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A Hybrid Coding Technique for Efficient Bandwidth Usage in Conformity with IEEE 802.11 WLAN Standard

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ABSTRACT

The contemporary Wireless Local Area Networks (WLANs) systems like IEEE 802.11a/g standards use Coded Orthogonal Frequency Division Multiplexing (COFDM) and offer data rates of up to 54 Mbps at 2.4 GHz or 5 GHz. IEEE 802.11n is a recent WLAN standard capable of not only providing increased data rate and improved range but also reduced signal fading. These benefits are achieved through the use of space-time coded Multiple-Input, Multiple-Output with Orthogonal Frequency Division Multiplexing (MIMO-OFDM) technique which provides the possibility of increased signal strength at the receiver with optimal bandwidth and power efficiency. In this paper, a novel hybrid space-time block coding (HSTBC) scheme is proposed for mitigating signal fading as well as enhancing the performance of MIMO–OFDM based WLANs. The signal to be transmitted is first pre-coded and the resulting output is then coded using space-time block code to form a HSTBC. Simulation results show that the HSTBC scheme considerably reduced the effect of multipath fading in wireless communication systems with improved bit error rate. Our proposed HSTBC improves the performance of the system in terms of data transmission as the capacity of the system almost doubled the capacity of a conventional STBC system.

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1. INTRODUCTION

The rate of acquisition and usage of wireless local area network (WLAN) technology, internet, internet supported mobile telephony systems and multimedia services has put a lot of pressure on spectrum demand particularly in wireless communication systems (WCS). The allocated radio spectrum to wireless systems and/or service providers is limited because of its scarce nature. As a result, the development of WCS has to focus on increasing data rate as well as improving performance without increase in bandwidth and transmission power [1-3].

The communication channelsenvironment that WCS operates determines their performance. These channels are characterized by time varying propagation medium, which influences the quality of signals being transmitted causing them to vary rapidly. The received signals may be impaired due to lack of line-of-sight during transmission, multiple reflection of radiated energy from man-made objects, scattering, as well as mobility-also known as Doppler [4-6]. By the time-varying nature of the received signals, the resultant effects of the impairments could be constructive, or occasionally destructive, forming a periodically fading signal at the receiver. Strong destructive interference is often referred to as a deep fade. Consequently, signal-to-noise ratio (SNR) drops significantly resulting in deep notch in the received signal [6].

Fading, not only leads to degradation in the quality of the propagated signal but also, restricts the speed and reliability of the system. Fading-effect is more pronounced in systems operating in the Unlicensed National Information Infrastructure (UNII) operating frequency range like the WLAN systems. A plethora of techniques has been proposed in the literature to reducing the effects of fading, with application to WCS particularly, some of such applications are: (1) the combination of MIMO and OFDM which is potentially robust to channel frequency selectivity as well as in combating fading effects [6-9]; (2) the forward error correction technique such as space-time coding in MIMO channels [10, 11]. These approaches have proved to increase data rate by improving the *bit error rate* (BER) performance of the system.

At present various IEEE 802.11a/g WLAN standards based on OFDM that support broadband multimedia communications are being deployed around the world. These standards provide data rates up to 54 Mbps at 2.4 GHz or 5 GHz.

With the new IEEE 802.11n standard, data rates up to 600Mbps are possible, based on physical layer (PHY). MIMO-OFDM techniques are used to achieve these rates and the actual data rate depends on the number of antennas at both sides of the link, distance between transmit and receive antennas, interference, and other devices operating in the area [12]. IEEE 802.11 standards along with their other specifications are listed in Table 1 [13].

Table 1. IEEE 802.11 WLAN standards

Specifications	**Standards**			
	IEEE 802.11a	IEEE 802.11b	IEEE 802.11g	IEEE 802.11n
Frequency	5 GHz	2.4 GHz	2.4 GHz	2.4 GHz or 5 GHz
Maximum Speed	54 Mbps	11 Mbps	54 Mbps	Up to 600 Mbps
Maximum Range	150 Ft.	300 Ft.	300 Ft.	1200 Ft.
Channels (Non-Overlapped)	23 (12)	11 (3)	11 (3)	2.4GHz-23(12 or 6) 5 GHz-11(3 or 1)
Modulation Technique	OFDM	DSSS, DQPSK,	DSSS, OFDM,	MIMO-OFDM and others, depending on implementation
Backwards-Compatibility	N/A	No	With 802.11b	With 802.11a/b/g, depending on implementation

In this paper, a novel hybrid space-time block coding (HSTBC) scheme is proposedfor enhancement of the performance of MIMO-OFDM based WLANs. The performance of the proposed HSTBC over both flat and frequency selective channels is compared with that of conventional AlamoutiSTBC. The HSTBC scheme can relatively reduce the effect of multipath fading in WCS and can double the capacity of a conventional Alamouti STBC system.

