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Data Transmission Techniques for Current and Future High Speed Wireless Communication System: From Theory to Practice

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ABSTRACT: This paper presents a Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM) communication system with space-time and space-Frequency block coded (STBC/SFBC) of present generation downlink channel. Space-time block coding (STBC) and space-frequency block coding are transmit diversity schemes used in a wireless communication system to mitigate the effect of channel fading. The system is aimed to reduce the error rate (BER) by mitigating the effect of multipath fading which increase the quality of the system. In the proposed system, 2 transmit and 2 receive antennas are used, to transmit modulated symbols of block N across an OFDM channel, using SFBC Alamouti's based encoding algorithm (SFBC-OFDM) derives from the basic criteria for space-time block codes (STBC). The signals from the first and second antennas are encoded and transmitted simultaneously in space and frequency over frequency-selective Rayleigh fading channel using two adjacent carriers. The work examines the SFBC and spatial diversity benefits realized based on the BER performance. The result is simulated effectively using MATLAB application software and the BER performance is compared with the conventional STBC-OFDM. It is shown that both STBC and SFBC techniques achieve similar performance with a diversity gain of four (4) over a slow fading channel with 2 antennas at both ends of the link under simple processing across the transmit and receive antennas.

KEYWORDS: Multipath fading channel, Transmit diversity, Alamouti Coding, Bit Error Rate (BER), MIMO, OFDM.

I. INTRODUCTION

Now a day, mobile communications have become one of the daily necessities considering its vital role in the entire global communities. Since the 20th century, modern wireless communications techniques and services have been adopted worldwide which are beyond people's imaginations before [1] In the past decades, Wireless communication systems become a significant area of often research in both academia and telecommunication industries due to the motivation by continuing increase in demand for high-rate and reliable data [2], [3]. Multiple input multiple output (MIMO) combine with orthogonal frequency division multiplexing (OFDM) provides a good coverage, reliable transmission, high data rates and high spectrum efficiency [4], [1], [5]. Furthermore, The use of MIMO and OFDM systems together has become a significant model for the deployment of the current and emerging wireless communication systems as witnesses by their existence in many recent technologies standards, such as IEEE 802.11n, IEEE 802.16ac, Worldwide Interoperability for Microwave Access (WiMAX) and 3GPP LTE/4G among others [6], [7]. MIMO involves the use of multiple antennas at both ends of the communication link to exploit the multipath and improve the system performance without increasing the bandwidth or the transmit power, by creating spatial diversity which in return achieve high diversity order [2]. OFDM is employed potentially to provide free space interface solution for future wireless communication systems [1], [8], [9]. It is suggested in wireless communications to combat the effect of multipath fading and prevents the communication channel against both the inter-symbol interference (ISI) and inter-carrier interference (ICI) by efficiently dividing the bandwidth into many narrow-bands, hence can also avoid the use of complex equalizers at the receiving end of the link.

In this paper, a coded MIMO-OFDM wireless transmission system with 2 transmits and 2 receive antennas was design. The complete system comprises of many tasks such as; Data encoding, Data modulation, Space-frequency/MIMO encoding, OFDM modulation, OFDM demultiplexing, Space-frequency/MIMO detection, Data demodulation and decoding respectively.

II. EXPLOITING MIMO IN WIRELESS COMMUNICATION SYSTEM

The basic idea behind a MIMO wireless system is to improve the performance of communications by taking the advantage of multipath and diversity [2], [10]. Among the early contributions towards MIMO concept for wireless communication system was the work of Winters (93) in his paper [11] which proposed the techniques of using multiple antennas at both ends of the link to transmit data from multiple users to improve the performance of the system using spatial diversity scheme. Salz and Winters (94) published another vital contribution [12], which exploits the benefits of using multiple antennas in the wireless communications link. Research studies on MIMO systems are still ongoing for the actual likelihood of continuing advances in the concept. MIMO system is considered to be the leading technology for our journey to a future generation of emerging wireless communication system [1, 13, 14].

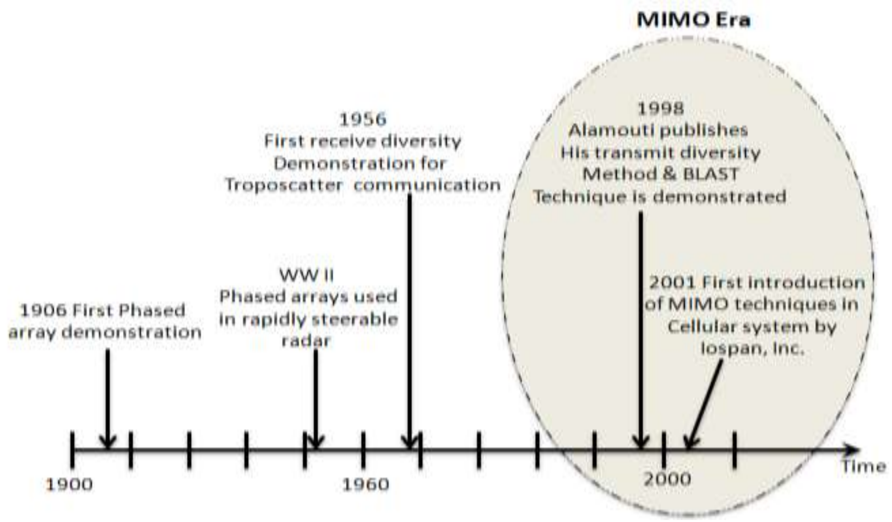

Figure 2.1: Timeline of key multi-antenna advances (Adapted from [6])

