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Orthogonal Frequency Division Multiplexing Performance efficiency on a space time blocks coding of next generation mobile communication

Oborkhale, L[1], Amadi, A.O[2], Nwaogu, C.C[3] and Ehikhamenle, M*[4]
Department of Electrical/Electronic Engineering Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.
Department of Electrical/Electronic Engineering, University of Port-Harcourt, Port-Harcourt, River State
*Corresponding author's email: matthew.ehikhamenle@uniport.edu.ng

Abstract
Digital communication models constantly seek to improve the spectrum efficiency/capacity, coverage of wide area and link reliability. Space-time wireless technology that uses multiple antennas along with appropriate signaling and receiver techniques offers a powerful tool for improving wireless performance. The Space Time Coding has evolved as the most vibrant research area in digital communications. Space-Time Block Coding (STBC) is a state of art for the forthcoming generation of mobile communication standard which aims to deliver true multimedia capability. This paper x-ray the performance of the network with STBC is compared with model without space-time block coding. The STBC which includes the Alamouti Scheme as well as an orthogonal STBC for six transmit antenna case were simulated with MATLAB Simulink and were carefully studied, on simulations of models with Simulink. The result shows that model with STBC performs significantly better than the link without STBC. Multiple antennas when used with appropriate Space-Time Coding (STC) techniques can achieve huge performance gains in multipath fading wireless links.
Keywords: *Multiple input-multiple output, Space-time block code, Orthogonal frequency-division multiplexing and interference*
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1. Introduction

Orthogonal frequency-division multiplexing (OFDM) is a method of digital signal modulation in which a single data stream is split across several separate narrowband channels at different frequencies to reduce interference and crosstalk. It is interesting to observe that Orthogonal Frequency Division Multiplexing is used for many of the latest wide bandwidth and high data rate wireless systems including Wi-Fi, cellular telecommunications and holds many more promise for next generation mobile wireless networks. The main difference between OFDM and OFDMA (Orthogonal Frequency Division Multiple Access) system is that the OFDM user are allocated on the time domain only while OFDMA user would be allocated by both time and frequency (Gartner et al., 2006). The reliability of wireless communication system is primarily limited by fading characteristics. According to Coronel et al. (2008), OFDM is a multi-carrier modulation (MCM) used in transmitting data by splitting it into several components and sending each of these components over separate carrier signals. They said that the individual carriers have narrow bandwidth, but the composite signal can have broad bandwidth. It has the advantage relative immunity to fading caused by transmission over more than one path at a time (multipath fading), less susceptibility than single-carrier systems to interference caused by impulse noise, and enhanced immunity to inter-symbol interference. Sharma et al. (2012) spotted the Limitations it creates in modulation which includes difficulty in synchronizing the carriers under marginal conditions, and a relatively strict requirement that amplification be linear.

To overcome such limitations Space-time coding for multiple input-multiple outputs (MIMO) systems evolved which has been used to enhance the data rate and increase the reliability of a wireless communication system. Space-time block codes (STBCs) for single user MIMO system have been extensively studied over the last decade. Single user schemes for various antenna configurations are already part of the latest LTE standard (GPP, 2010).

2. Mathematical model

2.1 Rayleigh channel

The Rayleigh flat fading channel is commonly used to describe multipath fading channels when there is no Line-Of-Sight (LOS) component. The number of independent copies (multipath) of the signal arriving at the receiver is large, and the coherence bandwidth of the channel is greater than the bandwidth of the signal itself (Omidi et al., 1999) hence transmitted signal. The received signal as the Rayleigh distributions which has a Probability Density Functions (PDF) is given by:

$$\boldsymbol{P(r)} = \{\frac{r}{a2}\ \boldsymbol{exp}\ (-\ \frac{r2}{2a2})\}\ (0 \leq r) \qquad (1)$$

where, r is the Root Mean Square (RMS) value of voltage in a received signal, and $0 \leq r$ is the time-average power of the received signal.

