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Beamforming in Massive MIMO

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Abstract: Beamforming is a type of spatial filtering and a process of signal processing techniques that is used in sensor arrays or antenna array for directing the signal transmission or reception. This is achieved by combining elements that in a phased array in such as a way that signals at specific angles face constructive interference while others facing destructive interference. Beamforming is used at both the transmitting end and receiving end in order to realize spatial selectivity. The main problem occurs while serving a huge number of Users on a network with a limited network resources which reduce the performance of the network, some of the urban-areas can be fulfill with users in a unique direction. The beamforming become is a technique used to focus the network resources to a specific direction and change the pattern of the antenna. The goal of the project is to design and simulate the adaptive beamforming technique in Matlab environment after study and analysis the beamforming techniques especially the adaptive beamforming method and selecting two beamforming algorithms to be evaluated in term of QoS parameters.

INTRODUCTION

Preface: The diversity coding is a type of spatial coding techniques for used for MASSIVE MIMO system in wireless channels. Usually, wireless channels severely affected from many factors such as fading that causes unreliability in data decoding. Fundamentally, in diversity coding multiple copies of codes is send through multiple transmitter antennas, so as to improve the QoS of the data in the reception. If one of channels fails to deliver, the others channel used for data decoding. Beamforming is required achieves spatial diversity and spatial multiplexing for massive MIMO. Beamforming is used in radio signals or sound waves. It has found a various applications in many radar systems, sonar systems, wireless communications, radio astronomy, acoustics and biomedicine an adaptive bamforming is used to detect/ estimate a spacific signal at the output of a sensor-array by means of optimal spatial filtering and interference rejection (Jagannatham, 2012).

The beamforming algorithms applied at digital baseband can get very complex procedure, if all beamforming is done at baseband, each antenna requires a unique radio frequency feed. With the high frequencies while using large number of antenna elements, it causes a very costly and increase loss also increase the complexity in the system in order to solve these issues, a hybrid beamforming was used analog components and not digital components.

There are many different functionality that can be performed based on analog components compared with the digital baseband (Goldsmith, 2005).

Multiple-output (MASSIVE MIMO) systems are developments in antenna array communication. The advantages of multiple Antenna at the receiver such as gain and spatial diversity.

The advantages of MASSIVE MIMO communication which distribute the physical channel between many transmiters and receivers antenna.

The MASSIVE MIMO systems provides many advantages compared to single-antenna-to-single-antenna communication such as the sensitivity to fading is reduced by using spatial diversity that is provided by multiple-channels or pathes under varity of environmental conditions, the power that is required for a high spectral-efficiency communication can be theoratically reduced by avoiding the compressive region of the information-theoretic capacity bound. and the spectral efficiency can be defined as the total number of in formation bits/second/Hertz transmitted from one array to the other array (Haque *et al*., 2013).

Problem definition: The increase demand on system capacity, requires the usage of array antenna with a dedicated Quality of Service parameters (QoS), thus, the development of the multi antenna transmission and receiving require a beam forming in order to focus on the target. The main problem is non beamforming in MASSIVE MIMO can results a decreasing quality of service parameter order.

Objective:

- Study and analysis to multiple in multiple out MMO system of Antenna
- Study and analysis MASSIVE MIMO of beamforming techniques
- Study and analysis the mathematical model

MATERIALS AND METHODS

- Descriptive analysis
- Mathematical model
- Implement codes
- Design of computer model
- Implement MATLAB simulation

Project scenario: In order to get results from the simulation some parameters should be figured out as assumption based on related works such as the reference bandwidth and the power on the transmitter site and the optimal value of the noise value. In this results ten users was configured into the simulation in order to evaluate the performance of beamforming, each user has a distance and different parameters, thus, a randomized function was used to generate random values (Monica and Quanitah, 2012).

Table 1: Simulation parameters

Parameters	Values
Simulation time	20 sec
Bandwidth	20 MHz
No. of users	10 users
Attenuation	1.4553e+03
Transmission power	1.029671474965957e+02
Power Ratio	0.332675171227804

The following Table 1 represent the parameters used in the simulation. Moreover, the results investigate the performance of adaptive beamforming in term of delay, throughput, data rate, spectral efficiency and bandwidth based on LMS and RLS algorithms.