By considering a communication system with N_T and N_R antennas at both end of the link, the aim is to transmit separate data streams on the separate antennas, as a function of time t, which can be denoted as S_i (t). The transmitted signal from the i-th transmit antenna might use a different path to arrive at the j-th receive antenna, i.e direct and indirect paths along various reflections. This concept is known as Multipath. In general, if we assumed all the multipath components of the system (between i-th and j-th antennas) are summed up into a single term $h_{ji}(t)$. Because the transmit signals are sent at the same frequency, therefore, the j-th receive antenna will receive the signals from all N_T transmitters not just from i-th when we omit the noise for the first instance and for simplicity, this can be represented by the following equation [15].

$$r_j = \sum_{i=0}^{nTx} h_{j,i}(t) s_i\,(t) \qquad (2.1)$$

On the other hand, a matrix notation can be used to represent all the received signals into a single equation [16]:

$$\mathbf{S}(t) = \begin{pmatrix} s_1(t) \\ s_2(t) \\ \vdots \\ s_{nTx}(t) \end{pmatrix}, \mathbf{r}(t) = \begin{pmatrix} r_1(t) \\ r_2(t) \\ \vdots \\ r_{nRx}(t) \end{pmatrix} \& \ \mathbf{H}(t) = \begin{pmatrix} h_{11}(t) & h_{12}(t) \dots & h_{1nT}(t) \\ h_{21}(t) & h_{22}(t) \dots & h_{2nT}(t) \\ \vdots & \vdots \quad \ddots & \vdots \\ r_{nR2}(t) & r_{nR2}(t) \dots & r_{nRnT}(t) \end{pmatrix} \qquad (1.2)$$

This can be written as

$$\mathbf{r}(t) = \mathbf{H}(t)\mathbf{s}(t) \tag{2.3}$$

That is:

$$\begin{pmatrix} r_1(t) \\ r_2(t) \\ \vdots \\ r_{nRx}(t) \end{pmatrix} = \begin{pmatrix} h_{11}(t) & h_{12}(t) \dots & h_{1nT}(t) \\ h_{21}(t) & h_{22}(t) \dots & h_{2nT}(t) \\ \vdots & \vdots \quad \ddots & \vdots \\ r_{nR2}(t) & r_{nR2}(t) \dots & r_{nRnT}(t) \end{pmatrix} \begin{pmatrix} s_1(t) \\ s_2(t) \\ \vdots \\ s_{nTx}(t) \end{pmatrix}$$

Briefly, since MIMO techniques are designed to work in a scattering environment, this paper also focus on the channel phenomena that increases this scattering called Multipath channel phenomenon [6]. In the absence of scattering and multipath, channels between different sets of transmitting and receiving antennas become correlated, resulting in poor MIMO performance [6, 14]. Therefore, having good knowledge of propagation is significant for predicting and understanding the performance of MIMO communication systems [6]. In this research work, a multipath fading channel is considered where the transmitter does not know the channel at all, but perfectly known at the receiver.

Over Rayleigh flat fading channel, MIMO system with N_T transmit and N_R receive antennas jointly with channel noise can be represented by the following equation, and let y^T denote the transpose of any vector y, [16]:

$$\mathrm{r}(t) = \mathbf{H}_i(t)\mathrm{s}(t) + \mathrm{n}(t) \tag{2.4}$$

Where,

$$\mathrm{s}(t) = [s_1(t), s_2(t), \dots, s_{nT}(t)]^T \tag{2.5}$$

and

$$\mathrm{r}(t) = [r_1(t), r_2(t), \dots, s_{nT}(t)]^T \tag{2.6}$$

and

$$n(t) = [n_1(t), n_2(t), \dots, n_{nT}(t)]^T \tag{2.7}$$

In which s(t), r(t) and n(t) are the transmit, receive signal and the noise vectors between the transmit and receive antennas respectively, and each element is circularly symmetric complex Gaussian random vector with variance $N_o/2$ per complex dimension [16] and $\boldsymbol{H_i}(t)$ is channel matrix for a MIMO channel.

