A SCHEME FOR AN STF CODING AND ADAPTIVE MULTIPLE ANTENNA SELECTION FOR IMPROVING THE PERFORMANCE OF MULTIPLE-INPUT SINGLE-OUTPUT OFDM SYSTEM

N.K. Noordin and B.M. Ali.
Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Malaysia
Email: nknordin@eng.upm.edu.my

ABSTRACT

This paper describes a multiple-input single-output (MISO) orthogonal frequency division multiplexing employing space-time-frequency coding with antenna selection at the receiver. The system in tested in a severe IEEE 802.16 broadband wireless access channels. Adaptive multiple antenna selection (AdMAS) was performed based on the second-order moment of the channel impulse response and only good channels were use for data transmission. Results show that our second-moment-based AdMAS scheme with 2 most faded transmitters turned off outperforms similar schemes based on the mean of the CIR, and conventional coded STF-OFDM. Second-moment-based scheme shows significant gain in terms of Signal to Noise Ratio (SNR) requirement especially at higher level constellations which makes it a potential scheme to be employed for realization of high data rates system.

Keywords*: STF coding, OFDM system, antenna*

INTRODUCTION

Multiple-Input Multiple-Output (MIMO) antenna links are increasingly important because of their potential to provide high data rate at extremely high spectral efficiencies [1]. One example of spatial modulation technique for such MIMO systems is known as spatial multiplexing [1, 2]. It obtains a high spectral efficiency by dividing the incoming data into multiple substreams and transmitting each substream on different antenna. The substreams are consequently separated at the receiver by means of various techniques [3, 4].

The performance of MIMO systems can be improved by employing a larger number of antennas than actually used and selecting the optimal subset based on channel state information. Mobiles in future broadband systems supporting spatial multiplexing will be capable of receiving substreams from multiple transmit antennas on one or more base stations. Simultaneous transmission from all available transmit antennas may be difficult due to hardware costs. It is therefore of interest to select a subset of available antennas for transmission.

Selection has been considered in the past in the context of both transmit and receive diversity. Selection for multiple-transmit multiple-receive antenna systems was first presented in [5] based on the argument that it increases capacity. The selection criterion proposed in [6] is based on Shannon capacity and does not readily apply to spatial multiplexing. In [4], antenna selection algorithms that minimized the BER of linear receivers in spatial multiplexing systems were presented, while [7, 8] proposed selection algorithms to minimize SER when orthogonal block coding is used in MIMO systems.

This paper proposes adaptive multiple antenna selection (AdMAS) in which a subset of '*strong*' antenna is chosen among the many available multiple transmit antennas at the base station for transmissions. This selection is based on the second-order moment of the channel impulse response of the channel realization. We assume that the channel is characterized by quasi-static Rayleigh flat-fading when orthogonal frequency division multiplexing (OFDM) is employed when the subchannels fade independently. We also assume that the channel state information (CSI) is readily known at both the transmitter and receiver thus allowing the transmitter to determine the '*strong*' channel to use. This is normally obtained via a dedicated feedback channel from the receiver to the transmitter or as in time division duplex (TDD) where both transmitter and receiver share the same channel.

The rest of the paper is organized as follows. Section 2 explains the motivation behind the proposed antenna selection method. Section 3 describes the integration of our coded Space-Time-Frequency (STF)-OFDM with the proposed AdMAS scheme. We explain the new algorithm used in our scheme in Section 4. Section 5 presents our findings and discussion and we conclude in Section 5.