2.2. Rician channel

Rician fading channel is statistical radio propagation model for multipath propagation caused by partial affection of transmitted symbols itself. It is given by:

$$\boldsymbol{P(r)} = \left(\frac{r}{a^2}\right) \boldsymbol{exp} \frac{r^2+A^2}{2a^2}\ \boldsymbol{I_0}\left(\frac{Ar}{a^2}\right) (\boldsymbol{A \geq 0, r \geq 0}) \qquad (2)$$

2.3 Nakagami channel

Nakagami fading channel represents both Rayleigh and Rician fading channel with change in only one parameter which is generally denoted mainly as “m” called the nakagami factor. It is given by the PDF.

$$\boldsymbol{P_R(r)} = \frac{2}{r(m)}\left(\frac{m}{a}\right) \boldsymbol{m_r 2m - 1_e - m_r\ ^2/_a} \qquad (3)$$

At the transmitter level

The encoder has an Alamouti matrix that maps those bits according to following code matrix S:

$$S = \begin{bmatrix} s_1 & -s_2 * \\ s_2 & s_2 * \end{bmatrix} \qquad (4)$$

$$s^2 = [s_1\, s_2 *],\ s^1 = [-s_2\, s_2 *] \qquad (5)$$

where s^1 is the information sequence from the first antenna and sequence from the second antenna.

$$s^1 s^2 = s_1 s_2 * - s_2 * s_1 = 0 \qquad (6)$$

At the receiver

For the case of one receive antenna the receive signals are:

$$\mathbf{r_1^{(1)} = r_1(t) = h_{1,1}{}^{S}{}_1 + h_{1,2} s_2 + n_1{}^1,}$$
$$\mathbf{r_1^{(2)} = r_1(t+T) = -\ h_{1,1} S_2 + h_{12} si + n_1^{(2)},}$$
$$\mathbf{r_m^{(1)} = r_m(t) = -\ h_{m,1} S_2 + h_{m2} s_2 + n_m^{(21},}$$
$$\mathbf{r_m^{(2)} = r_1(t+T) = -\ h_{m,1} S_2 + h_{m2} si + n_1^{(2)},} \qquad (7)$$

where, $r_1^{(\cdot)}$ is the received signal at t and t+T respectively and *hij* is the channel transfer function from the j[th] transmit antenna and the i[th] receive antenna, n) is the independent complex variables with zero mean and unit variance, representing additive white Gaussian noise samples at time t and t + T, respectively.

Before the received signals are sent to the decoder, they are combined as follows:

$$\mathbf{S_1 = hi._1 r_1{}^{(1)} + - - - + h_{m2} r_m \wedge^{(2)}}$$
$$\mathbf{S_2 = h*_M, r_1 + - - - + h_{1.1} r*_m{}^{\{2)}} \qquad (8)$$

and substituting (4) in (5) yields:

$$\mathbf{S_1 = (a^2{}_{1.1} + \bullet\bullet\bullet + a_2 m^2, i) si - h_{1.1} ni*_m{}^{\{2)} + h*_{m2}{}^{11(2)}{}_m}$$
$$\mathbf{S_2 = (a^2{}_{1.1} + \bullet\bullet\bullet + a_2 m^2, i) si - h_{1.1} ni*_m{}^{\{2)} + h*_{m2}{}^{11(1)}{}_m} \qquad (9)$$

where $a^2 ij$ is the squared magnitude of the channel transfer function hq.

The calculated s_1 and s_2 are then sent to a Maximum Likelihood (ML) decoder to estimate the transmitted symbols s_1 and s_2 respectively.

2.4 Single user MIMO system

Multi-user communication system allows users to simultaneously transmit data by sharing the same frequency and time interval. The next generation cellular networks are being designed for an expected multi-fold increase in user demand. Multi-user MIMO is one of the promising techniques that is expected to meet this demand (Larsson et al., 2014). STBCs for multi-user MIMO systems have recently gained attention. Multi-user MIMO channels can be divided into two categories: multiple accesses channel (MAC) and broadcast channel (BC). In the MAC (typically uplink), decentralized mobile users transmit to a base station (BS), while in the BC (typically downlink), the BS - MIMO (multiple input, multiple output) is an antenna technology for wireless communications in which multiple antennas are used at both the source (transmitter) and the destination (Hong and Viterbo, 2008) The antennas at each end of the communications circuit are combined to minimize errors and optimize data speed. Single-user MIMO (SU-MIMO) is a multi-transmitter and receiver technology for wireless communication that allocates the bandwidth of a wireless access point to a single device.SU-MIMO enables multiple data streams to be transmitted to or received between Wi-Fi devices MIMO technology can be used in non-wireless communications systems (Badr and Belfiore, 2008). One example is the home networking standard ITU-T G.9963, which defines a powerline communications system that uses MIMO techniques to transmit multiple signals over multiple AC wires (phase, neutral and ground) (Tse et al., 2004).