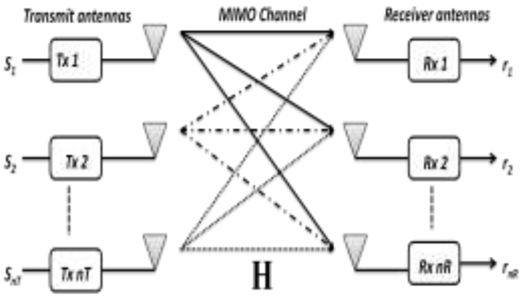

Figure 2.2: Schematic diagram of the generic MIMO system (Adapted from [2])

III. TRANSMISSION DIVERSITY MODEL

This paper proposed to consider a wireless communication system transmission model with **n** transmits antennas and **m** antennas at the receive station, in the similar way with [15], [17] which define the received signal $\boldsymbol{r_t^j}$, at the receive antenna j, as:

$$\boldsymbol{r_t^j = \sum_{i=1}^{n} \alpha_{i,j}\, c_t^j + n_t^j}$$

(3.1)

Where $\boldsymbol{n_t^j}$ is the noise samples, which are independent samples of a zero-mean complex Gaussian random variables with variance **n/(2 SNR)** per complex dimension [17].

As mention in many sections of this paper previously, the information will be transmitted using 2x2 matrix base on the Alamouti's scheme [15] as shown in Fig. (1).

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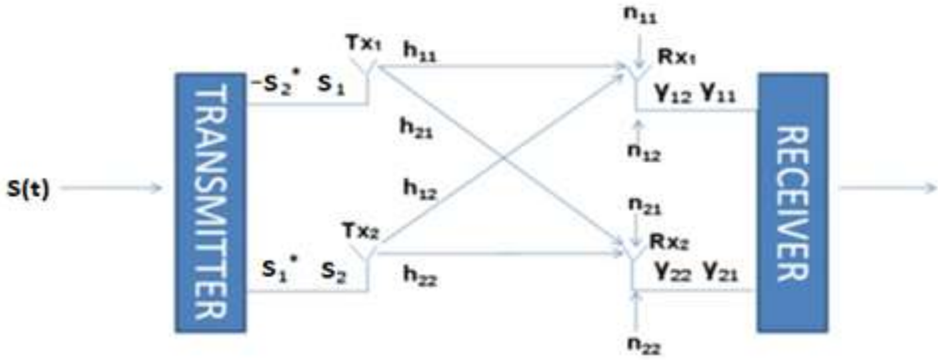

Figure 3.1 A Complete system of 2x2 MIMO Alamouti' scheme

The received signal **y** can be obtained as:

$$\mathbf{y_r} = \mathbf{H_k}\, \mathbf{S_k} + \mathbf{n_k} \quad (3.2)$$

Where $\mathbf{n_k}$ are circularly symmetric complex Gaussian random variables and $\mathbf{S_k}$ is the transmit information signal given as [15]:

$$S_k = \begin{bmatrix} S_1 & -S_2^* \\ S_2 & S_1^* \end{bmatrix} \quad (3.3)$$

The Alamouti Space-time coded transmits symbols at first and second-time slot will be considered and design as in [15]:

For the general **m x n** matrix, we know an estimate $\hat{\mathbf{s}}_\mathbf{k}$ of transmit symbols $\mathbf{S_k}$ can be obtained by finding the pseudo-inverse of the matrix, which is defined as [6]:

$$\mathbf{H^+ = (H^H H)^{-1} H^H} \quad (3.4)$$

And the estimate can be obtained using the equation below [2]:

$$\begin{bmatrix} \hat{s}_1 \\ \hat{s}_2^* \end{bmatrix} = \mathbf{(H^H H)^{-1} H^H} \begin{bmatrix} y_1^1 \\ y_2^1 \\ y_1^{2*} \\ y_2^{2*} \end{bmatrix} \quad (3.5).$$

where $\mathbf{H^H H}$ is:

$$H^H H = \begin{bmatrix} \alpha & 0 \\ 0 & \beta \end{bmatrix} \quad (3.6)$$

and

$$\alpha = |h_{11}|^2 + |h_{21}|^2 + |h_{12}|^2 + |h_{22}|^2 \quad (3.7)$$

$$\beta = |h_{11}|^2 + |h_{21}|^2 + |h_{12}|^2 + |h_{22}|^2 \quad (3.8)$$

Lastly, the decision is made using the maximum likelihood decoder [15], [3].

IV. SPACE FREQUENCY BLOCK CODES IN OFDM SYSTEM

SFBC are widely applied schemes using 2 transmit and M receive antenna to achieve diversity order of 2M [10]. Similarly, in this paper, a 2x2 systems we simulated, using the same SFBC techniques. 2 symbols are transmitted in two adjacent carriers simultaneously to achieves a full rate of (R=1). Alamouti's scheme was considered because it is the only orthogonal SFBC technique that achieves full rate and full diversity gain without requiring any data rate sacrifice under simple or complex modulation techniques [10].