In Section 2, the mathematical description of the space-time coded OFDM is discussed. Section 3 discusses the MIMO system model using a 2×2 scheme as a case study. Section 4 presents the HSTBC Scheme. Section 5 contains the mathematical descriptions of capacity of an ergodic channel. Section 6 presents the performance curves generated based on simulation models developed in MATLAB® while Conclusions are drawn in Section 7.

2. SPACE-TIME CODING (STC) AND ORTHOGONAL FREQUENCY-DIVISION MULTIPLEXING (OFDM)

The need to enhance the quality of wireless communication systems in the range of their wired counterparts leads to development of space-time processing for MIMO wireless communications. In wireless channels of WCS, forward error correction technique is employed to combat effects of fading. Space-time code (STC) is an example of forward error correction techniques employed in multi-antenna systems to reduce the effects of fading particularly in MIMO channels [14, 15].

In an application of MIMO transmit strategy, the STC technique exploits transmit diversity and gives high system reliability, and leads to various coding methods: e.g. space-time trellis codes (STTC); space-time block codes (STBC); space-time turbo trellis codes and layered space-time (LST) codes [15 - 17]. STTC and LST have an advantage over STBC by offering coding gain although they are very difficult to design and require complex encoders and decoders [18, 19].

Though the design of space-time codes in frequency-selective-fading channel is intricate because of the existence of Inter Symbol Interference (ISI), the OFDM technique attempts to combat the ISI problem [19-21]. OFDM converts a frequency selective MIMO channel into a set of parallel frequency flat MIMO channels and randomizes the burst errors caused by a wideband-fading channel [5, 9]. In an OFDM system, the entire channel is partitioned into sub-channels and a block of low rate data stream is modulated to a set of subcarriers [21 - 23]. In communication systems, multiple-access schemes are said to be orthogonal when an ideal receiver can completely reject arbitrarily strong unwanted signals using different basis functions than the desired signal.

Hence, if suppose there are *N* numbers of sub-channels in an OFDM symbol, and the pair of OFDM symbols in an STBC block is written as

$$\mathbf{X} = \begin{bmatrix} x_{(n)} & x_{(n+1)} \end{bmatrix}^T \tag{1}$$

where $x_{(n)}$ and $x_{(n+1)}$ are the modulated symbols and $[.]^T$ denotes the transpose operation. Suppose the ST encoder maps $\boldsymbol{X}$ into

$$\mathbf{X}_{(\mathbf{n})} = \begin{bmatrix} x_{(n)} & -x^*_{(n+1)} \\ x_{(n+1)} & x^*_{(n)} \end{bmatrix} \tag{2}$$

where $\mathbf{X}_{(\mathbf{n})}$ is the output of ST encoder, symbols $-x^*_{(n+1)}$ and $x^*_{(n)}$ are orthogonal copies of the original symbols.

Then, at the first time *t*, the symbols $x_{(n)}$ and $x_{(n+1)}$ are transmitted simultaneously from the two transmit antennas. Assuming that each symbol has duration *T*, at the next time slot *t*+*T*, symbols $-x^*_{(n+1)}$ and $x^*_{(n)}$ are transmitted from the two antennas respectively. In this scheme, at the first timeslot, the original sequence is transmitted unaltered, while at the second timeslot, space-time coded version is transmitted. Upon application of Alamouti’s space-time block coding, symbol can be transmitted both in space and time [2, 6].

