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Image Transmission through OFDM System using Alamouti-STBC under AWGN, Nakagami and Rayleigh Channels

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Abstract – **Recent communication world is facing drastic changes in the format related to OFDM system. An OFDM system deals with multiple channels over which information are sent at different frequencies to boast up bandwidth efficiency. These techniques were used for audio or video signals in OFDM but in this paper it has been done for image processing to recover original image. Along with this IFFT and FFT filters are used at the transmitter and at the receiving end of OFDM system. During communication, an extra unwanted noise signals come across with real signal due to any reason. This paper deals with these noise called AWGN, Rayleigh and Nakagami. At the receiver side, bit error rate is improved to recover real image which is transmitted from transmitter to receiver. In order to achieve this, the methodology has gone through BPSK modulation technique and Alamouti space time block codes. This system was implemented using MATLAB, in order to simulate these functionalities and to obtain results in the form of BER and SNR to evaluate these performances.**

Keywords – **AWGN, BER, BPSK, OFDM, Nakagami, Rayleigh, SNR.**

I. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is a method of modulation where the spectrum associated with each data is a small portion of the total bandwidth, which is divided into N sub-channels. Each sub-channel is modulated with a symbol and multiplexed in frequency [1]. In order to avoid a large number of modulators and filters in the transmitter, as well as complementary filters and demodulators in the receiver, modern techniques of digital signal processing such as the fast Fourier transform are used [2]. To generate OFDM, several parameters must be taken into account, such as: the number of subcarriers, the modulation scheme and the guard interval to be used.

OFDM is a multi-carrier modulation that effectively combats frequency selectivity [3]. This technique has the advantage of transforming a frequency-selective broadband channel into a set of non-frequency selective narrow-band channels, which ensures the robustness of the OFDM modulation to propagation delays while preserving the orthogonality in the frequency domain. The principle of OFDM is to divide the bandwidth of the transmission channel into N independent subbands. The symbols of the signal to be transmitted are then multiplexed on the N sub-carriers relating to the N frequency subbands [4]. The spacing between the different sub-carriers is defined with respect to the symbol time T_S to ensure the orthogonality between the sub-carriers. The N symbols are transmitted simultaneously, thus forming an OFDM symbol. The OFDM symbols first undergo an Inverse Fast Fourier Transform (IFFT) transform around a carrier frequency f_0 and then are transmitted over the channel. At the receiver, the signal undergoes inverse transformations leading to the reconstruction of emitted symbol vectors [5].

The advantages of this technique are many among which we site:

- Efficiency of the use of spectrum and power (use of N orthogonal carriers very close to each other.
- High immunity against multi-path propagation, or some symbols of a previous transmission may arrive late.
- Immunity against interference between channels (insertion of null carriers at each end of the symbol.
- Ease of channel synchronization and estimation thanks to pilot subcarriers.

The objective of the transmission strategies is to better regulate the constituent parameters of the

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different blocks composing the digital communication chain to guarantee a better image quality in reception [6]. In general, these strategies are based on the hierarchization of the output data of the source encoder. This hierarchy is exploited by giving better protection to the most important data to the detriment of the least important data in terms of distortion [7].
The main objective of this paper is to implement an image transmission framework through OFDM using Alamouti STBC under Rayleigh and Nakagami Channels with zero forcing equalizer.

II. OFDM System

A basic OFDM system is described in Figure 1. Here an input data symbols are supplied into a channel encoder that data are mapped onto BPSK constellation.
The data symbols are converted from serial to parallel and using Inverse Fast Fourier Transform (IFFT) to achieve the time domain OFDM symbols. Time domain symbols can be represented as [8]:

$$x_n = IFFT\{X_k\}$$
$$= \frac{1}{N}\sum_{k=0}^{N-1} X_k e^{\frac{j2\pi kn}{N}} \quad 0 \le n \le N-1 \quad (1)$$

Where, X_k is the transmitted symbol on the kth sub-carriers.
N is the number of subcarriers.

Time domain signal is cyclically extended to prevent Inter Symbol Interference (ISI) from the former OFDM symbol using cyclic prefix (CP).
The Digital to Analog Converter (DAC) is performed to convert the baseband digital signal into analog signal. This operation is executed in DAC block of diagram. Then, the analog signal is proceeded to the Radio Frequency (RF) frontend. The RF frontend performs operations after receiving the analog signal. The signal is up converted to RF frequencies using mixer and amplified by using Power Amplifier (PAs) and then transmitted through antennas.
At the receiver side, the received signal is down converted to base band signal by RF front end. The analog signal is digitized and re-sampled by the Analog to Digital Converter (ADC). The ADC is used to digitize the analog signal and re-samples it. In the figure, frequency and time synchronization block are not shown because of simplicity.