Hence, a simple scheme with N_T =2 and N_R =2 is proposed here, it works by transmitting the sequence {s_1, $-s_2$*} on the first antenna and {s_2, s_1*} on the second antenna [18] across two consecutive frequencies as is shown in Figure 4.1**:**

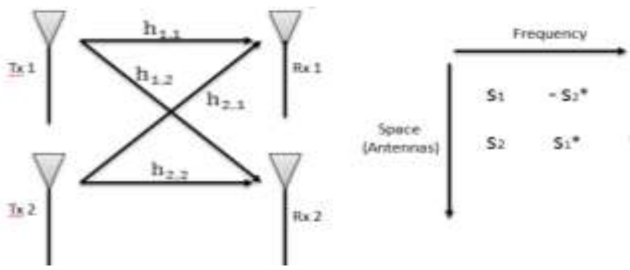

Figure 4.1: A description of Alamouti SFBC 2x2 schemes (Adapted from [18])

We assumed the channel is frequency selective Rayleigh fading and perfectly known at the receiver. The four channel coefficients are denoted by h_{11}, h_{12}, h_{21} and h_{22} and considered to be in Rayleigh fading channel from i^{th} transmit to the j^{th} receive antenna. At the receive antennas i^{th}, noise is added which has a Gaussian pdf. The received symbol r_j^k on the k^{th} subcarrier and j receive antenna as illustrated in Figure 3.1, can be represented by the matrix notation as follows [10]:

$$\begin{bmatrix} r_1^1 \\ r_2^1 \\ r_1^{2*} \\ r_2^{2*} \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \\ h_{12}^* & -h_{11}^* \\ h_{22}^* & -h_{21}^* \end{bmatrix} \begin{bmatrix} s_1 \\ s_2 \end{bmatrix} + \begin{bmatrix} n_1^1 \\ n_2^1 \\ n_1^{2*} \\ n_2^{2*} \end{bmatrix} \tag{4.1}$$

Where:

$$r_1^1 = h_{11}s_1 + h_{12}s_2 + n_1^1 \tag{4.2}$$

$$r_2^1 = h_{21}s_1 + h_{22}s_2 + n_2^1 \tag{4.3}$$

$$r_1^2 = h_{11}s_2^* + h_{12}s_1^* + n_1^2 \tag{4.4}$$

$$r_2^2 = h_{21}s_2^* + h_{22}s_1^* + n_2^2 \tag{4.5}$$

and the channel matrix

$$\boldsymbol{H} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \\ h_{12}^* & -h_{11}^* \\ h_{22}^* & -h_{21}^* \end{bmatrix} \tag{4.6}$$

V. SFBC-OFDM TRANSMISSION AND DETECTION TECHNIQUES

Figure 3.3 shows the SFBC sub-carriers transmitting technique when using two transmit antennas with the OFDM system.

Table 3.1: Space Frequency Block Encoding [10]

Subcarriers	Antenna 1	Antenna 2
f_1	S_1	S_2
f_2	$-S_2^*$	S_1^*

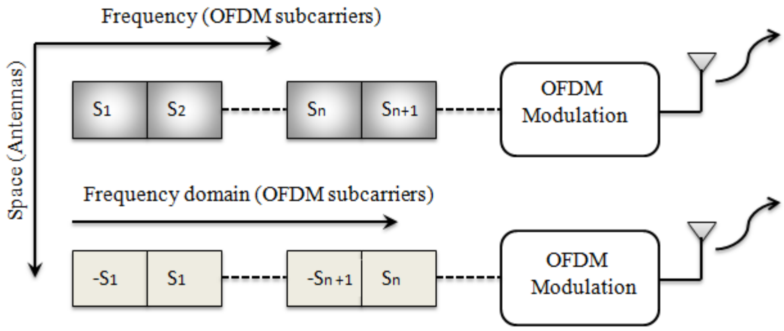

Figure 5.1: SFBC transmitter techniques with 2 transmit antennas (Adapted from [19])

Where N is also the fast Fourier transform (FFT) size of the OFDM system and depends on the system considered (WiFi or LTE) during the design of the implementation process. Assumed, we consider the system using Long Term Evolution (LTE) commonly know 4G LTE, from the standard [20] the total size of N will not be loaded with data especially when it comes to practical implementation. For example, if we use a 10MHz or 5MHz spectrum, the size of N=1024 or N=512. So, only 600 of the 1024 or 300 of the 512 will be usable. At the other end of the link, 2 receive antennas are used to receive the transmitted data streams, the signals at the receiver will be received on odd and even frequency indexes assembled in the order of $\mathbf{r}_{odd} = [r_1, r_3, \ldots r_{N-3}, r_{N-1}]$ and $\mathbf{r}_{even} = [r_2, r_4, \ldots r_{N-2}, r_N]$ and express by the equations [19]:

$$r_{1\,odd}^{1} = h_{11}{}^{odd} s_1{}^{odd} + h_{12}{}^{odd} s_2{}^{odd} + n_{1\,odd}^{1} \quad (5.1)$$
$$r_{2\,even}^{1} = h_{21}{}^{eve} s_1{}^{eve} + h_{22}{}^{2\,eve} s_2{}^{eve} + n_{2\,even}^{1} \quad (5.2)$$
$$r_{1\,odd}^{2} = h_{11}{}^{2\,odd} s_2{}^{odd} + h_{12}{}^{2\,odd} s_1{}^{odd} + n_{1\,odd}^{2} \quad (5.3)$$
$$r_{2\,even}^{2} = h_{21}{}^{eve} s_2{}^{eve} + h_{22}{}^{2\,eve} s_1{}^{eve} + n_{2\,even}^{2} \quad (5.4)$$