3. MIMO SYSTEM MODEL

For a generalized MIMO scheme with N_t transmitantennasand N_r receive antennas, the received signal vector $\boldsymbol{y}$ can be modeled as [4]:

$$\boldsymbol{y} = \boldsymbol{Hx} + \boldsymbol{n} \tag{3}$$

where $\boldsymbol{x}$ is the transmitted signal vector, $\boldsymbol{H}$ is the channel matrix —also known as channel state information—between transmitter and receiver, and $\boldsymbol{n}$ is the complex additive white,Gaussian noise vector. The channel matrix is expressed according to [3] as:

$$\boldsymbol{H} = \begin{bmatrix} h_{11} & h_{12} & h_{13} & \cdots & h_{1N_t} \\ h_{21} & h_{22} & h_{23} & \cdots & h_{1N_t} \\ h_{31} & h_{32} & h_{33} & \cdots & h_{3N_t} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ h_{N_r1} & h_{N_r2} & h_{N_r3} & \cdots & h_{N_rN_t} \end{bmatrix} \tag{4}$$

where elements $h_{i,j}$ are channel coefficients from the *j*thtransmit to *i*threceive antennas. The channel coefficients between transmitter and receiver are assumed constant during the transmission of two consecutive symbols. So, channel coefficients are constant across two successive symbol periods.

Basically in a multipath-fading channel with an additive white Gaussian noise (AWGN), the MIMO receiver is designed to exploit time and space diversity so as to maximize the diversity reception of the symbols. With proper cyclic extension, the received symbols $y_{i,j}$ at the first and second time slots after Fast Fourier Transform (FFT) process are [2]:

$$\begin{aligned} y_{1,1} &= h_{1,1}x_{(n)} + h_{1,2}x_{(n+1)} + n_{1,1} \\ y_{1,2} &= -h_{1,1}x^*_{(n+1)} + h_{1,2}x^*_{(n)} + n_{1,2} \\ y_{2,1} &= h_{2,1}x_{(n)} + h_{2,2}x_{(n+1)} + n_{2,1} \\ y_{2,2} &= -h_{2,1}x^*_{(n+1)} + h_{2,2}x^*_{(n)} + n_{2,2} \end{aligned} \tag{5}$$

The AWGN $n_{i,j}$ are assumed as having zero mean but variance σ_n^2.

To decode $x_{(n)}$ and $x_{(n+1)}$, the combiner is designed to give an estimated values of received signals $\hat{x}_{(n)}$ and $\hat{x}_{(n+1)}$ respectively in both time slots of symbols transmissions as:

$$\begin{aligned} \hat{x}_{(n)} &= h^*_{1,1}\, y_{1,1} + h_{1,2}\, y^*_{1,2} + h^*_{2,1} y_{2,1} + h_{2,2} y^*_{2,2} \\ \hat{x}_{(n+1)} &= h^*_{1,2}\, y_{1,1} - h_{1,1}\, y^*_{1,2} + h^*_{2,2} y_{2,1} - h_{2,1} y^*_{2,2} \end{aligned} \tag{6}$$

Detection of $x_{(n)}$ and $x_{(n+1)}$ is greatly simplified since there is no interference between $x_{(n)}$ and $x^*_{(n+1)}$. This implies that

$$\begin{aligned} \hat{\boldsymbol{x}}_{(n)} &= \left(\gamma^2_{1,1} + \gamma^2_{1,2} + \gamma^2_{2,1} + \gamma^2_{2,2}\right)\boldsymbol{x}_{(n)} + \boldsymbol{h}^*_{1,1}\, \boldsymbol{n}_{1,1} + \boldsymbol{h}_{1,2}\, \boldsymbol{n}^*_{1,2} + \boldsymbol{h}^*_{2,1}\boldsymbol{n}_{2,1} + \boldsymbol{h}_{2,2}\boldsymbol{n}^*_{2,2} \\ \hat{\boldsymbol{x}}_{(n+1)} &= \left(\gamma^2_{1,1} + \gamma^2_{1,2} + \gamma^2_{2,1} + \gamma^2_{2,2}\right)\boldsymbol{x}_{(n+1)} - \boldsymbol{h}_{1,1}\boldsymbol{n}^*_{1,2} + \boldsymbol{h}^*_{1,2}\boldsymbol{n}_{1,1} - \boldsymbol{h}_{2,1}\boldsymbol{n}^*_{2,2} + \boldsymbol{h}^*_{2,2}\, \boldsymbol{n}_{2,1} \end{aligned} \tag{7}$$

where $\gamma^2_{i,j}$ and $h^*_{i,j}$ are the squared magnitude and complex conjugate of the channel transfer function $h_{i,j}$ respectively, and $n^*_{i,j}$ is the complex conjugate of the noise $n_{i,j}$ for both time slots. The combined signals are sent to a *maximum likelihood,* or *zero forcing* decoder [2] to estimate the transmitted symbols.