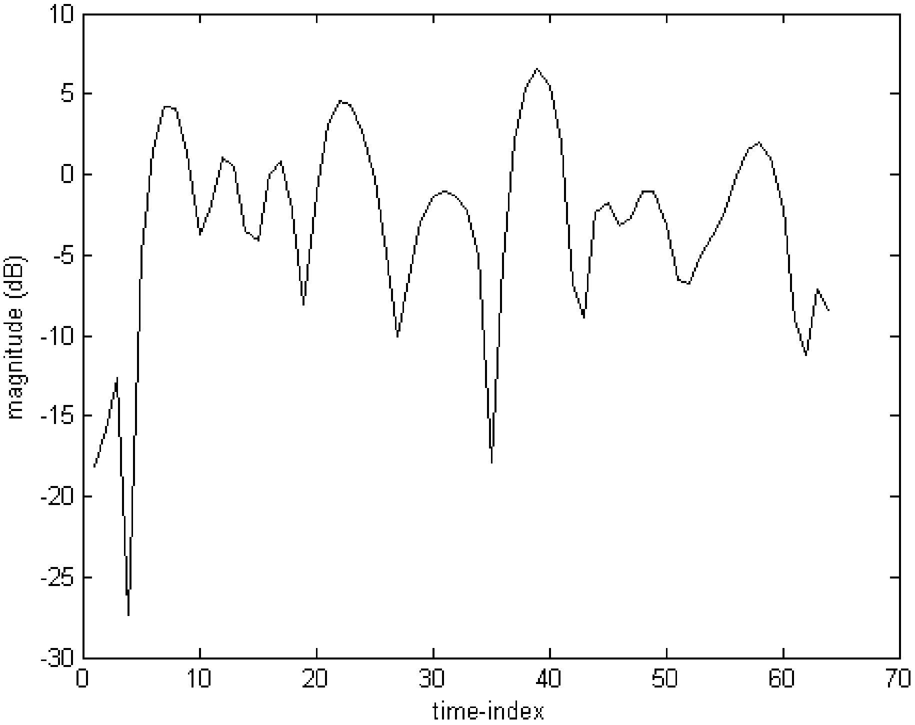
MOTIVATION

The adaptive selection of good channels at the transmitting antennas to be employed in our proposal comes from the idea of adaptive subcarriers used in adaptive modulation OFDM system (e.g. [9] and [10]). Instead of using the good subcarriers of OFDM we shall alternatively use the subchannels of the multiple antennas system to determine which antenna to use and which to switch off.

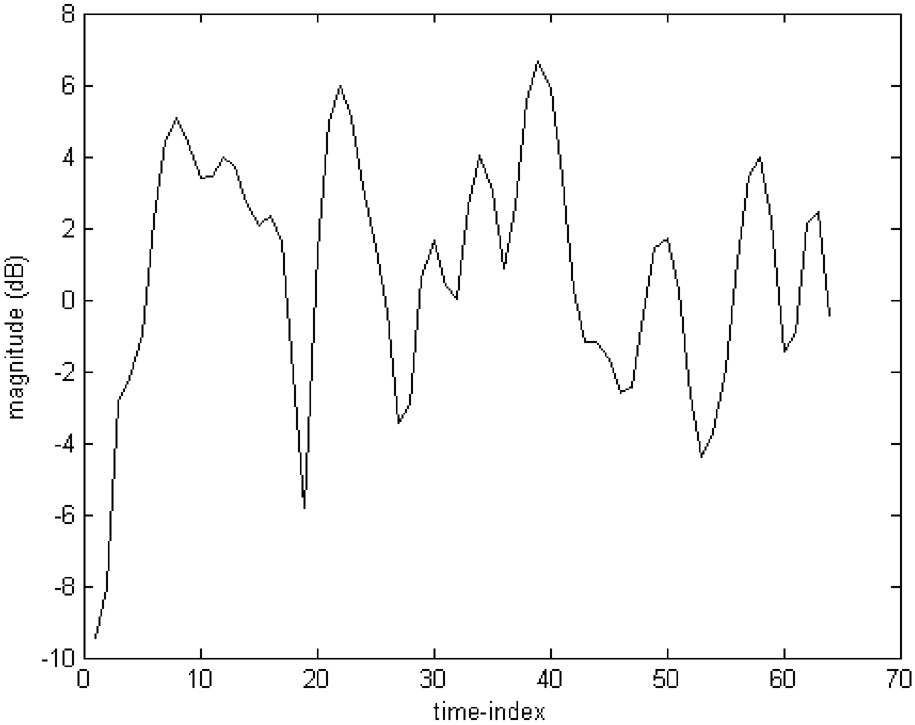
Consider a case where $h_i(t) \quad i = 1, 2, \cdots, M$ are multipath components of a channel impulse response with the number of maximum available antennas equals 8. Note that in Figure 1, deepest fade of envelope $h_1(t)$ has been reduced in the two-path envelope (Figure 1b) and further reduced in the resultant eight-path envelope channel (Figure 1c) which will then make it more reliable from a communication perspective. We extend this hypothesis one step further by removing 2 channels with worst fade from the total channels and found that the resultant channels improve significantly in terms of magnitude as shown in Figure 1d. Note that the simulated example shown is based on the famous Clarke fading channel models described in [11].

