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European Journal of Advances in Engineering and Technology, 2015, 2(6): 14-19

Research Article ISSN: 2394 - 658X

Beamforming for MIMO-OFDM Wireless Systems

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ABSTRACT

The smart antennas are widely used for wireless communication, because it has a ability to increase the coverage and capacity of a communication system. Smart antenna performs two main functions such as direction of arrival estimation (DOA) and beam forming. Using beam forming algorithm smart antenna is able to form main beam towards desired user and null in the direction of interfering signals. In this project Direction of arrival (DOA) is estimated by using MUSIC algorithm. Receive Beam forming is performed by using LMS and LLMS algorithm .In this Paper, in order to perform secure transmission of signal over wireless communication we have used chaotic sequences. This paper evaluates the performance of Beam forming with and without LMS and LLMS algorithm for MIMO-OFDM wireless system. The simulations are carried out using MATLAB.

Key words: OFDM, MIMO, MUSIC, LMS, LLMS

INTRODUCTION

The phenomenon of multipath propagation has contributed significantly towards deterioration of quality of signal received in a wireless communication system. Several techniques for multipath mitigation are in use in the current wireless communication technology standards. With the steady rise in the number of wireless devices active in the environment, the concept of beam forming has gained popularity. When multiple communications are carried out simultaneously, then in multipath environment the interference from different directions will also increase. This multipath propagation causes the signal at the receiver to distort and fade significantly, leading to higher bit error rates (BER). To minimize the interference from different directions, smart antennas can be used at the receivers which form the beam in the direction of the incoming multipath and reject the interference coming from other directions.

In a wireless communication scenario, transmitted signals often propagate via just a few distinct paths, for example via a line-of-sight path between transmitter and receiver and/or via paths that are associated with significant reflectors and diffractors in the environment (such as large buildings or mountains). If the directions of these dominant propagation paths are known at the receiver side, beam forming techniques can be applied, in order to adjust the receiver beam pattern such that it has a high directivity towards the dominant angles of reception. By this means, significant SNR gains can be accomplished in comparison to an antenna array with an omni-directional beam pattern. Such SNR gains due to beam forming techniques are often called antenna gains or array gains in the literature. Similarly, if the directions of the dominant propagation paths are known at the transmitter side, the transmit power can be concentrated within the corresponding angular regions and is not wasted for directions that do not contribute to the received signal. Beam forming techniques can also be useful, in order to reduce the delay spread of the physical channel caused by multipath signal propagation. To this end, receiver beam pattern is adjusted such that it exhibits nulls in the directions of dominant distant reflectors. Correspondingly, echoes with excessively large delays are eliminated from the received signal. The basic principle of beam forming is illustrated in Fig.1.

In the considered example, a beamformer is employed both at the transmitter and at the receiver side. In a practical system, the directions of dominant propagation paths must be estimated. This can, for example, be done by means of the well-known MUSIC algorithm. Moreover, when transmitter or receivers are moving, the antenna patterns must be updated on a regular basis. Such adaptive antenna arrays are often called smart antennas or software antennas in the literature. Due to the required equipment and processing power, however, the use of smart antenna technologies is currently limited to fixed stations, such as base stations, or mobile stations that are fixed on vehicles. Yet, for future wireless communication systems it is anticipated that smart antennas will also be feasible for hand-held devices employing small phased arrays fabricated by microstrip technology.

In beam forming, both the amplitude and phase of each antenna element are controlled. Combined amplitude and phase control can be used to adjust side lobe levels and steer nulls better than can be achieved by phase control alone. The combined relative amplitude a_k and phase shift q_k for each antenna is called a “complex weight” and is represented by a complex constant w_k (for the kth antenna). A beamformer for a radio transmitter applies the complex weight to the transmit signal (shifts the phase and sets the amplitude) for each element of the antenna.