The novel hybrid space-time block coding (HSTBC) scheme proposed for enhancement of the performance of OFDM-STBC based WLANs is for the improvement in the system reliability and data rates.

4. HYBRID SPACE-TIME BLOCK CODING (HSTBC) SCHEME

Here the signal to be transmitted is serial to parallel converted and then pre-coded. The resulting output is processed and coded using space time block code to form a hybrid space-time block coding (HSTBC). The coded symbol is parallel to serial converted before being sent to the antennas. The proposed scheme is based on the transmit diversity technique proposed in [2]. Figure 1 is the block diagram of code generation of the proposed scheme.

Unlike the existing schemes, the codes are multiplexed at the transmitter side to enhance the performance of the system. The new scheme does not require increase in the bandwidth as redundancy is applied in space across multiple antennas, not in time or frequency. Also, channel state information is not required at the transmitter which makes its design simple and computation complexity relatively low.

From Figure 1, $\tau_{(n)}$ and $\tau_{(n+1)}$ are given as:

$$\tau_{(n)} = x_{(n)} + x_{(n+1)} \tag{8}$$

$$\tau_{(n+1)} = x^*_{(n)} + x^*_{(n+1)} \tag{9}$$

Suppose

$$\chi = \left[\tau_{(n)} \quad \tau_{(n+1)}\right]^T \tag{10}$$

then the HSTBC encoder maps χ into

$$\chi_{(\mathbf{n})} = \begin{bmatrix} \tau_{(n)} & -\tau^{*}_{(n+1)} \\ \tau_{(n+1)} & \tau^{*}_{(n)} \end{bmatrix} \tag{11}$$

where $\chi_{(\mathbf{n})}$ is the output of ST encoder, and symbols $-\tau^{*}_{(n+1)}$ and $\tau^{*}_{(n)}$ are orthogonal copies of the original symbols.

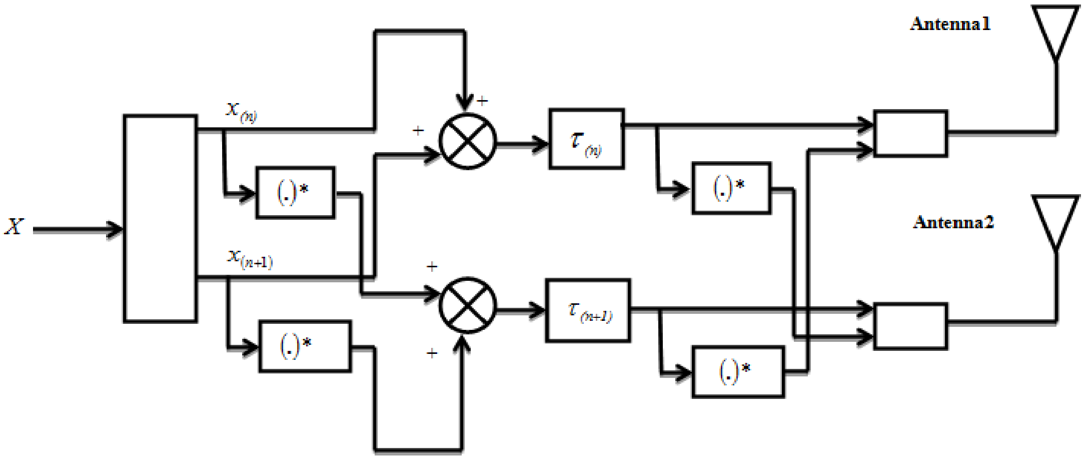

Figure 1. HSTBC Code Generation

At first time*t*, the symbols $\tau_{(n)}$ and $\tau_{(n+1)}$ are transmitted simultaneously from the two transmit antennas. By assuming that each symbol has duration *T*, then at the next time slot $t+T$, symbols $-\tau^{*}_{(n+1)}$ and $\tau^{*}_{(n)}$ are transmitted from the two antennas respectively.