INTEGRATION OF CODED STF-OFDM WITH THE SECOND-MOMENT BASED ADAPTIVE MULTIPLE ANTENNA SELECTION (AdMAS)

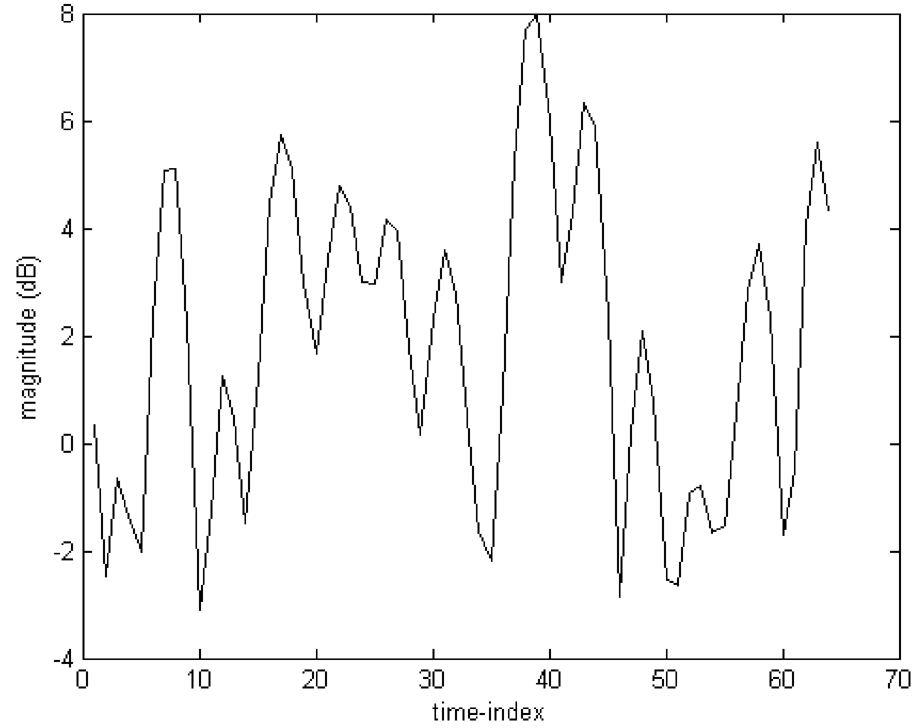
In this section we present an adaptive multiple antenna selection (AdMAS) integrated with a 4-transmit and 1-receive Multiple-Input Single-Output (MISO) coded STF-OFDM as per the system described in [12]. Since modulation is non-coherent in our system, hence the selection of antenna is also non-coherent [13]. The transmission of the proposed system is made over Broadband Wireless Access IEEE 802.16 Stanford Interim University (SUI) channels. The coded STF-OFDM is a product of phase-shift-keying (PSK) modulated STF block code which has been concatenated with convolutional codes of either rate 1/3, constant length of 8, with code generator of [225 331 367], or rate ½, length of 5, with code generator of [23 35], termed as Code B and Code D, respectively.