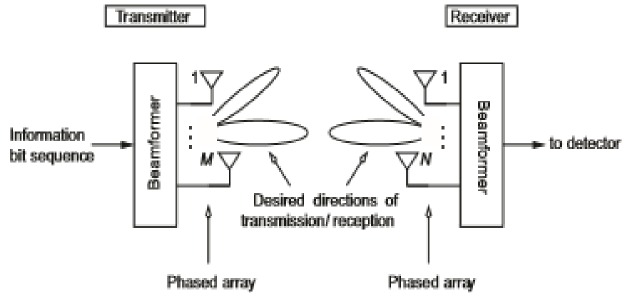

Fig. 1 Principle of Beam forming

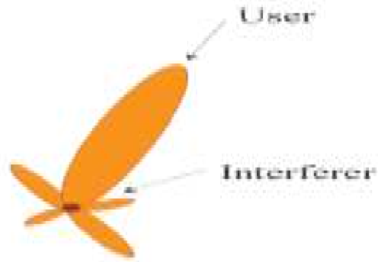

Fig. 2 Adaptive Beam forming

Adaptive Beam forming

The complex weights w_k for the antenna elements are carefully chosen to give the desired peaks and nulls in the radiation pattern of the antenna array. In a simple case, the weights may be chosen to give one central beam in some direction, as in a direction-finding application. The weights could then be slowly changed to steer the beam until maximum signal strength occurs and the direction to the signal source is found. In beam forming for communications, the weights are chosen to give a radiation pattern that maximizes the quality of the received signal. Usually, a peak in the pattern is pointed to the signal source and nulls are created in the directions of interfering sources and signal reflections.

There are two types of beam forming, they are:

Digital Beam Forming

In digital beam forming, the operations of phase shift and amplitude scaling for each antenna element, and summation for receiving, are done digitally. Either general-purpose DSP’s or dedicated beam forming chips are used. Digital processing requires that the signal from each antenna element is digitized using an A/D converter. Since radio signals above shortwave frequencies (>30 MHz) are too high to be directly digitized at a reasonable cost, digital beam forming receivers use analog “RF translators” to shift the signal frequency down before the A/D converters. Once the antenna signals have been digitized, they are passed to “digital down-converters” that shift the radio channel’s center frequency down to 0 Hz and pass only the bandwidth required for one channel. The down-converters produce a “quadrature” baseband output at a low sample rate.

Adaptive Beam Forming

It is the process of altering the complex weights on-the-fly to maximize the quality of the communication channel. Here are some commonly used methods:

Minimum Mean-Square Error

The shape of the desired received signal waveform is known by the receiver. Complex weights are adjusted to minimize the mean-square error between the beamformer output and the expected signal waveform.

Maximum Signal-to-Interference Ratio

Where the receiver can estimate the strengths of the desired signal and of an interfering signal, weights are adjusted to maximize the ratio.

Minimum Variance

When the signal shape and source direction are both known, chose the Weights to minimize the noise on the beamformer output antenna array.Adaptive beam forming systems for communications are sometimes referred to as “smart antenna” systems. For cellular telephone, one base station with a smart antenna system can support more than one user on the same frequency, as long as they are in different directions, by steering individual antenna beams at each user. This is sometimes called “spatial domain multiple access” (SDMA). It’s estimated that the capacity of cellular telephone systems can be doubled by using smart antennas. Smart Adaptive Array Antenna can track the unknown interference signal in real time automatically, that is, it can direct antenna pattern with nulls towards the interference and offer gain to the required signal to ensure the required signal reception, so output SINR (signal to Interference and Noise Ratio) is improved.

PROPOSED WORK

The proposed system uses a technique of adaptive beam forming algorithm (LMS and LLMS) for MIMO-OFDM system at receiving side by finding first the direction of arrival (DOA) of signal by using well known MUSIC algorithm for the improvement of BER performance. Here we have used encryption for security purpose by using chaotic encoder. This combined technique enhances security and performance of the system in terms of BER. The study has focused on various adaptive beam forming algorithms and its use in the system to improve the performance in terms of BER.