Where;
$h_n^{odd} = [\ H_n[1], H_n[3], \dots\ , H_n[N-3], H_n[N-1]\ ]$, $h_n^{eve} = [H_n[2], H_n[4], \ \dots, H_n[N-2], H_n[N]]$, and $n = 1, 2,$ $s_1^{odd} = [s_1, s_3, \dots s_{N-3}, s_{N-1}]$, $\boldsymbol{s}_2^{even} = [s_2, s_4, \dots s_{N-2}, s_N]$, $s_2^{eve} = [s_1^*, s_3^*, \dots s_{N-3}^*, s_{N-1}^*]$, $s_1^{eve} = [-s_2^*, -s_4^*, \dots -s_{N-2}^*, -s_N^*]$,
$n_{odd} = [\ n[1], n[3], \dots\ , n[N-3],\ n[N-1]]$ and
$n_{even} = [n[2], n[4], \dots, n[N-2], n[N]]$
It is important to note that;

$$s_1^{eve} = -s_2^{*\,odd} \ and \ \ s_2^{eve} = s_1^{*\,odd} \quad (5.5)$$

Thus, (5.2) and (5.4) can be written as

$$r_{2\,even}^{1} = h_{21}{}^{eve} - s_2^{*\,odd} + h_{22}{}^{2\,eve} s_1^{*\,odd} + n_{2\,even}^{1} \quad (5.6)$$
$$r_{2\,even}^{2} = h_{21}{}^{eve} s_1^{*\,odd} + h_{22}{}^{2\,eve} - s_2^{*\,odd} + n_{2\,even}^{2} \quad (5.7)$$

By examine (5.1) and (5.6), it can be seen that they can be written in matrix form $\boldsymbol{r}_F[j] = \boldsymbol{B}_F[j]\boldsymbol{h}_F[j] + n[j]$, $1 \le j \le N/2$ as follows

$$\begin{bmatrix} \boldsymbol{r}_{1\ 2j-1}^{1} \\ \boldsymbol{r}_{2\ 2j}^{1} \end{bmatrix} = \begin{bmatrix} \boldsymbol{s}_{2j-1} & \boldsymbol{s}_{2j} \\ -\boldsymbol{s}_{2j}^* & \boldsymbol{s}_{2j-1}^* \end{bmatrix} \begin{bmatrix} \boldsymbol{H}_1^1\,[2j] \\ \boldsymbol{H}_2^1\,[2j] \end{bmatrix} + \begin{bmatrix} \boldsymbol{n}_1^1[2j-1] \\ \boldsymbol{n}_2^1\,[2j] \end{bmatrix} \quad (5.8)$$

And (5.3) and (5.7), can also be written in the same way as

$$\begin{bmatrix} \boldsymbol{r}_{1\ 2j-1}^{2} \\ \boldsymbol{r}_{2\ 2j}^{2} \end{bmatrix} = \begin{bmatrix} \boldsymbol{s}_{2j} & \boldsymbol{s}_{2j-1} \\ \boldsymbol{s}_{2j-1}^* & -\boldsymbol{s}_{2j}^* \end{bmatrix} \begin{bmatrix} \boldsymbol{H}_1^2\,[2j] \\ \boldsymbol{H}_2^2\,[2j] \end{bmatrix} + \begin{bmatrix} \boldsymbol{n}_1^2\,[2j-1] \\ \boldsymbol{n}_2^2\,[2j] \end{bmatrix} \quad (5.9)$$

Now, it is clear from (5.8) and (5.9) that the signals obtained at each receiver can be combined using the conventional method proposed by Alamouti [10]:

$$\begin{bmatrix} \hat{s}_{2j-1} \\ \hat{s}_{2j}^* \end{bmatrix} = \begin{bmatrix} \boldsymbol{H}_1[j]^* & \boldsymbol{H}_2\,[j] \\ \boldsymbol{H}_2[j]^* & -\boldsymbol{H}_1[j] \end{bmatrix} \begin{bmatrix} \boldsymbol{r}_{1\ 2j-1}^{2} \\ \boldsymbol{r}_{2\ 2j}^{2} \end{bmatrix}, 1 \le j \le N/2 \quad (5.10)$$

The same for the second antenna and these combined signals from both receivers will the sent to the detector for detection. Hence SFBC-OFDM achieves the diversity order of 2M, even in frequency selective channels with condition that the channel maximum delay spread is less than the length of the CP.