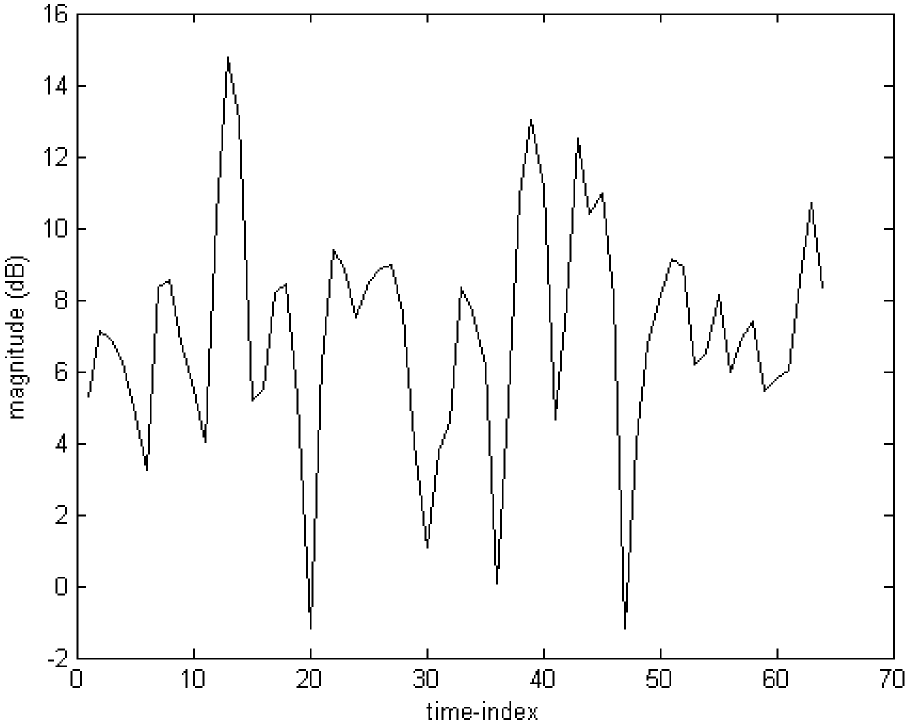
a) a random single-path envelope



b) a two-path envelope



c) a resultant eight-path envelope



d) the resultant six-path envelope with the 2 worst faded channels turned off

Figure 1: a) single path, b) two-path , c) resultant eight-path, d) resultant six-path channel with the two worst faded channels turned off in an 8-antenna transmit diversity system

In transmitting data we adaptively select channel with the least fade and turn off the most faded channel at the transmitter side. We determine levels of fading of the channel from each transmitter based on the calculated second moment of the channel impulse response (CIR). We also compare results when level of fading is based on the mean of the CIR. We tested our scheme in the most severe case of SUI channel, i.e. SUI-6, and compare results with that of SUI-2 channel as a benchmark. Results show that the employment of AdMAS does not give a significant improvement (less than a dB) to the performance either adapting to the second moment or mean of the CIR at low-level constellations. However significant gain is observed at higher constellations that make our proposed scheme a potential scheme to employ for a high data rate system.

CHANNEL MODEL WITH AdMAS

We generate a set of four SUI-6 channels that correspond to independent fading between transmitting antennas and the receiving antenna. As mentioned earlier, we determine the level of fading using the second moment of the CIR, with the assumption that the CSI is known to both the transmitter and receiver. Based on the calculated value, we turn off the most faded channel(s) and transmit data only from the good channels. The algorithm of the method can be summarized at follows.