2.5 Orthogonal frequency division multiplexing systems

According to Bhatnagar et al. (2009) in Orthogonal Frequency Division Multiplexing systems the original bandwidth is subdivided into multiple subcarriers. Each of these subcarriers can them be individually modulated. Typically, in OFDM systems we can have hundreds of subcarriers with a content spacing between them in Fig. 1 (15KHz on the LTE case). Since the multiple subcarriers in OFDM are transmitted in parallel, it's possible for each one to transmit with a lower symbol rate. That improves robustness on the technology for mobile propagation conditions, the chain to generate an OFDM signal starts by paralyzing the symbols that need to be transmitted, after they are modulated (in LTE the modulation can be QPSK, 16AQM, 64QAM). Then they are used as input bands for an inverse fast Fourier transform operation. This operation produces OFDM symbols, which will be transmitted. (Alamouti, 1998) Notice that a conversion from the frequency to the time domain was made when the IFFT was used. Before the transmission, however, a cyclic prefix is included in the OFDM symbols in order to avoid intersymbol interference. This cyclic prefix in LTE has 5.2us on the first symbol, 4.7us for the rest of them and an extended cyclic prefix for larger cells. On the receiving side of the OFDMA system we should expect an FFT operation that will them convert the symbol to the frequency domain again (Lu et al., 2011).

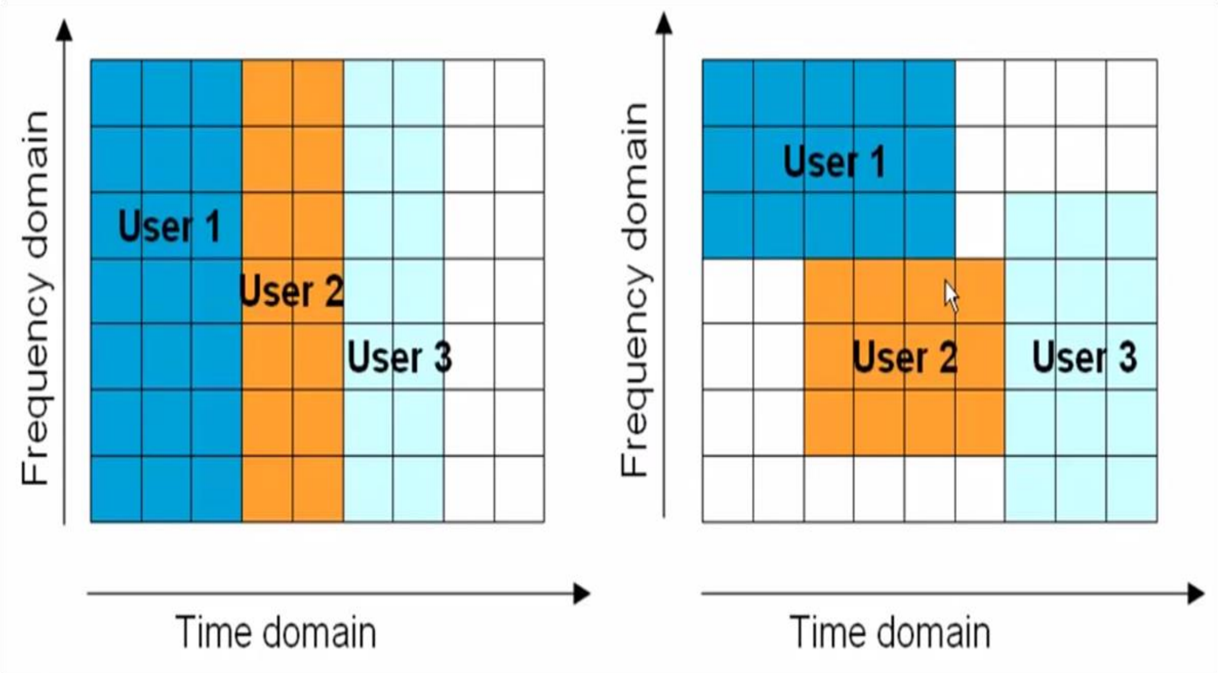

Fig. 1: Typical operational diagram of OFDM and OFDMA

From the operational diagram, OFDMA is used on the downlink, but since it presents a high Peak-to-average Power Ratio, it is not possible to use it on the uplink. For the uplink SC-FDMA will be used. SC-FDMA (Singe Carrier FDMA) presents the benefit of a single carrier multiplexing of having a lower Peak-to-average Power Ratio as in Fig. 2. On SC-FDMA before applying the inverse fast Fourier transform (IFFT), the symbols are pre coded by a DFT (Discrete Fourier Transform). This way each subcarrier after IFFT will contain part of each symbol (Lu et al., 2009).