It can be demonstrated that the proposed code matrix satisfies orthogonal condition

$$\chi_{(\mathbf{n})}\chi^{\dagger}_{(\mathbf{n})} = \begin{bmatrix} \tau_{(n)} & -\tau^{*}_{(n+1)} \\ \tau_{(n+1)} & \tau^{*}_{(n)} \end{bmatrix} \begin{bmatrix} \tau^{*}_{(n)} & \tau^{*}_{(n+1)} \\ -\tau_{(n+1)} & \tau_{(n)} \end{bmatrix} \tag{12}$$

$$\chi_{(\mathbf{n})}\chi^{\dagger}_{(\mathbf{n})} = \begin{bmatrix} \tau_{(n)}\tau^{*}_{(n)} + \tau_{(n+1)}\tau^{*}_{(n+1)} & \tau^{*}_{(n+1)}\tau_{(n)} - \tau^{*}_{(n+1)}\tau_{(n)} \\ \tau_{(n+1)}\tau^{*}_{(n)} - \tau_{(n+1)}\tau^{*}_{(n)} & \tau_{(n+1)}\tau^{*}_{(n+1)} + \tau_{(n)}\tau^{*}_{(n)} \end{bmatrix}$$

$$\begin{aligned} \chi_{(\mathbf{n})}\chi^{\dagger}_{(\mathbf{n})} &= \begin{bmatrix} \left|\tau_{(n)}\right|^{2} + \left|\tau_{(n+1)}\right|^{2} & 0 \\ 0 & \left|\tau_{(n)}\right|^{2} + \left|\tau_{(n+1)}\right|^{2} \end{bmatrix} \\ &= \left(\left|\tau_{(n)}\right|^{2} + \left|\tau_{(n+1)}\right|^{2}\right) \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \\ &= \left(\left|\tau_{(n)}\right|^{2} + \left|\tau_{(n+1)}\right|^{2}\right) \mathbf{I}_{2} \end{aligned} \tag{13}$$

In general, following [4, 17] the preceding expression can be represented by:

$$\chi_{(\mathbf{n})}\chi^{\dagger}_{(\mathbf{n})} = \left(\sum_{i=n}^{n+1}\left|\tau_{i}\right|^{2}\right)\mathbf{I}_{2} \tag{14}$$

where $\mathbf{I}_2$ is a 2×2 identity matrix and † is the Hermitian transpose. When a HSTBC satisfies this property, it is called an orthogonal HSTBC. This orthogonal property infers that $\tau_{(n)}$ and $\tau_{(n+1)}$ can be detected independently at the receiver by a simple linear signal processing operation from the superimposed received

signals. This enables full transmit diversity and allows a simple maximum likelihood decoding at the receiver.
With proper cyclic extension, the vector of the received symbols at the first and second time slots after FFT process can be expressed in terms of the transmitted symbols and channel coefficients:

$$\begin{bmatrix} y_{1,1} \\ y_{1,2} \\ y_{2,1} \\ y_{2,2} \end{bmatrix} = \begin{bmatrix} h_{1,1} & h_{1,2} \\ h_{2,1} & h_{2,2} \end{bmatrix} \begin{bmatrix} \tau_{(n)} & -\tau^{*}_{(n+1)} \\ \tau_{(n+1)} & \tau^{*}_{(n)} \end{bmatrix} + \begin{bmatrix} n_{1,1} \\ n_{1,2} \\ n_{2,1} \\ n_{2,2} \end{bmatrix} \tag{15}$$

By expansion, the received signals are

$$\begin{aligned} y_{1,1} &= h_{1,1}\tau_{(n)} + h_{1,2}\tau_{(n+1)} + n_{1,1} \\ y_{1,2} &= -h_{1,1}\tau^{*}_{(n+1)} + h_{1,2}\tau^{*}_{(n)} + n_{1,2} \\ y_{2,1} &= h_{2,1}\tau_{(n)} + h_{2,2}\tau_{(n+1)} + n_{2,1} \\ y_{2,2} &= -h_{2,1}\tau^{*}_{(n+1)} + h_{2,2}\tau^{*}_{(n)} + n_{2,2} \end{aligned} \tag{16}$$