Algorithm

i. Generate a set of 4 channels $\mathbf{h}_{j,1} \quad j = 1,2,3,4$.

ii. If there are two rows of $\mathbf{h}_{j,1} \quad j = 1,2,3,4$ that are identical in magnitude and the lowest, delete either one.

iii. Calculate the second moment, $\mathcal{E}\{\mathbf{h}_{j,\mathbf{1}}{}^2\} - (\mathcal{E}\{\mathbf{h}_{j,\mathbf{1}}\})^2$ of each of the channel impulse response after performing the initial selection.

iv. Select the minimum value found and set the channel response to zero.

v. Transmit

For comparison purposes, we replace step (iv) when the level of fading is determined by the mean of the CIR.

iv. Calculate the mean, $\mathcal{E}\{\mathbf{h}_{\mathrm{j},\mathbf{1}}\}$ of each channel in the set.

We measure the performance of our second-moment-based AdMAS coded STF-OFDM using a 30° directional antenna, over a very severe SUI-6 channels. We compare the performance of our proposed scheme to mean-based AdMAS.

SIMULATION AND RESULTS

Simulation of Coded STF-OFDM with AdMAS is performed based on the simulation parameters shown in Table 1. Figure 2 shows the performance of our Coded STF-OFDM AdMAS system adapting to the second-order moment of CIR by turning OFF two worst faded channels in conjunction with Code B and Code D for channel coding. Results show that employing Code B improves the BER performance especially in high level constellation such as 16-QPSK in severe SUI-6 channels. However, Code D is sufficient to withstand channel error for low modulation scheme.

We also tested our proposed scheme by turning OFF one or two transmitters adapting to the second-order moment of CIR. Results in Figure 3 show that turning off two most faded channels provides significant gain of about 7.5 dB for 16QPSK (at BER of 10^{-4}) compared to turning off just one antenna.

We also compared our results when adapting to the mean of the CIR and found that our scheme outperformed the mean-based AdMAS and conventional coded STF-OFDM especially at higher constellations as shown in Figure 4. It is interesting to note that since the diversity is three-fold, i.e., in space, time, and frequency dimension, we could also turn off 3 transmitted antennas and leave the best antenna to be operational. The results are not significant as shown in Figure 5, and are comparable to the ones by turning off 2 worst antennas. However, turning off 3 worst antennas and only operate with the best channel can be cost-saving in terms of Radio Frequency (RF) chains from the transmitter to the receiver but at higher complexity of signal processing.

Figure 4 shows the performance comparison of our proposed scheme to the mean-based AdMAS and the conventional fixed transmitter coded STF-OFDM with no AdMAS. We observed that our proposed scheme does not contribute much gain at low level constellation but show significant improvement of more than 10 dB (at BER of 10^{-4}) at higher constellation of 16-PSK. This is due to the ability of the second-moment to capture information on the time (or frequency) selectivity of the channel within the adaptation window over time (or frequency) [25]. Note also that the diversity degree is retained even when employing AdMAS compared to full-complexity system when no antenna selection is employed.

Table 1: Coded STF-OFDM with AdMAS Parameters Setup

Parameters	Value	Remarks
Operating frequency, f_c	5.25 Ghz	-
Number of subcarriers, N	1024	$N \times \Delta f \leq BW$
FBWA IEEE802.16 Channel	SUI2 and SUI-6	SUI-2 (close to flat fading condition) and SUI-6 (a very severe channel)
Broadband bandwidth, BW	200 MHz	Broadband
OFDM subcarrier spacing, Δf	195.3125 kHz	BW/N
OFDM symbol duration, T_{OFDM}	5.12 μs	$1/\Delta f$
Cylic prefix, T_{CP}	1.28 μs	At least 25% of T_{OFDM}
Channel Coding	Convolutional	Rate 1/3 with length 8, code generator =[225 331 367] (Code B) Rate ½, length of 5, code generator = [23 35] (Code D)

CONCLUSION

We have described and simulated a 4 transmit 1 receive second-moment-based AdMAS coded STF-OFDM over IEEE 802.16 broadband wireless access channels particularly in a severe SUI-6 channels. Results show that our second-moment-based AdMAS scheme with 2 most faded transmitters turned off outperforms similar schemes based on the mean of the CIR, and basic coded STF-OFDM. Second-moment-based scheme show significant gain in terms of Signal to Noise Ratio (SNR) requirement especially at higher level constellations which makes it a potential scheme to be employed for realization of high data rates system. Note also that antenna selection retains the diversity degree for our space-time-frequency coded system.