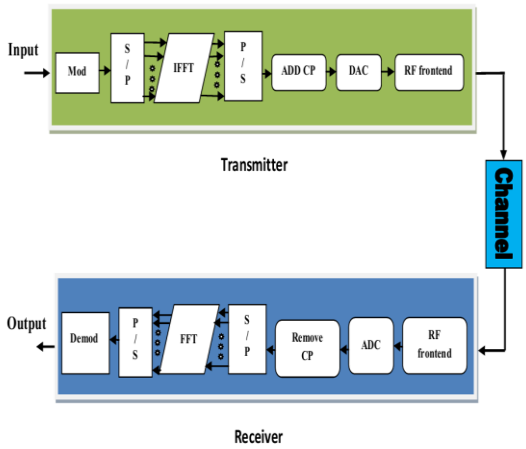

Figure 1: A basic diagram of OFDM transceiver [9]

Cyclic prefix is removed from the signal in frequency domain. This step is done by the Fast Fourier Transform (FFT) block. The received symbols in the frequency domain can be represented as [10]:

$$Y(k) = H(k)X_m(k) + W(k) \quad (2)$$

Where, $Y(k)$ is the received symbol on the Kth subcarrier, $H(k)$ is the frequency response of the channel on the same subcarrier and $W(k)$ is the additive noise added to Kth, subcarrier which is generally assumed to be Gaussian random variable with zero mean and variance of σ_w^2. Thus, simple one tap frequency domain equalizers can be employed to get the transmitted symbols. After FFT signals are de-interleaved and decoded to recover the original signal.

Mathematical Definition of OFDM Signal
OFDM consists of multiple carriers. Each carrier can be presented as a complex waveform like [11]:

$$s_c(t) = A_c(t)e^{j[\omega_c + \phi_c(t)]} \quad (3)$$

Where,
$A_c(t)$ is the amplitude of $s_c(t)$.
$\phi_c(t)$ is the phase of the signal $s_c(t)$.
The complex signal can be described by:

$$s_s(t) = \frac{1}{N}\sum_{n=0}^{N-1} A_n(t)e^{j[\omega_n + \phi_n(t)]} \quad (4)$$

This is a continuous signal. Each component of the signal over one symbol period can take fixed values of the variables like:

$$\phi_n(t) \rightarrow \phi_n$$
$$A_n(t) \rightarrow A_n$$

Where, n is the number of OFDM block.
T is a time interval and the signal is sampled by $1/T$ then it can be represented by:

$$s_s(kT) = \frac{1}{N}\sum_{n=0}^{N-1} A_n e^{j[(\omega_0 + \omega\Delta n)kT + \phi_n]} (5)$$

Let $\omega_0 = 0$ then the signal becomes:

$$s_s(kT) = \frac{1}{N}\sum_{n=0}^{N-1} A_n e^{j[\omega\Delta n)kT + \phi_n]} \quad (6)$$

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III. PROPOSED METHOD

This section aims to provide principal and theoretical background to digital modulation technique. As depicted in Figure 2, the simplified OFDM transceiver is divided into three main sections of Transmitter, Channel and Receiver. Modulation/De-modulation, IFFT/FFT, CP insertion/removal are the most important blocks in this simplified OFDM transceiver.

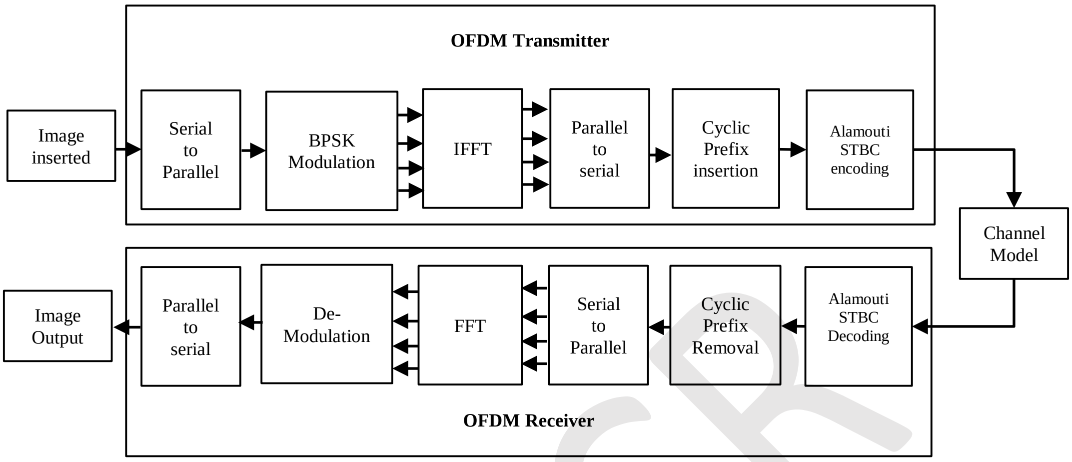

Figure 2: Block diagram for proposed approach

As depicted in Figure 2, the initial stage prior to the actual OFDM transmission is to transmit the generated message. In our case this message is a digitally processed image and the BPSK is used as the modulation scheme.