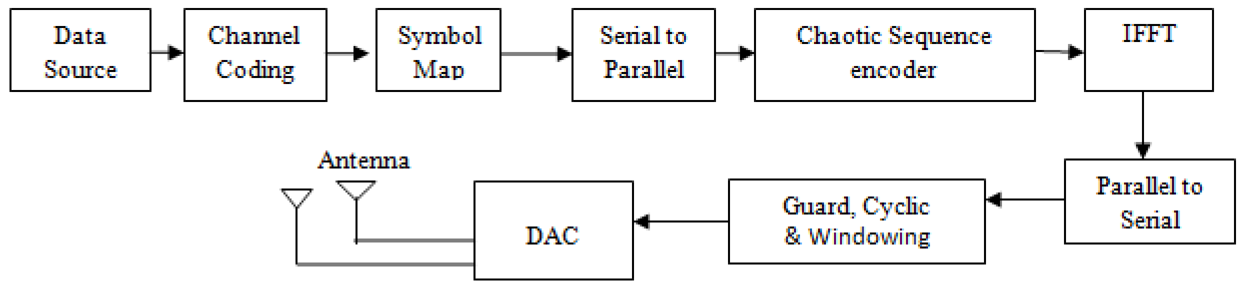

Fig. 3 Block diagram for the simulated MIMO- OFDM Transmitter

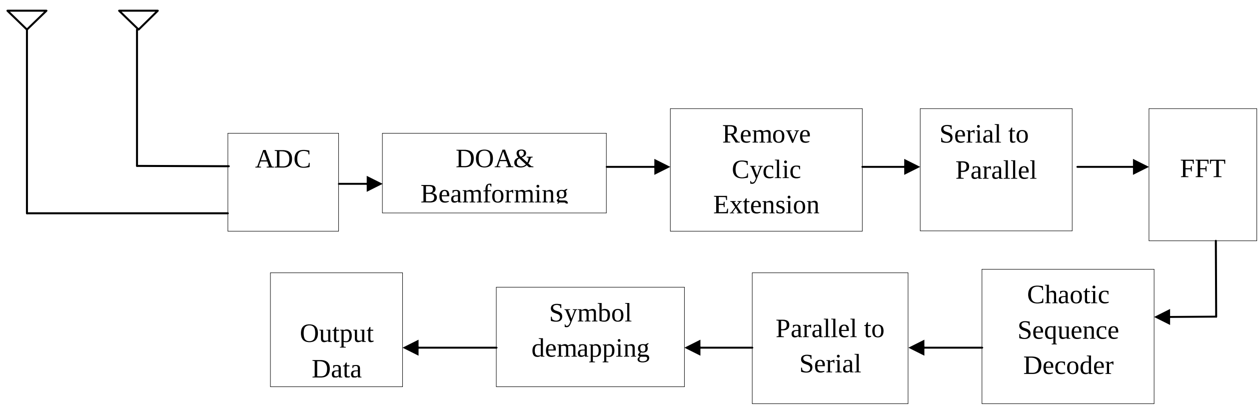

Fig. 4 Block diagram for the simulated MIMO- OFDM Receiver

At the transmitter, the user information bit sequence is first subjected to channel encoding to reduce the probability of error at the receiver due to the channel effects.Convolution encoding is used. Then the bits are mapped to symbols. Usually, the bits are mapped into the symbols of either BPSK, QPSK, 16PSK, 256PSK. The symbol sequence is converted to parallel format and it is encrypted for security purpose by using chaotic encoder and IFFT (OFDM modulation) is applied and the sequence is once again converted to the serial format.

Guard time is provided between the OFDM symbols and the guard time is filled with the cyclic extension of the OFDM symbol. Windowing is applied to the OFDM symbols to make the fall-off rate of the spectrum steeper. The resulting sequence is converted to an analog signal using a DAC and passed on to the RF modulation stage. The resulting RF modulated signal is, then, transmitted to the receiver using the transmit antennas.

At the receiver, Receive beamforming is performed by LMS and LLMS algorithm but before that by using MUSIC algorithm the direction of arrival of signal is found. MUSIC the method estimates the noise subspace from available samples. This can be done by either eigenvalue decomposition of the estimated array correlation matrix or singular value decomposition of the data matrix once the noise subspace has been estimated, a search for angle pairs in the range is made by looking for steering vectors that are orthogonal to the noise subspace as possible. This is normally accomplished by searching for peaks in the MUSIC spectrum. First RF demodulation is performed. Then, the signal is digitized using an ADC and timing and frequency synchronization are performed. Synchronization will be dealt with in the later sections. The guard time is removed from each OFDM symbol and the sequence is converted to parallel format and FFT (OFDM demodulation) is applied. The output is then decrypted by using Chaotic decoder and then serialized and symbol de-mapping is done to get back the coded bit sequence. Channel decoding is, then, done to get the user bit sequence.