Mathematical confederations and equations

LMS algorithm: In to c the LMS algorithm there are some initial calculations is required. Such as the received signal at the nth element can be given as:

The least mean squares algorithm is a gradient based optimization technique. The reference signal used to update the weights at each iteration is given by:

$$W(n+1) = w(n)+\mu x(n)\, e^*(n)$$

The constant μ is called the step size. It determines how close the weights are moving to optimum value. The convergence of the algorithm depends on the step size. Typical values for the step size are $0<\mu<\lambda$ max.

NLMS algorithm: The normalized LMS algorithm was modified form of the standard LMS algorithm. It uses a time varying adaptive step size μ(n):

$$\mu(n) = \propto / \left(^{\gamma} + X^H(n) X(n) \right)$$

RLS algorithm: Recursive Least Squares (RLS). At every iteration the LMS algorithm minimizing the estimation error whereas the RLS algorithm minimizing the errors up to and including the current iteration. The auto correlation matrix (Rss) and the cross-correlation (P_{ss}) vectors of the desired signals are updated and then used to compute weight vector (Wk) (Fig. 1):

$$R_{ss,k+1} = R_{ss,k} + X(k) X^T(k)$$

Signals to interference and noise ratio comparison: Figure 2 represents the signal to interference and noise ratio before and after adding RLSs the X axis represent the simulation time in msec and the Y axis represents the signal to interference noise ratio in db. The signal to

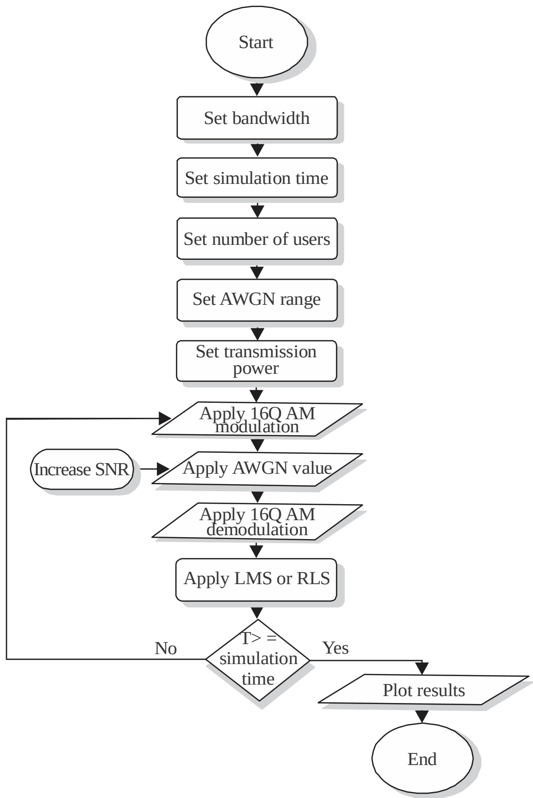

Fig. 1: Computer model

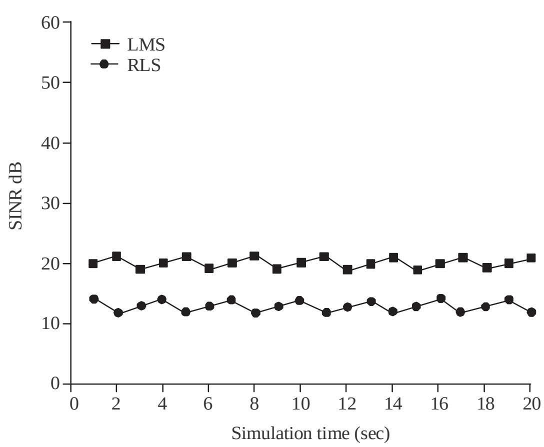

Fig. 2: Signal to interference noise ratio (dB) LMS vs. RLSs

interference and noise ratio has been improved by 63% in case of RLS and this improvement was occurred due to the amplification and noise reduction of the signal from LMS to the end users through RLS.

Accumulated throughput comparison: Figure 3 illustrates the accumulated throughput before and after RLSs the X axis represent the simulation time in msec

