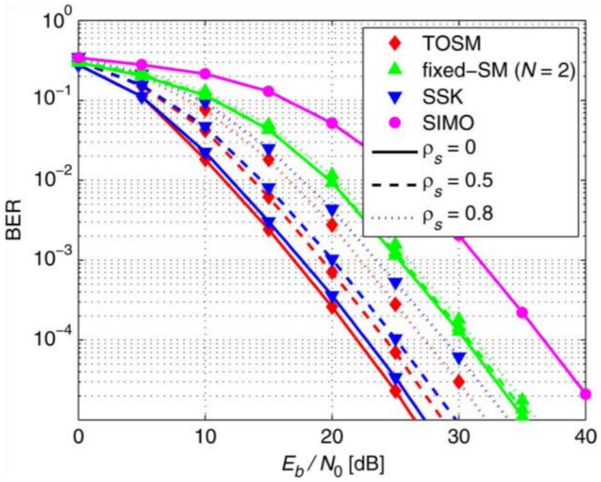

Figure 11: BER performance of TOSM/STBC against E_b/N_0 for $\eta_s = 6$.

E. Energy Consumption

The overall BS energy consumption of TOSM and STBC is studied in contrast fixed-SM. The simulations are restricted in two aspects. On the one hand, the number of transmit antennas is limited due to the constraint $N_r \geq N_t$. On the other hand, when using more transmit antennas, TOSM/STBC can save more energy in RF chains. The motivation here is to validate the energy efficiency of TOSM. To carry out a relatively fair comparison, the case of $\eta_s = 4$ and $N_r = 4$ is chosen, where TOSM employs four transmit antennas for the channel correlation varied from 0 to 0.8.

Fig. 12 gives the transmit energy consumption results for a target BER value of 1×10^{-4}. It is noticed that, STBC provides a remarkable and stable gain of around 5 dB in comparison with SM. The overall BS energy consumptions in both the continuous mode and the DTX mode are shown in Fig. 13. To maintain a certain E_b, $P_{\max}$ leads to a ceiling of the transmission rate. For this reason, a bit rate of 30 Mbit/s is chosen to ensure the BS works physically, and we compare TOSM with STBC to show the trends. The following outcomes are observed: i) using the DTX mode for STBC provides a gain of around 1.4 dB over the continuous mode; ii) STBC significantly outperforms both the continuous mode and the DTX mode with energy-saving gains of at least 6.3 μJoule/bit (56%) and 5.8 μJoule/bit (62%), respectively; iii) compared with multi stream MIMO schemes, STBC requests much less energy because of the single RF chain requirement; iv) in both modes, the gain obtained by TOSM increases as ρ_s increases; and v) TOSM and STBC saves more energy in the DTX mode than the continuous mode, especially at high channel correlations. When $\rho_s = 0.8$, for example, STBC outperforms SM by 7.7 μJoule/bit (57%) and 8.0 μJoule/bit (63%) in the continuous mode and the DTX mode, respectively.

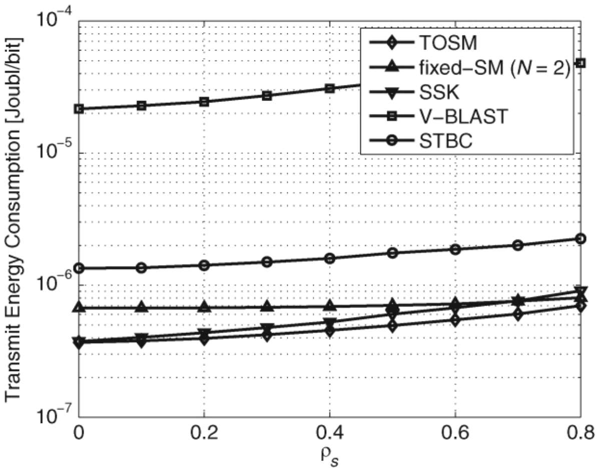

Figure 12: Transmit energy consumption of STBC.

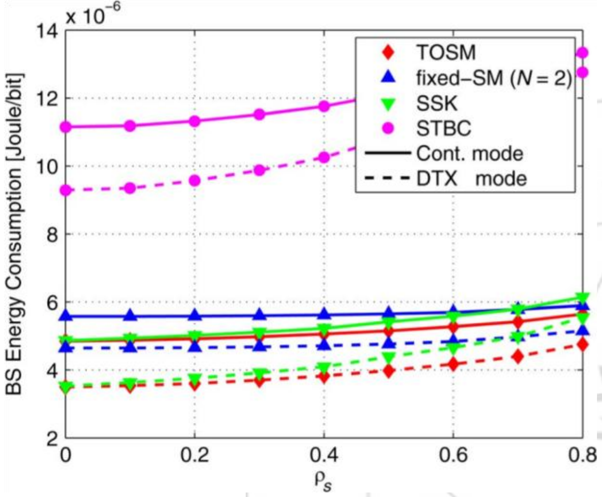

Figure 13: BS energy consumption of STBC for $R_b = 30$ Mbit/s.