SIMULATION

Table - 1 Parameters considered for simulation

Parameter	Value/Type
Input size	700 bits
No. of Carriers	64
IFFT/FFT size	64
SNR range	1-30db
Carrier modulation used	BPSK,QPSK,16PSK,256PSK
Channel used	AWGN,Rayleigh,Rician
Coding Technique	convolution based forward error correction with rate 1/3
No of transmitting antenna	2
No of Receiving Antenna	2
Interfering Angle	10^0
Transmitting Angle	10^0&90^0 compared with 20^0&180^0

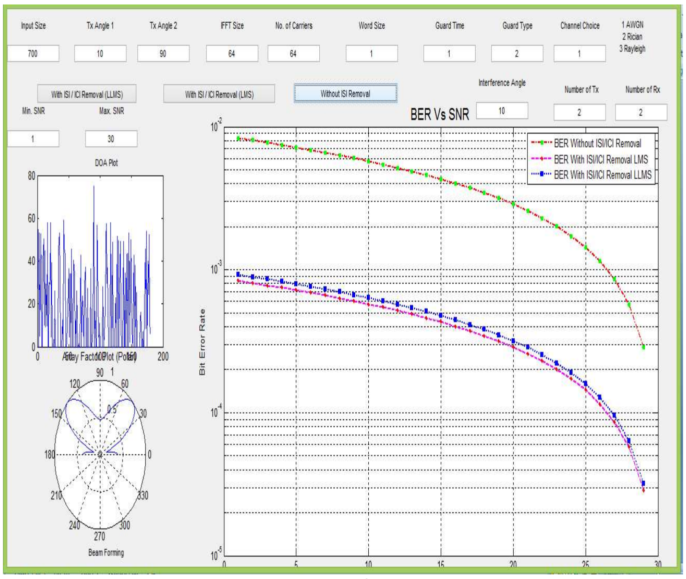

Fig. 5 Beamforming

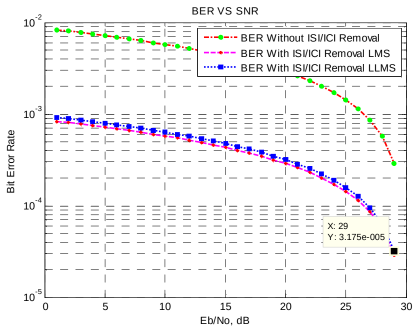

Fig. 6 AWGN Channel

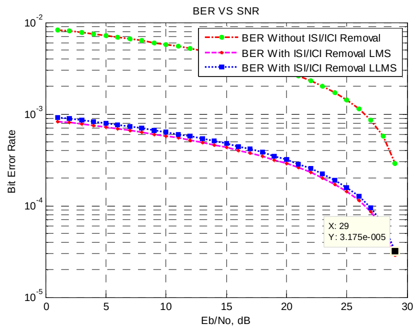

Fig. 7 Rician Channel

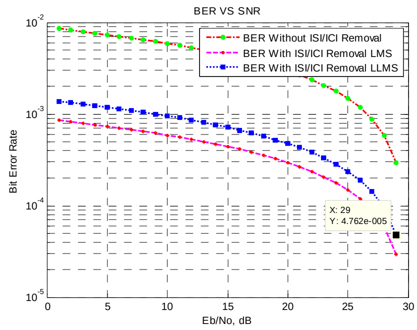

Fig. 8 Rayleigh channel

Table - 2 Simulation result for BPSK

Angle for tx1=10^0 and tx2=90^0

	AWGN Channel		Rician Channel		Rayleigh Channel	
SNR	Without Beam forming	With Beam Forming	Without Beam forming	With Beam forming	Without Beam forming	With Beam forming
4	0.01002	0.0009826	0.009237	0.00112	0.006092	0.0006092
8	0.008484	0.0008314	0.007816	0.0009478	0.005155	0.0005155
12	0.006939	0.0006803	0.006395	**0.0007755**	0.004218	0.0004218
16	0.005397	0.0005291	0.004974	0.0006032	0.00328	0.000328
20	0.003855	**0.0003779**	0.003553	0.0004308	0.002343	**0.0002343**
24	0.002313	0.0002268	0.002132	0.0002585	0.001406	0.0001406
28	0.000771	0.00007559	**0.0007105**	0.00008617	0.0004686	0.00004686
29	**0.0003855**	0.00003779	0.0003553	0.00004308	**0.0002343**	0.00002343