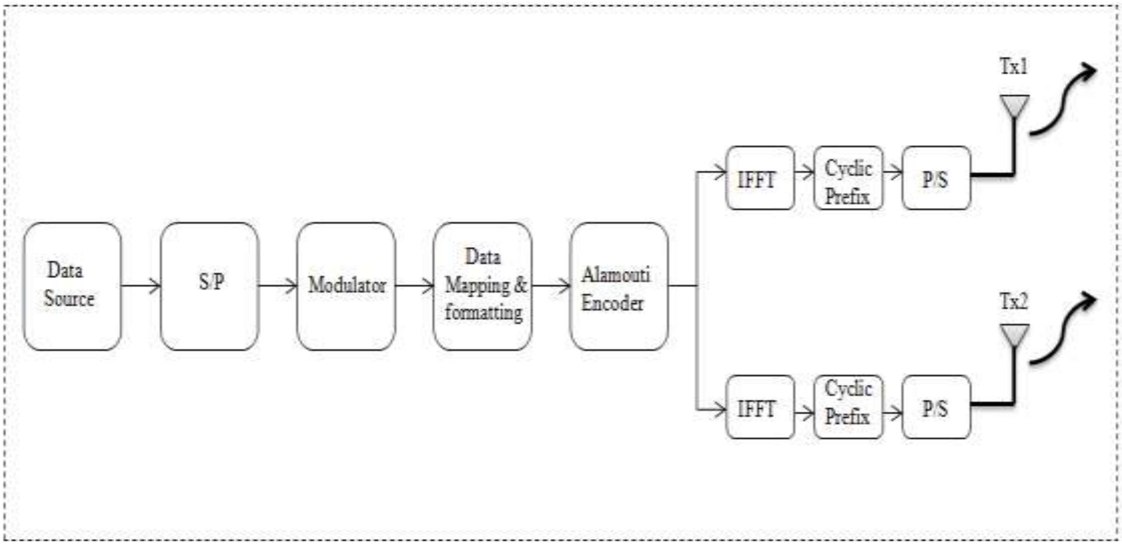

Figure 5.2: SFBC-OFDM transmitter using 2 transmits and 2 receive antennas

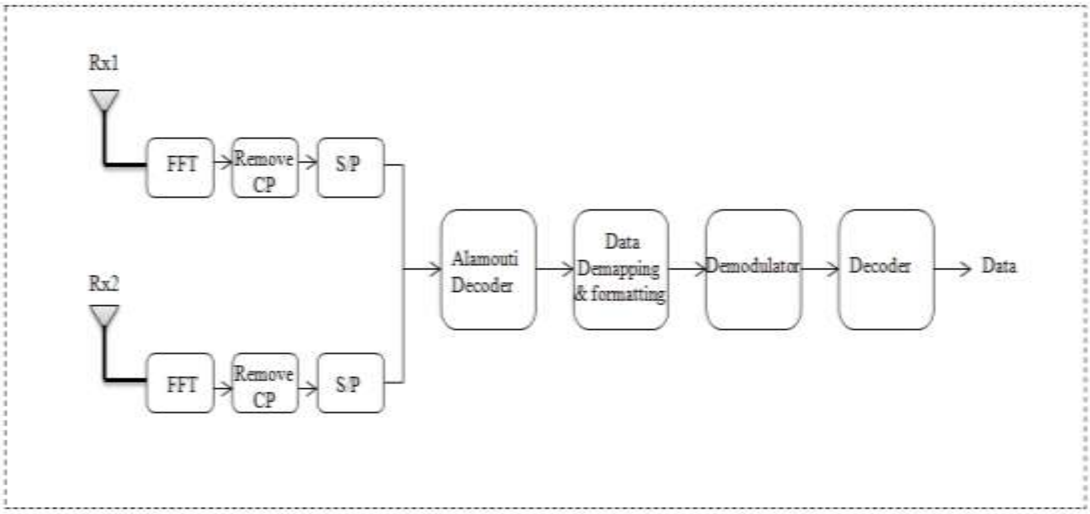

Figure 5.3: SFBC-OFDM receiver using 2 transmits and 2 receive antennas

VI. SFBC-OFDM ENCODING AND TRANSMISSION PERFOMANCE

The modulated information is mapped onto each block code based on Alamouti's code block orthogonal design scheme using two transmit antennas, the encoding is done in space and frequency (space-frequency coding) using two adjacent sub-carriers [10]. The information is transmitted through OFDM channel, the modulated symbols of N sub-carriers is converted from serial to parallel form prior to fed into OFDM modulators to perform inverse fast Fourier transform (IFFT) on a block of N length. Let assumed the N length of the of the data symbols block is Y = Y_O, Y1,...., Y_{N-1}. A serially converted parallel sequence symbols y = y_o, y_1, ... , y_{n-1} in the time domain is produced after the IFFT operation. Cyclic prefixes (CP) of length $Tp > \tau_m$ are pre-appended, by taking the length N_{cp} period at the end of each frame and appending it at the beginning of the each frame, where τ_m is the maximum delay spread [14, 21]. The data is converted back from parallel to serial form. Random channels impulse responses were also generated and the OFDM signals are applied to the channel in the time domain and the noise is added to the signals and reshaped back to parallel form individually. At the receiver side, the cyclic prefixes are removed and fast Fourier transform (FFT) is performed by the OFDM demodulators back to the frequency domain. Finally, the estimate transmits symbols are detected similar to the conventional method proposed in [10], by multiplying the pseudo inverse of the matrix **H** by the received signals as well as their conjugations separately**.** The decision is made using zero forcing techniques prior to the data demodulation and counting errors. Finally, the simulation result is plotted successfully using MATLAB software.