Consequently, to decode $\tau_{(n)}$ and $\tau_{(n+1)}$, the combiner is designed to give estimated values of received signals $\hat{r}_{(n)}$ and $\hat{r}_{(n+1)}$, respectively, in both time slots of symbols transmissions as

$$\begin{aligned} \hat{\mathbf{r}}_{(n)} &= \sum_{i=1}^{N_r} \left\{ \mathbf{h}^{*}_{i,1}\, \mathbf{y}_{i,1} + \mathbf{h}_{i,2}\, \mathbf{y}^{*}_{i,2} \right\} \\ \hat{\mathbf{r}}_{(n+1)} &= \sum_{i=1}^{N_r} \left\{ \mathbf{h}^{*}_{i,2}\, \mathbf{y}_{i,1} - \mathbf{h}_{i,1}\, \mathbf{y}^{*}_{i,2} \right\} \end{aligned} \tag{17}$$

In view of (16) in (17)

$$\begin{aligned} \hat{\mathbf{r}}_{(n)} &= \left(\gamma^{2}_{1,1} + \gamma^{2}_{1,2} + \gamma^{2}_{2,1} + \gamma^{2}_{2,2}\right)\left(\mathbf{x}_{(n)} + \mathbf{x}_{(n+1)}\right) + \mathbf{h}^{*}_{1,1}\,\mathbf{n}_{1,1} + \mathbf{h}_{1,2}\,\mathbf{n}^{*}_{1,2} + \mathbf{h}^{*}_{2,1}\mathbf{n}_{2,1} + \mathbf{h}_{2,2}\mathbf{n}^{*}_{2,2} \\ \hat{\mathbf{r}}_{(n+1)} &= \left(\gamma^{2}_{1,1} + \gamma^{2}_{1,2} + \gamma^{2}_{2,1} + \gamma^{2}_{2,2}\right)\left(\mathbf{x}_{(n)} + \mathbf{x}_{(n+1)}\right) - \mathbf{h}_{1,1}\mathbf{n}^{*}_{1,2} + \mathbf{h}^{*}_{1,2}\mathbf{n}_{1,1} - \mathbf{h}_{2,1}\mathbf{n}^{*}_{2,2} + \mathbf{h}^{*}_{2,2}\,\mathbf{n}_{2,1} \end{aligned} \tag{18}$$

Comparison of (7) and (18) shows that the proposed HSTBC scheme doubles the capacity of the conventional STBC. Unlike the conventional STBC whereby there is a symbol for estimated values of received signals at each time slot, in the proposed scheme both symbols are received at each time slot, and could thereby improve the error performance and capacity of WLAN standards significantly.

Alternately, (18) can be written as:

$$\hat{\mathbf{r}}_{(n)} = \sum_{j=1}^{N_t} \sum_{i=1}^{N_r} \left|\gamma^{2}_{i,j}\right|^{2} \left(\mathbf{x}_{(n)} + \mathbf{x}_{(n+1)}\right) + \sum_{i=1}^{N_r} \left\{ \mathbf{h}^{*}_{i,1}\, \mathbf{n}_{i,1} + \mathbf{h}_{i,2}\, \mathbf{n}^{*}_{i,2} \right\} \tag{19}$$

$$\hat{\mathbf{r}}_{(n+1)} = \sum_{j=1}^{N_t} \sum_{i=1}^{N_r} \left|\gamma^{2}_{i,j}\right|^{2} \left(\mathbf{x}_{(n)} + \mathbf{x}_{(n+1)}\right) + \sum_{i=1}^{N_r} \left\{ \mathbf{h}^{*}_{i,2}\, \mathbf{n}_{i,1} - \mathbf{h}_{i,1}\, \mathbf{n}^{*}_{i,2} \right\} \tag{20}$$

where N_t and N_r represent number of transmitand receive antennas respectively. $\sum_{j=1}^{N_t} \sum_{i=1}^{N_r} \left|\gamma^{2}_{i,j}\right|^{2} \left\{\tau_{(n)}\right\}$ and $\sum_{j=1}^{N_t} \sum_{i=1}^{N_r} \left|\gamma^{2}_{i,j}\right|^{2} \left\{\tau_{(n+1)}\right\}$ are the amplified spatial division multiplexed transmitted signals.The combined signals are sent to a *maximum likelihood*or *zero forcing* decoder to estimate the transmitted symbols.