Serial to Parallel Conversion

Data to be transmitted is typically in the form of a serial data stream. Serial to parallel conversion block is needed to convert the input serial bit stream to the data to be transmitted in each OFDM symbol. The data allocated to each symbol depends on the modulation scheme used. During symbol mapping the input data is converted into complex value constellation points, according to a given constellation. Typical constellations for wireless applications are, BPSK, QAM, and QAM out of which this research work uses BPSK.

The amount of data transmitted on each subcarrier depends on the constellation. Channel condition is the deciding factor for the type of constellation to be used. In a channel with high interference a small constellation like BPSK is favorable as the required signal-to-noise-ratio (SNR) in the receiver is low. For interference free channel a larger constellation is more beneficial due to the higher bit rate. Known pilot symbols mapped with known mapping schemes can be inserted at this moment. Cyclic prefix is inserted in every block of data according to the system specification and the data is multiplexed to a serial fashion.

BPSK Modulation

In the constellation BPSK two phases are represented, one inverted with respect to the other with the same amplitude. Comparing the BPSK with the FSK, it can be verified that the BPSK is more immune to noise, because it must be of greater power (greater distance to move the point to enter the area of the other symbol) for the receiver to decode correctly. Only the ASK signal can be detected per envelope, while the detection of a PSK signal is necessarily synchronous.

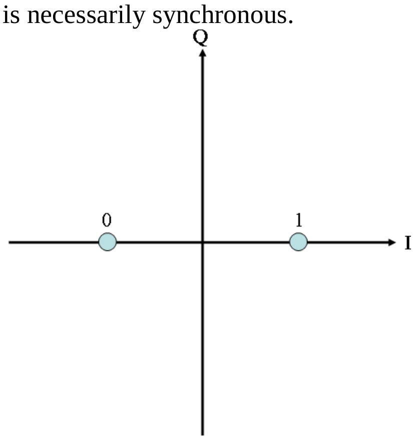

Figure 3: Constellation diagram for BPSK

Cyclic Prefix

The Cyclic Prefix or Guard Interval is a periodic extension of the last part of an OFDM symbol that is added to the front of the symbol in the transmitter, and is removed at the receiver before demodulation.

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Alamouti Space-Time Block Code

It is simple method for achieving spatial diversity with two transmit antenna. The scheme is as follows:

1. Consider that we have a transmission sequence, for example
$$\{x_1, x_2, x_3, \ldots\ldots, x_n\}$$
2. In normal transmission, we will be sending x_1 in the first time slot, x_2 in the second time slot, x_3 and so on.
3. However, Alamouti suggested that we group the symbols into groups of two. In the first time slot, send x_1 and x_2 from the first and second antenna. In second time slot send $-x_2^*$ and x_1^* from the first and second antenna. In the third time slot send x_3 and x_4 from the first and second antenna. In fourth time slot, send $-x_4^*$ and x_3^* from the first and second antenna and so on.
4. Notice that though we are grouping two symbols, we still need two time slots to send two symbols. Hence, there is no change in the data rate.
5. This forms the simple explanation of the transmission scheme with Alamouti Space Time Block coding.

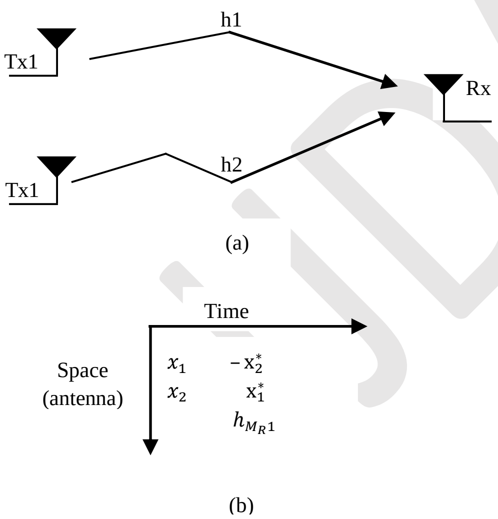

Figure 4: (a) Transmit, (b) Receive Alamouti STBC coding

Channel Model

AWGN Channel

Additive White Gaussian Noise (AWGN) is a noise channel. This channel effects on the transmitted signals when signals pass through the channel. The mathematical expression as in receiving signal $r(t) = s(t) + n(t)$ is shown in Figure 5 which passed through the AWGN channel where $s(t)$ is transmitted signal and $n(t)$ is background noise.