Fig. 2 shows that it is possible to see the difference between SC-FDMA and OFDMS. Also, it is possible to notice that the intersymbol interference will be reduced since all subcarriers on a period of time represent the same symbol.

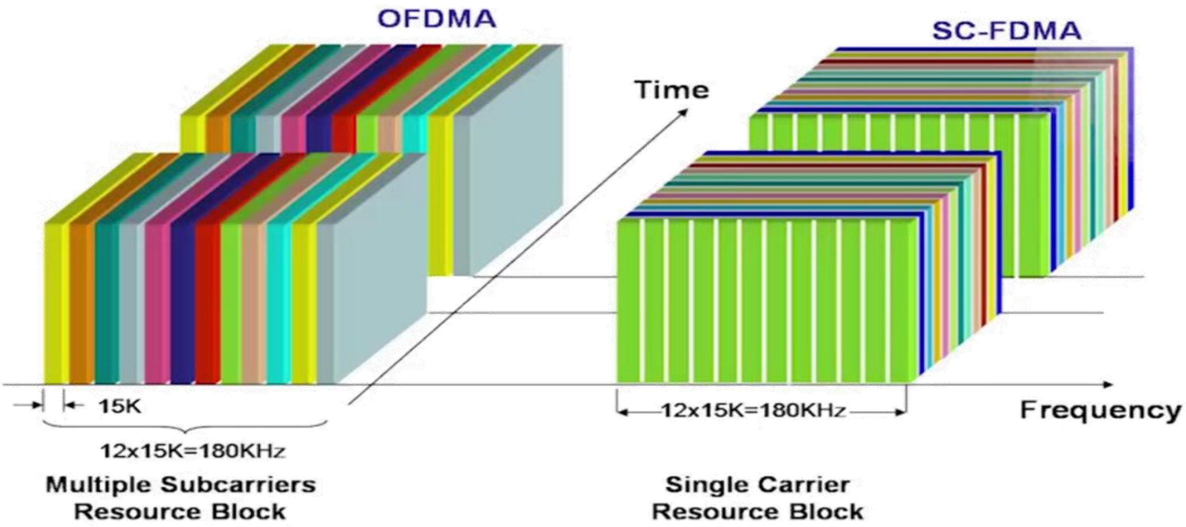

Fig. 2: Simplified long-term evolution (LTE) architecture for OFDMA and SC-FDMA

3. Materials and methods

3.1 Materials

The materials used in achieving the Orthogonal Frequency Division Multiplexing (OFDM) Techniques Performance efficiency in a next generation mobile communication in digital modulation included: Input data generator (Bernoulli Binary Generator), Rectangular BPSK Modulator Baseband, Rectangular QPSK Modulator Baseband, Rayleigh Channel, AWGN Channel. The data to be transmitted through the channel is 100000 bits. With Output data Encoded of Phase noise, Discrete-Time Scatter Plot Scope/ eye diagram, Rectangular 16-QAM Demodulator Baseband, Rectangular 256-QAM Modulator Baseband, Error rate calculation, workspace to Output BER, space –time block coding.

3.2 Methods

The methodology in the communication system models included: Generation of random bit data that models a downlink burst consisting of an integer number of OFDM symbols; Forward Error Correction (FEC) consisting of a Reed-Solomon (RS) outer code concatenated with a rate-compatible inner convolutional code (CC); Data interleaving; Modulation using one of the BPSK, QPSK, 16-QAM or 64-QAM constellations specified; Orthogonal Frequency Division Multiplexed (OFDM) transmission using 192 sub-carriers, 8 pilots, 256-point FFTs, and a variable cyclic prefix length; Space-Time Block Coding using OFDM scheme implemented using the Embedded MATLAB function block for both the encoder at the transmitter and the combiner at the receiver; A single OFDM symbol length preamble that was used as the burst preamble - for the optional STBC model, the single symbol preamble was transmitted from both antennas; A Multiple-Input-Single-Output (MISO) fading channel with AWGN for the STBC model; A choice of non-fading, flat-fading or dispersive multipath fading channel for the non-STBC model; OFDM receiver that included channel estimation using the inserted preambles; and Hard-decision demodulation followed by DE interleaving, Viterbi decoding, and Reed-Solomon decoding.