5. CHANNEL CAPACITY

The capacity of an ergodic channel is given in terms of bits/sec or by normalizing with bandwidth by bits/sec/Hz.
As in [24], the capacity of MIMO channel can be expressed as

$$C = \log_2 \det\left(\mathbf{I}_{N_r} + \frac{p_k}{\sigma_n^2}\boldsymbol{HH}^{\dagger}\right) \tag{21}$$

Upon expansion, and generalization, we write expression for channel capacity without channel state information at the transmitter thus:

$$C = \sum_{k=1}^{K} \log_2\left(1 + \lambda_k^2 \frac{p_k}{N_t \sigma_n^2}\right) \tag{22}$$

where$p_k$is the transmit power and λ_k^2 is the channel gainon the *k*th sub-channel.

6. SIMULATION RESULT AND DISCUSSION

The simulation was run for over 10^5 transmitted blocks of data with varying signal-noise ratio values ranging from 0 dB to 15 dB with BPSK modulation.The 2×2 schemes of STBC-OFDM and HSTBC-OFDM systems were simulated and their bit error performances were compared. Figure 2 shows the performance comparison between the two schemes. For instance, to achieve a*bit error rate (BER)* of 10^{-4} for an HSTBC system, a 7-dB SNR is needed. However, a 10-dB SNR is required to achieve the same BER for an Alamouti STBC system. This means that an increase of 3 dB in signal power is required for STBC system to achieve the same BER of 10^{-4} as the proposed HSTBC. From the results, it is observed that the proposed HSTBC system outperforms the STBC system presented in [2].

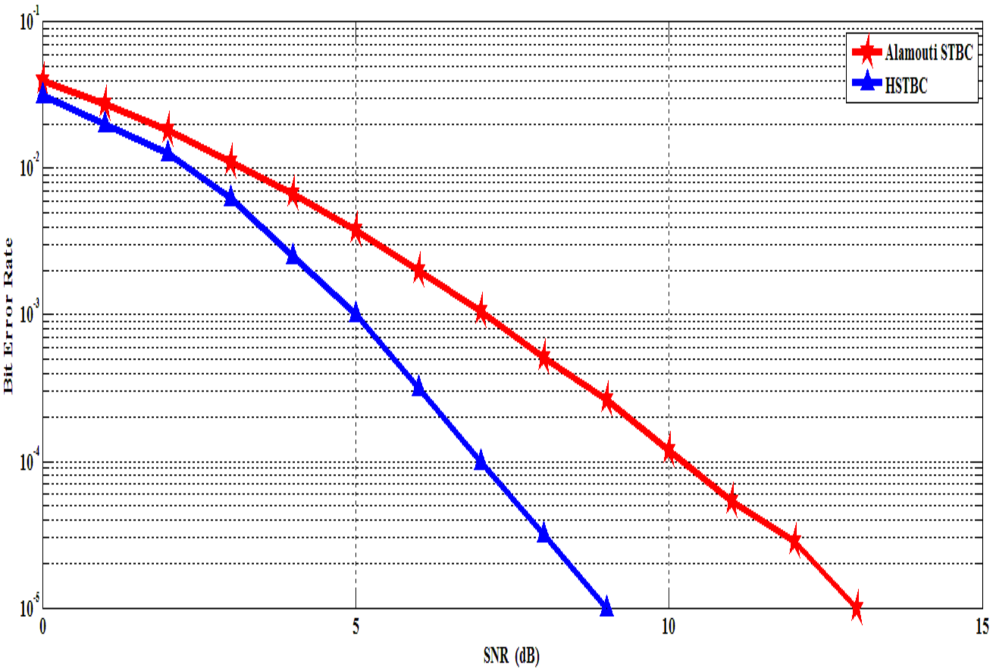

Figure 2. Bit Error Rates for BPSK modulation with 2×2 Alamouti STBC and HSTBC

Further simulations were carried out for different bit rates and various combination of receive and transmit antennas to verify the effectiveness of the proposed scheme in enhancing the channel capacity. For the performance comparison of different MIMO schemes and in compliance to IEEE 802.11n requirements, we restrict our investigation to four antennas at both sides of the link; i.e. N_t = N_r= 4. Furthermore, when complexity is considered, small number of antennas is adequate for proper performance.