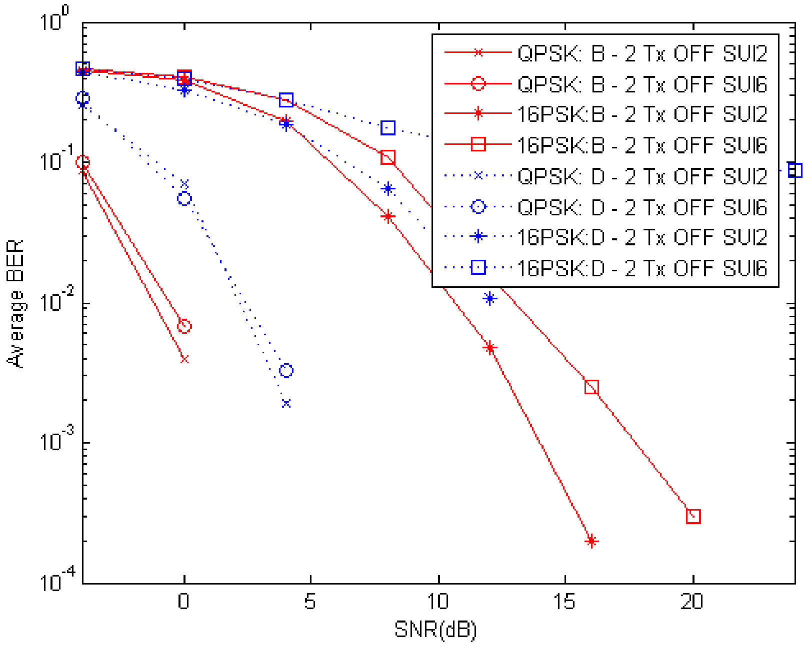


Figure 2: Performance comparison Coded STF-OFDM with 2 Tx OFF employing 30° directional antenna adapting to second-order moment of CIR

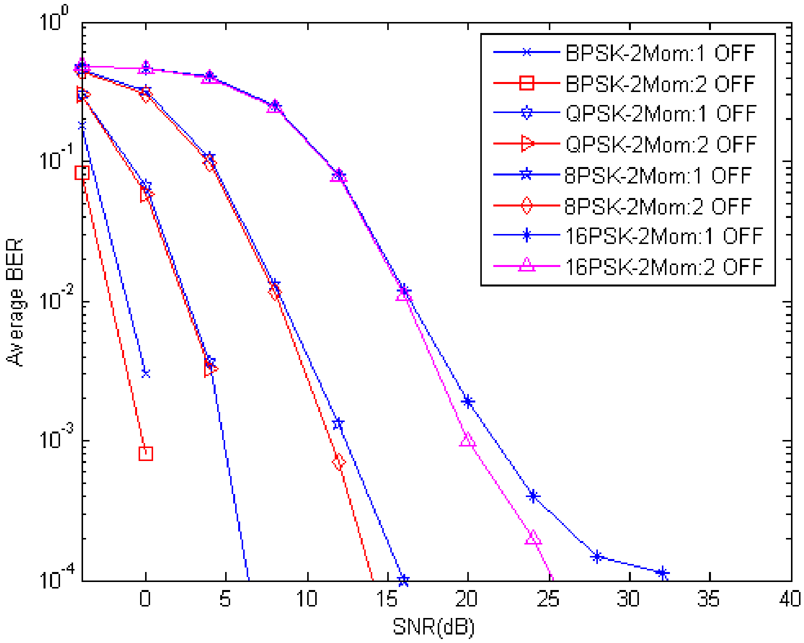


Figure 3: Second-moment-based AdMAS of coded STF-OFDM using directional antenna over SUI6 channels