OFDM modelling scheme

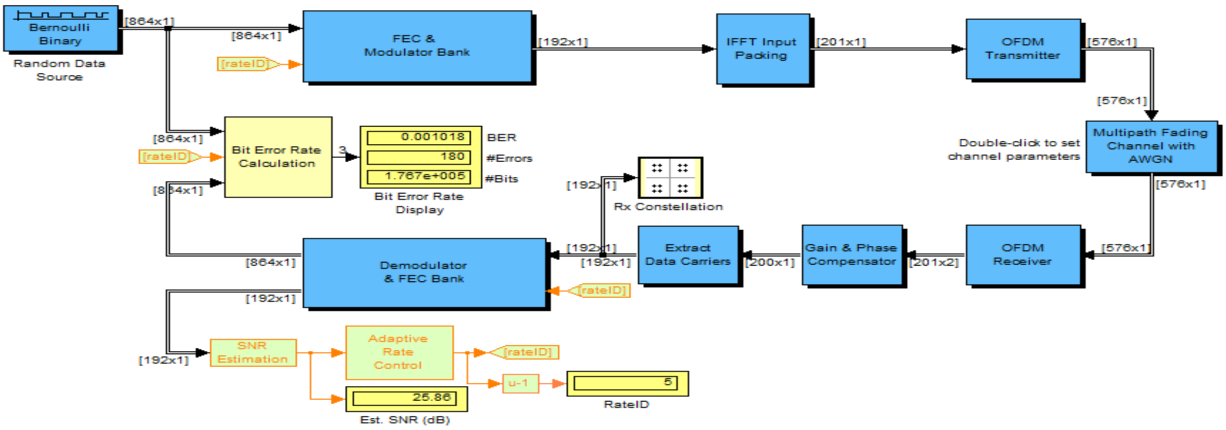

Fig. 3: OFDM Physical downlink link model without space-time block coding

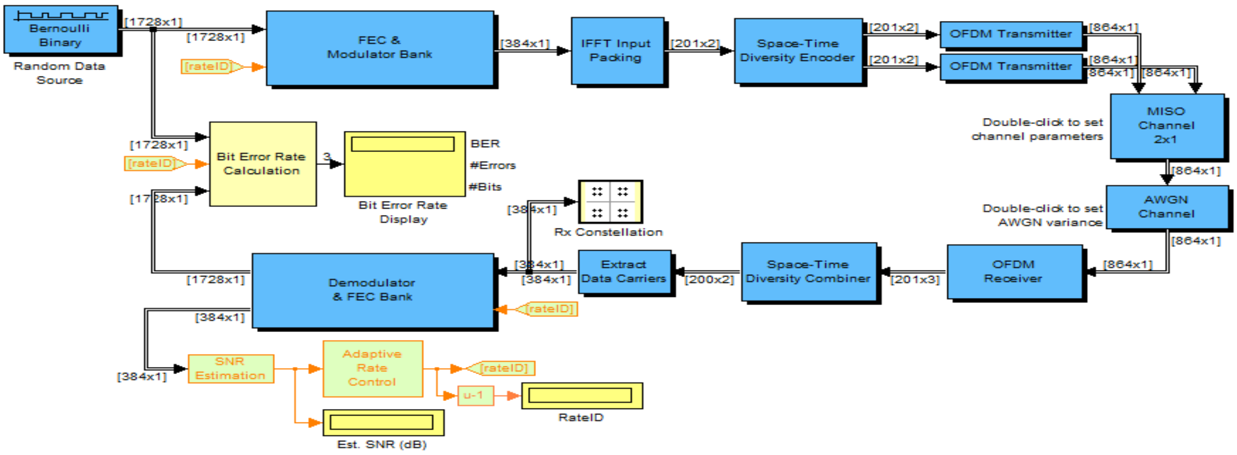

Fig. 4: OFDM Physical downlink model with space-time block coding

Both models also used an adaptive-rate control scheme based on SNR estimates at the receiver to vary the data rate dynamically based on the channel conditions. The models used the standard specified set of seven rates for OFDM-PHY, each corresponding to a specific modulation and RS-CC code rate as denoted by rate ID (Table 1).