VII. SIMULATION PARAMETERS USED AND RESULTS ACHIEVED

The MIMO-OFDM parameters used for the simulation of this work are considered based on 4G/LTE standard as shown in Table 7.1 below:

Table 7.1: Parameters of the LTE/4G physical layer. (Obtained from [20])

Parameters	**Range**
Channel Bandwidth (MHz)	10
FFT Size	1024
Occupied subcarriers	601
Guard Subcarriers	423
Cyclic prefix (%)	72
Number of bits/frame	9600
Occupied Channel Bandwidth (MHz)	9.015
Number of frames	10000

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Bandwidth efficiency (DL)	90%

This work is simulated in two ways, with tap weight (EPA model) and without tap weight (uniform) and were also plotted with theoretical graph as shown in figure 7.1, figure 7.1 and a comparisons in figure 7.3. Both are simulated and achieved fourth order diversity of with two antennas at both ends of the link. The EPA model achieves a better performance than the system without tap weight, below.

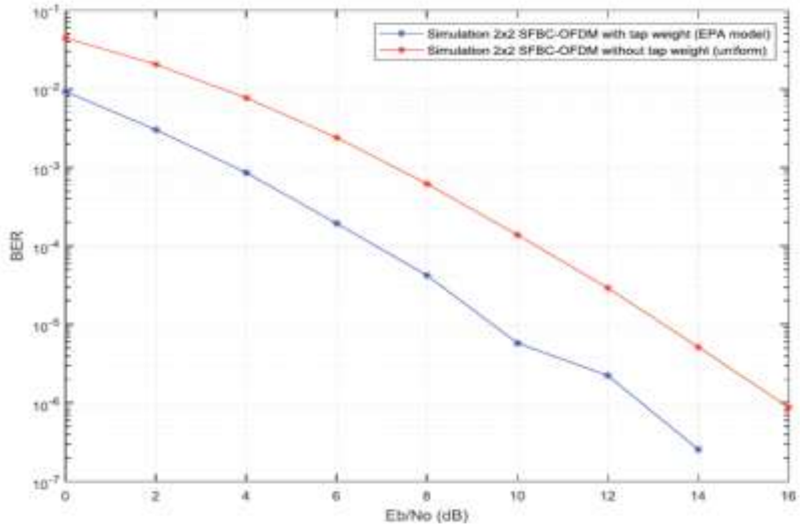

Figure 7.1: Performance of the simulated 2x2 SFBC-OFDM (uniform) and (EPA model)

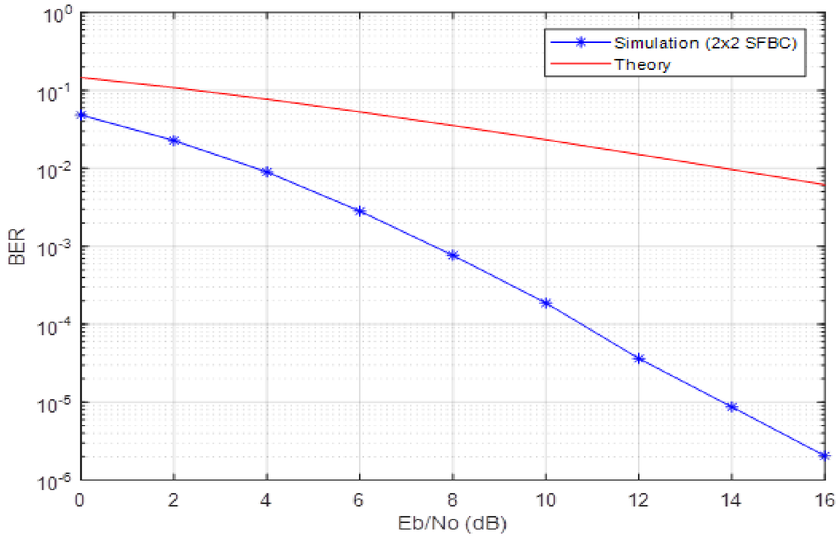

Figure 7.2: Performance of simulated SFBC 2x2 MIMO-OFDM Alamouti's Scheme

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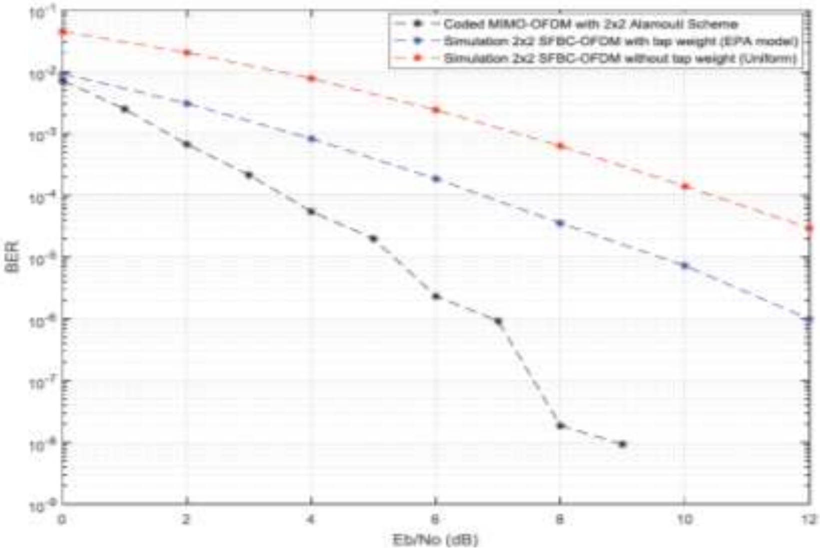