F. Maximum Transmission Rate

In contrast to multi-stream MIMO schemes, STBC requires only one RF chain, and therefore less energy is requested to drive it. However, the maximum RF output power of STBC is $1/N_{\text{act}}$ of the MIMO scheme with N_{act} active antennas, and this restricts the maximum transmission rate of STBC. Fig. 14 shows $R_{b\max}$ as a function of the channel correlation in the same scenario of the previous subsection. Meanwhile, TOSM offers a great improvement of maximum transmission rate to the original SM and overcomes this disadvantage. In Fig. 15, the BS energy consumption gains between TOSM and STBC are presented in terms of the transmission rate. As shown, the gain of TOSM obtained in the DTX mode is larger than the continuous mode for various correlation degrees. Also, DTX is much better than the continuous mode when R_b increases to the full load. This signifies that STBC is more robust and energy-efficient when combined with DTX.

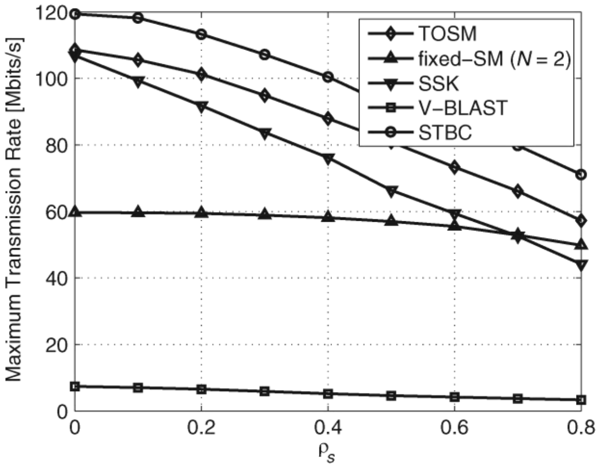

Figure 14: Maximum transmission rate of STBC.

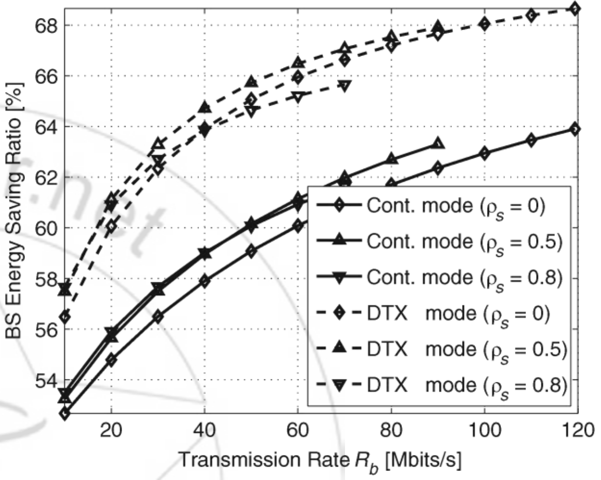

Figure 15: BS energy saving ratio between TOSM and STBC

6. Conclusion

In this paper, we proposed an optimum transmit structure using STBC, which balances the size of the spatial constellation diagram and the size of the signal constellation diagram. Instead of using exhaustive search, where the optimal number of transmit antennas and the specific antenna positions are determined separately. The first step is to obtain the optimal number of transmit antennas by minimizing a simplified ABEP . In the second step, a direct antenna selection method, named RCP, was developed to select the required number of transmit antennas from an antenna array. In addition, a look-up table was built in the case of c.i.d. Rayleigh fading, which can readily be used to determine the optimum transmit structure. Results show that STBC improves the BER performance, and outperforms TOSM greatly in terms of the overall BS energy consumption. A further study shows that STBC is more energy efficient when combined with the DTX mode than the continuous mode. Furthermore, the issue with respect to the maximum transmission rate in the STBC systems has been addressed, which is caused by the limited output power of a single RF chain. It was shown that STBC uplifts the maximum transmission rate, and diminishes the gap between SM and STBC significantly. All these merits make STBC a highly energy-efficient, low-complexity scheme to satisfy the requirement of high data rate transmission, and an ideal candidate for massive MIMO.

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