4. Results and discussion

This is the result of OFDM PHY downlink model with and without STBC, it obvious that both models use an adaptive-rate control scheme based on SNR estimates at the receiver to vary the data rate dynamically based on the channel conditions. The models use the standard specified set of seven rates for OFDM-PHY, each corresponding to a specific modulation and RS-CC code rate with a standard modulation technique. Perhaps, It provides a simple and robust synchronization and an accurate hardware affordable channel estimator to overcome the challenge of multipath fading channels. The coded bit error rate performance for 16 quadrature amplitude modulation can achieve less than10-6 under the vehicle speed of 120 km/hr.

Table 1: OFDM physical downlink with RS-CC Code rate

Rate ID	Modulation RS-CC rate
0	BPSK
1	QPSK
2	QPSK
3	16-QAM
4	16-QAM
5	64-QAM
6	64-QAM

The table unfold the significant of the modulation techniques on the STBC link model that uses a MISO fading channel to model a two transmitter, one receiver (2x1) system. The fading parameters specified are assumed to be identical for the two links. The Space-Time Diversity Combiner block uses the channel estimates for each link and combines the received signals. Hence the combining involves simple linear processing using the orthogonal signalling employed by the encoder which provides multiple-input multiple-output (MIMO) system is known to exploit the antenna diversity to develop the performances of wireless communication systems using multiple antenna elements at the transmitter and receiver ends. The main objective of MIMO technology is to improve bit error rate (BER) or the data rate of the communication by applying signal processing techniques at each side of the system. The capacity increases linearly with the number of antennas while using MIMO however it gradually saturates. MIMO can obtain both multiplexing gain and diversity gain and can help significantly increase the system capacity. The earliest studies considering MIMO channels were carried out.

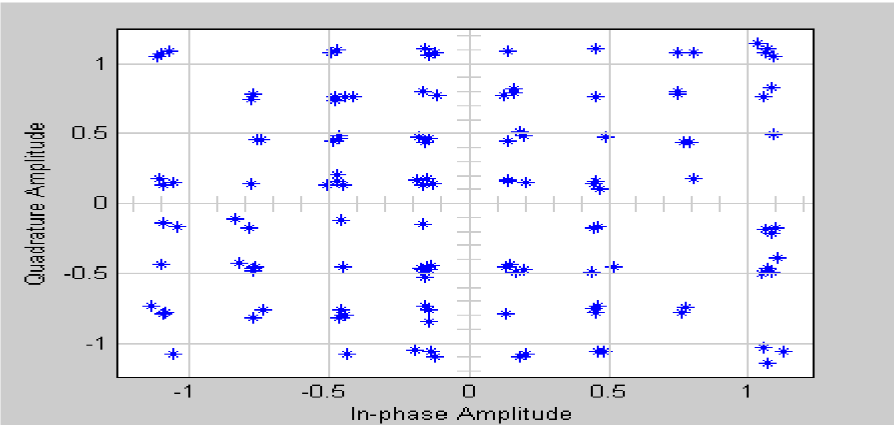

Fig. 5: Spectrum plots of channel bandwidth

The graph shows the spectrum plots of channel bandwidth; When either of the two models is simulated, windows come up automatically to display the spectrum plots. The plot shows a spectrum of inter-symbol interference transmitted signal per antenna and a scatter plot of the received signal prior to demodulation of the channel bandwidth on a scatter plot. The Mitigation factor is achieved by subtracting the jamming and interference components of the signal seen at one receiving antenna from signals received at other antennas. Without using multiple-antenna mitigation techniques, a typical communication link would simply fail or at best be forced to reduce its data rate by factors of thousands to millions, making the links effectively useless.