Angle For tx1=20^0 and tx2=180^0

	AWGN Channel		Rician Channel		Rayleigh Channel	
SNR	Without Beam forming	With Beam Forming	Without Beam forming	With Beam forming	Without Beam forming	With Beam forming
4	0.007468	0.0007075	0.007468	0.0007075	0.01238	0.001238
8	0.006319	0.0005986	0.006319	0.0005986	0.01048	0.001048
12	0.00517	0.000517	0.00517	0.0004898	0.008571	0.0008571
16	0.004021	0.000381	0.004021	0.000381	0.006667	0.0006667
20	0.002872	**0.0002721**	0.002872	**0.0002721**	0.004762	**0.0004762**
24	0.001723	0.0001633	0.001723	0.0001633	0.002857	0.0002857
28	0.0005745	0.00005442	0.0005745	0.00005442	0.0009524	0.00009524
29	**0.0002872**	0.00002721	**0.0002872**	0.00002721	**0.0004762**	0.00004762

By using BPSK modulation it is found that BER is improved for 20^0 and $180^0$for AWGN and Rician channels. Whereas the performance at angle $10^0$and $90^0$for Rayleigh channel is better.

Table - 3 Simulation result for QPSK

Considering Angle for tx1=10⁰ and tx2=90⁰

	AWGN Channel		Rician Channel		Rayleigh Channel	
SNR	Without Beam forming	With Beam Forming	Without Beam forming	With Beam forming	Without Beam forming	With Beam forming
4	0.01159	0.001159	0.01159	0.001022	0.0114	0.001238
8	0.009811	0.0008647	0.009811	0.0008647	0.009645	0.001048
12	0.008027	0.0007075	0.008027	0.0007075	0.007891	0.0008571
16	0.006246	0.0005503	0.006246	0.0005503	0.006138	0.0006667
20	0.00446	0.00039	0.00446	0.000393	0.004384	0.0004762
24	0.002676	0.0002358	0.002676	0.0002358	0.00263	0.0002857
28	0.0008919	0.0000786	0.0008919	0.0000786	0.0008768	0.00009524
29	0.000446	0.0000393	0.000446	0.0000393	0.0004384	0.00004762

Angle For tx1=20⁰ and tx2=180⁰

	AWGN Channel		Rician Channel		Rayleigh Channel	
SNR	Without Beam forming	With Beam Forming	Without Beam forming	With Beam forming	Without Beam forming	With Beam forming
4	0.01002	0.001061	0.01238	0.001238	0.0114	0.001238
8	0.008481	0.000898	0.01048	0.001048	0.009645	0.001048
12	0.006939	0.0007347	0.008571	0.0008571	0.007891	0.0008571
16	0.005397	0.0005714	0.006667	0.0006667	0.006138	0.0006667
20	0.003855	0.0004082	0.004762	0.0004762	0.004384	0.0004762
24	0.002313	0.0002449	0.002857	0.0002857	0.00263	0.0002857
28	0.000771	0.00008163	0.0009524	0.00009524	0.0008768	0.00009524
29	0.0003855	0.00004082	0.0004762	0.00004762	0.0004384	0.00004762

By QPSK modulation the BER is improved for angle 10⁰ and 90⁰ as compared to 20⁰ and 180⁰ for AWGN, Rician channels whereas it is same for Rayleigh channel.

CONCLUSION

In this work, performance comparison of MIMO-OFDM system is given with and without using adaptive beamforming. The use of chaotic sequences can increase the security prospective of the system due to it bifurcation behavior when varying the initial condition. Receive (Adaptive)beamforming can more effectively mitigate interference and enhances the system performance.As the beamforming is done at the receiving side by considering the parameters of multipath propagation characteristic of the channel like Scattering,reflection,diffraction,attenuation ,fading and noise,the performance of the system increases in terms of SNR thereby decreasing the BER. The proposed scheme has been verified in AWGN channel, Rayleigh Fading channel and Rician Fading channel. It has been observed that BER performance of the system is improved with adaptive beamforming.The adaptive beamforming improves the system performance greatly using BPSK modulation compared to the QPSK, 16PSK and 256PSK modulation. Many times QPSK and BPSK perform in similar manner especially during non stationary environment. In general BPSK scheme should have least priority compared to other mapping schemes, while considering in terms of spectral efficiency, bandwidth and bit rate support. Channels perform in the following order in terms of best (less SNR requirement) to worst (more SNR requirement) to maintain the required BER: AWGN, Rician, Rayleigh. Also it is found that angle 10⁰ and 90⁰ is having better performance in terms of BER as compared with transmitting angle20⁰ and180⁰.

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