Figure 7.3: Performance comparison of the simulated 2x2 coded and the non-coded systems

VIII. DISCUSSIONS OF RESULTS

The work is done perfectly and the result is obtained using SFBC Alamouti coding scheme with 2 transmits and 2 receive antennas (NT = NR = 2). The simulation results obtained are shown in figure 7.1 and figure 7.2 and figure 7.3 respectably over BPSK modulation scheme. The results obtained are very effective and achieved high performance. The results attained a diversity gain of about four (4) which is quite reasonable and precisely similar to the result achieved in [10] and [18] for STBC/SFBC and SFBC-OFDM with two transmits and 2 receive antennas respectively.

IX. DISCUSSION OF PRACTICAL IMPLEMENTATION ASPECTS

Most of the proposed results for research interests were limited to theoretical analysis and simulation only. Thus, they ignored the practical aspects and the drawbacks encountered when practical implementation needs arise, e.g packet loss, Packet handling jitters and many other defects. These problems need to be taken into consideration when it comes to the implementation aspect. The main challenge facing the practical Implementations of wireless communication systems is to provide high-speed wireless access at high QoS [22]. Alamouti 1998 in his paper [10], outline some practical implementation issues to be considered when transferring the theoretical findings into practice, such as power requirement (radiated power and amplifier(s) power handling), channel estimation error, delay effects, antenna configurations etc. Likewise, regarding the implementation of this system, similar approaches should be adopted since it is based on a similar scheme. i.e for the radiation power, the energy to be allocated to each symbol should be half of the total transmit power, in order to have the total transmit power from the two transmit antennas used, which result in **3dB** disadvantage in the error performance and may be advantageous for power amplifier handling considering the power reduction factor of two (2). For the channel estimation, the channel information can derive using minimum mean square error (MMSE) or Least Squares (LS) channel estimators. The performance of MMSE is quite good, but it has high complexity, while LS has low complexity but its performance is low compared to MMSE [23]. The channel can be estimated by pilot symbol insertion and extraction and can be done using training symbols that are applied to the entire subcarriers of the OFDM and assumed the receiver has all the channel information (CI). Yet some factors may affect this system, such as, when the channel is varied rapidly over time, mismatched interpolation coefficient and quantization [10]. Synchronization is required in the system when OFDM baseband signals applied, which will cause synchronization error due to symbol time offset (STO), phase offset (PO) etc. Which is aimed to estimate and correct the time offset and the frequency difference between the two antennas at the ends of the link (transmit and receive). Channel emulation may be required, to choose a suitable channel model that can fit the system and support the transfer of possible high data rate across the system. As for the delay effect, since the multicarrier system is considered in this work and the copies are also sent at N sub-carriers from both antennas using N branch diversity, hence the decoding delay will be N symbol periods [10].

When it comes to the antenna configurations, in practice, the signals from the transmit antennas should be sufficiently uncorrelated with equal average power (< **3dB**) difference to improve the diversity [10]. For the impact on interference, since the system requires the synchronous transmission of the signals from the two transmit antennas each transmitting half power, it emerges that the number of possible interferers is twice, each with interference power of half. In some applications, interference cancellation schemes may be applied effectively [10]. Therefore, these and more practical aspects like soft failure need to be considered when it comes to system practical implementation. Moreover, for the modem complexity, since the receiver is assumed to have all channel information, the system does not require any feedback from the receiver to the transmitter, which in turn adds complexity to both ends of the link. Besides, the computation complexity of the system is simple and straightforward [10].

X. CONCLUSION

In this paper, a MIMO-OFDM wireless transmission system using 2 antennas at both ends of the link has been presented. The concept of SFBC-OFDM system is proposed and its performance is analyzed in terms of BER and diversity gain using standard 4G downlink channel parameters. The modulated data encoding and detection processes are explained for 2 transmit and 2 receive antennas. The transmitted data symbols are successfully detected at the receiver using a simple linear processing technique as in STBC-OFDM system. The system is simulated in MATLAB software environment and quite achieved a better performance as justified by the simulation results above. The result indicte that space frequency block coding (SFBC) scheme can sufficiently achieve a remarkable performance increase over multipath fading channels compared to conventional orthogonal frequency division multiplexing (OFDM) techniques. SFBC-OFDM has high sensitivity to channel gain over frequency, while STBC-OFDM has over time as already attained and justified in this project. Furthermore, the SFBC attained similar diversity gain with STBC in a slow fading channel, though it is more robust in fast fading channel compared to STBC scheme [9], Conclusively, 4G and beyond SFBC-OFDM can only achieve optimal performance when the channel remains constant for at least two successive subcarriers.

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