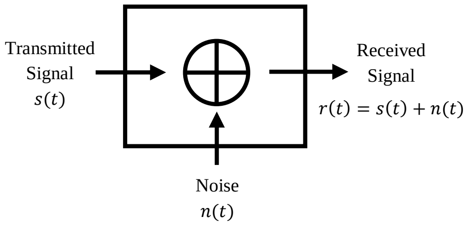

Figure 5: AWGN Channel

A Probability Distribution Function (PDF) of a Gaussian distributed random variable n, with mean value of μ, and the variance of σ can be written as:

$$p(n) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[\frac{1}{2}\left(\frac{n}{\sigma}\right)^2\right] \quad (10)$$

Rayleigh Fading Channel

Rayleigh fading is caused by multipath reception. The mobile antenna receives has large number of, say n, reflected and scattered replicas of same signal. Because of constructive and destructive interference, the instant received power seen by mobile antenna becomes a random variable, dependent upon the site of the antenna. The probability distribution function of phase and amplitude of this random variable is given by:

$$p(R) = \frac{R}{\sigma^2} \exp\left(-\frac{R^2}{2\sigma^2}\right) \quad (11)$$

Nakagami Fading Channel

Nakagami Fading occurs for multipath scattering with relatively larger time-delay spreads, with different clusters of reflected waves. Within any one cluster, the phases of individual reflected waves are random, but the time delays are approximately equal for all the waves. As a result the envelope of each cluster signal is Rayleigh Distributed. The average time delay is assumed to differ between the clusters. If the delay times are significantly exceed the bit period of digital link, the different clusters produce serious inter-symbol interference. The Nakagami Distribution termed the magnitude of the received envelope by the distribution

$$p(r) = \frac{2}{\Gamma(m)}\left(\frac{m}{\Omega_p}\right)^m r^{2m-1} exp\left\{-\frac{mr^2}{\Omega_p}\right\} \quad (12)$$

Demodulation

Demodulation is the technique by which the original data (or a part of it) is recovered from the modulated signal which is received at the receiver end. In this case, the received data is first made to pass through an Alamouti-STBC decoder and the cyclic prefix is removed. FFT of the signal is done after it is made to pass through a serial to parallel converter. A demodulator is used, to get back the original signal.

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The Bit Error Rate and the signal–to–noise ratio are calculated by taking into consideration the unmodulated signal data and the data (image) at the receiving end.

IV. Simulation And Results

The performance of proposed algorithms has been studied by means of MATLAB simulation.

Figure 6: Input image

Figure 7: Output image

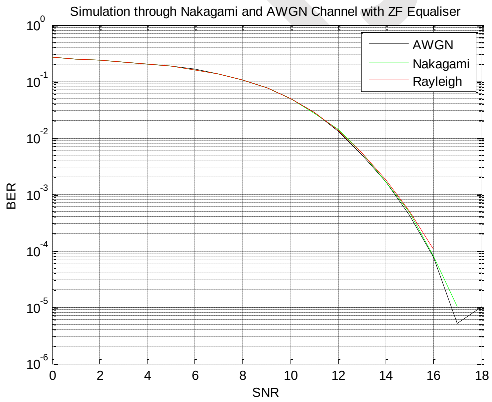

Figure 8: BER performance comparison for AWGN, Nakagami and Rayleigh channel with ZF equalizer

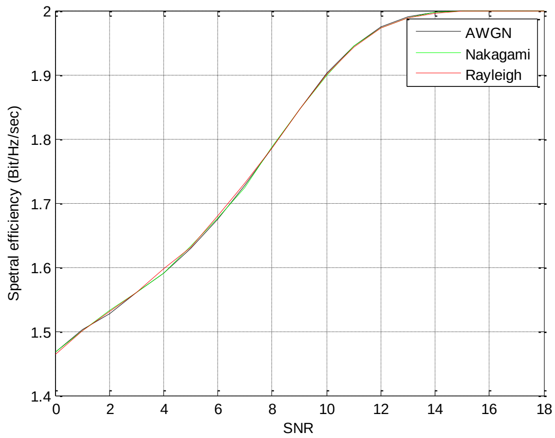

Figure 9: Spectral efficiency comparison for AWGN, Nakagami and Rayleigh channel with ZF equalizer

V. Conclusion

In future communication systems, such as WiMAX, LTE-A and 5G, which use multi-user access and OFDM multiplexing, optimization and scheduling are performed to improve their reliability while ensuring equitable access for users. Performance analysis of wireless communication systems is a very difficult task. It often requires the use of ultra-simplified models to the point of sacrificing Precision and Reliability, or Extremely Complex and Demanding System Level Simulations in time and money. In this paper, image transmission over wireless digital communication is simulated and examines the BPSK modulation technique using AWGN, Rayleigh and Nakagami channels. Effect of fading degrades the performance of system but use of suitable coding scheme can help to reduce this effects. An Alamouti Space-Time Block coding and decoding is added for performance enhancement.

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