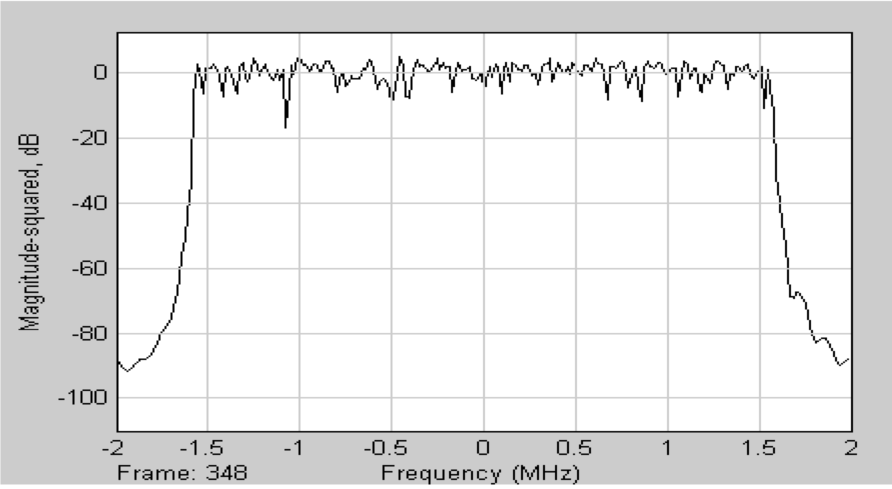

Fig. 6: Modulation type plot on a signal constellation of 2, 4, 16, or 64 points

This the graph of Modulation technique plot on a signal constellation of 2, 4, 16, or 64 points. The block Use the spectrum plots to verify the channel bandwidth in use and the subcarrier spacing. It also Use the scatter plots to gauge which modulation type is in use, as the plot resembles a signal constellation of 2, 4, 16, or 64 points under good channel conditions to show the performances level of the modulation on space time block coding. The first Doppler spectrum, represented by the dashed red line, is a theoretical spectrum based on the Doppler filter response used in the multipath channel model. In the preceding plot, the theoretical Doppler spectrum used for the multipath channel model is known as the Jakes spectrum. The second Doppler spectrum, represented by the blue dots, is determined by measuring the power spectrum of the multipath fading channel as the model generates path gains. This measurement is meaningful only after enough path gains have been generated. The title above the plot reports how many samples need to be processed through the channel before either the first Doppler spectrum or an updated spectrum can be plotted.

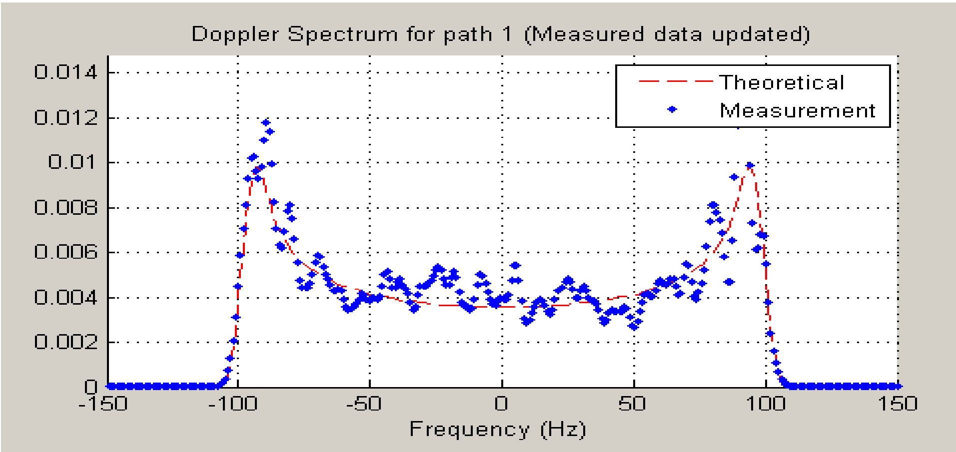

Fig. 7: Doppler spectrum

4. Conclusions

In this paper, a multi-user MIMO STBC for two users at 16-QAM constellation is presented. It is shown that the symbols transmitted by the two users can be decoded separately at the receiver. The performance of the proposed scheme is compared with the model that has STBC for multi-user MIMO and it is shown that with STBC a significant improvement in performance without compromising the data rate and decoding complexity was achieved. This work shows that Space-Time Block Codes (STBC) for digital networks that uses multiple numbers of antennas at both transmitter and receiver as Multi-user MIMO based techniques are a promising candidate to meet the demand of next generation wireless network. The result shows that Multiple-input multiple-output (MIMO) systems of Orthogonal Frequency Division Multiplexing (OFDM) on a space time blocks coding of next generation mobile communication are a key component of future wireless communication systems, because of their promising improvement in terms of performance and bandwidth efficiency. Such systems have the potential to combine the high throughput achievable with MIMO processing with the benefits of space division multiple accesses (SDMA). The bit error rate performance of AWGN channel is better compared to Rayleigh fading channel.

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