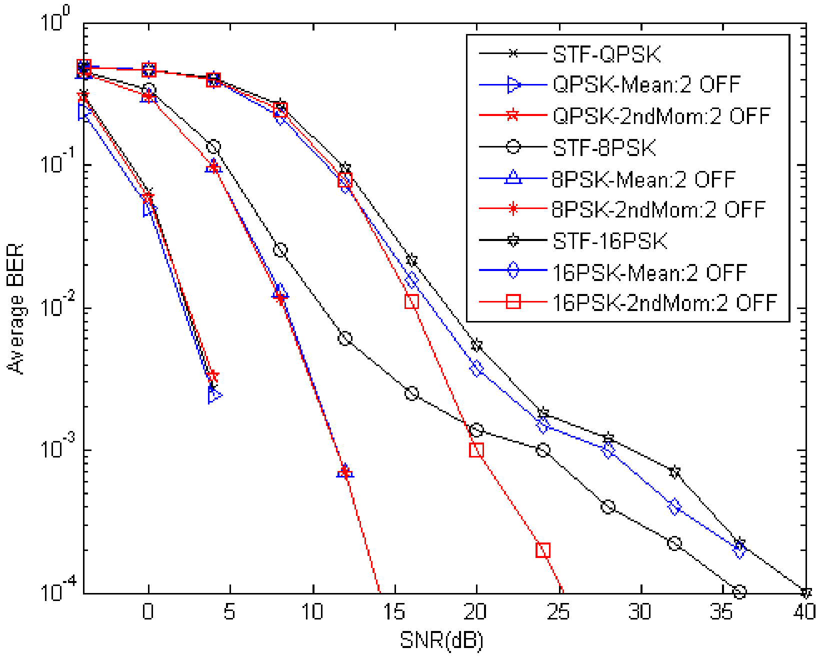


Figure 4: Comparison of second-moment and mean-based AdMAS of coded STF-OFDM using directional antenna over SUI6 channels

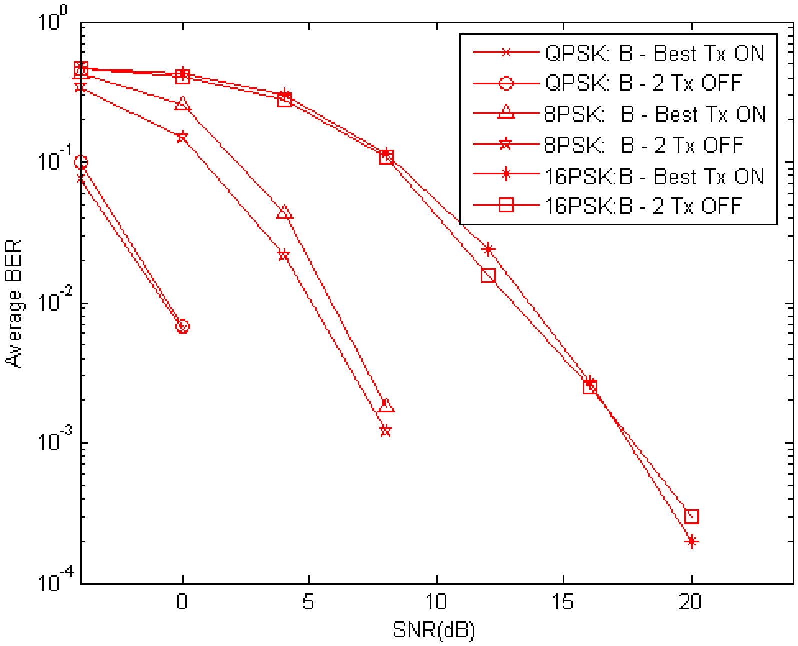


Figure 5: Performance comparison of Coded STF-OFDM with 2 Tx OFF and the best transmitter ON employing 30° directional antenna adapting to second-order moment of CIR over SUI6

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