As observed in Figure 3, there is an increase in performance in data transmissionas the number of transmit- and receive-antennas increases. For instance, it is observed that for 4×4 system at 12 dB, conventional STBC gives 14 bit/s/Hz channel capacities while the proposed HSTBC gives 26 bit/s/Hz (almost double the conventional STBC). As evident in Eqn. (21), the proposed scheme would double the capacity of the conventional AlamoutiSTBCon assumption that the channel coefficients between transmitter and receiver are constant during the transmission of two consecutive symbols. This is not so in real-world scenariobecause of the time-varying nature of the received signals. Figure 3 shows the capacity enhancement of the proposed scheme.

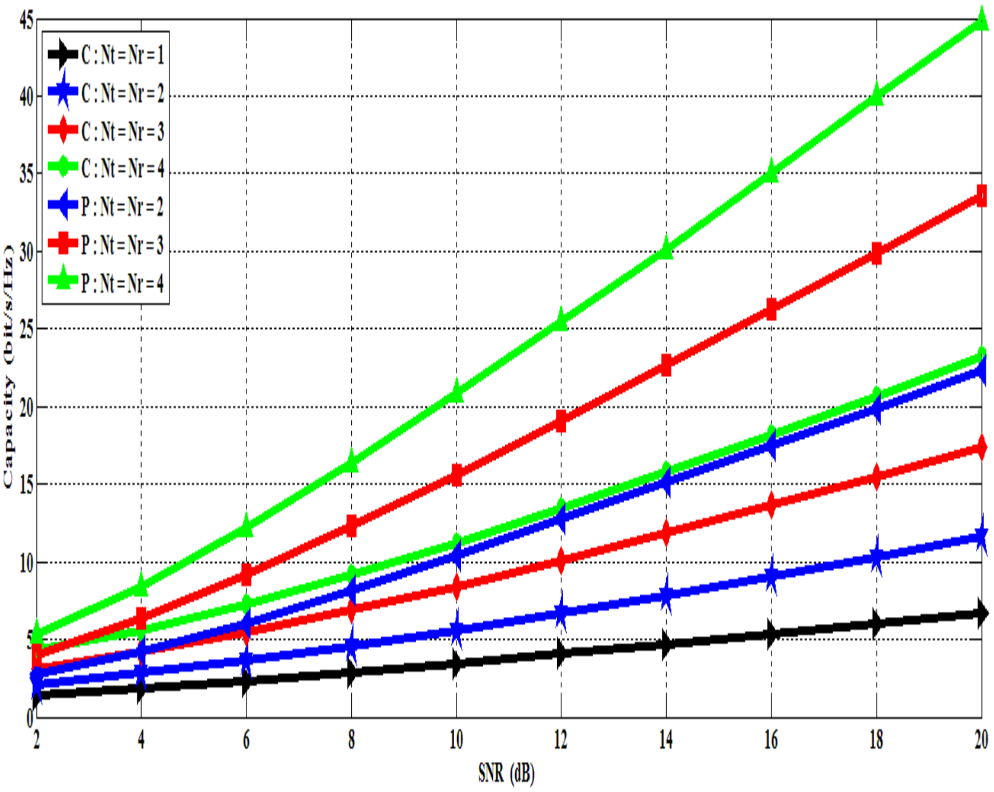

Figure 3. MIMO Channel Capacity Analysis for Conventional Space-Time Block Code (C) and the Proposed Hybrid Space-Time Block Code (P)

7. CONCLUSION

MIMO scheme has been investigated for the next generation WLANs over multipath fading channel with AWGN channels. Compared to a conventional STBC; our proposed HSTBC scheme provides improved data capacity at the given bandwidths leading to bandwidth efficiency of the scheme. Furthermore, performance of WLAN was significantly improved by the implementation of HSTBC scheme, which substantially reduced erroneous data transmission to give reliable communication systems. Simulation results show that the proposed hybrid space-time block coded OFDM-MIMO systems has less bit error rate and better performance with respect to conventional space-time block coded OFDM-MIMO systems.

The performance of the proposed HSTBC scheme is shown to outperform the conventional STBCgiven that the decoding complexity is comparatively similar to that of typical STBC. Therefore, efficient bandwidth utilization for IEEE 802.11 WLAN standards can be achieved when the proposed hybrid space-time block coded MIMO-OFDMsystems is employed.

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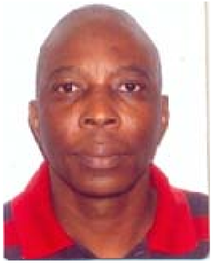

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