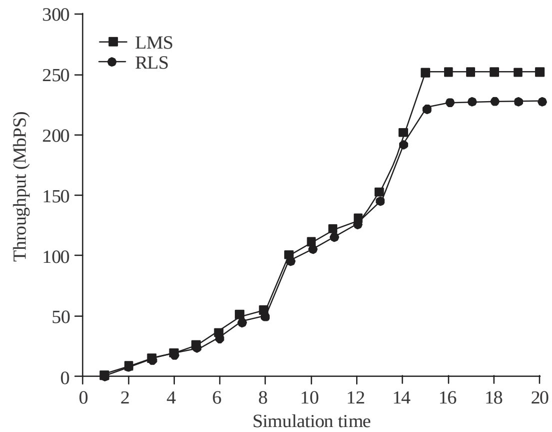

Fig. 3: Accumulated throughput LMS vs. RLSs

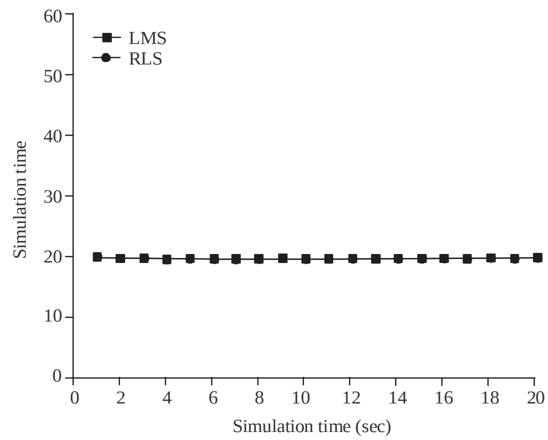

Fig. 4: Bit rate LMS vs. RLSs

and the Y axis represents accumulated throughput in Kbit sec^{-1}. The accumulated throughput has been improved by 47%. And this improvement was occurred due to the amplification of the RLS to the signal and the ability to establish new communication channel that increases the throughput of the system.

Bit rate comparison: Figure 4 clarifies the compression in term of theoretical maximum bit rate before and after adding RLSs the X axis represent the simulation time in ms and the Y axis represents the data rate in Mbit/sec in db. As recorded from the figure of theoretical maximum bit rate has been improved by 10-25%. The amount of improvement in theoretical maximum bit rate is caused by the improvement in the (SIR) due to the direct proportion bet between the signal to interference ratio and the theoretical maximum bit rate.

Spectral efficiency: Figure 5 shows the compression of the spectral efficiency before and after RLSs the X axis represent the simulation time in ms and the Y axis

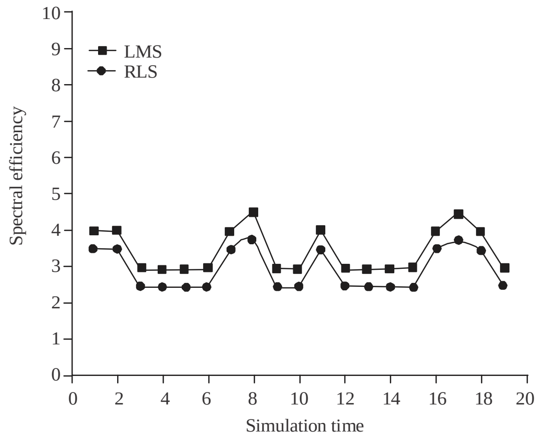

Fig. 5: Spectral efficiency LMS vs. RLSs

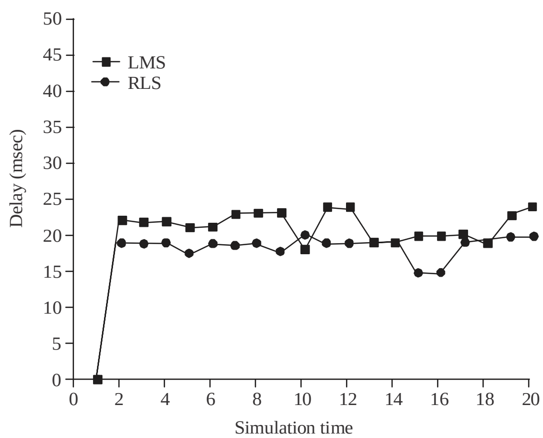

Fig. 6: Transmission delay LMS vs. RLSs

represents the spectral efficiency in db. It's very clear that the spectral efficiency has been improved by 40%. The value of spectral efficiency depends on amount of bite rate and the bandwidth. When the bit rate increases the spectral will increase too.

Transmission delay comparison: Figure 6 shows the variation of transmission delay before and after adding RLSs the X axis represent the simulation time in ms and the Y axis represents the transmission delay in seconds. It's clear that the value of time delay decreased in RLS case applied by 9% there is a reverse proportional between the transmission delay and the throughput which depends on the signal to interference ratio when it increases the throughput increases lead to decrement the transmission delay (Tse and Viswanath, 2005).

RESULTS AND DISCUSSION

Bandwidth comparison: Figure 7 represent the bandwidth before and after adding RLSs the X axis

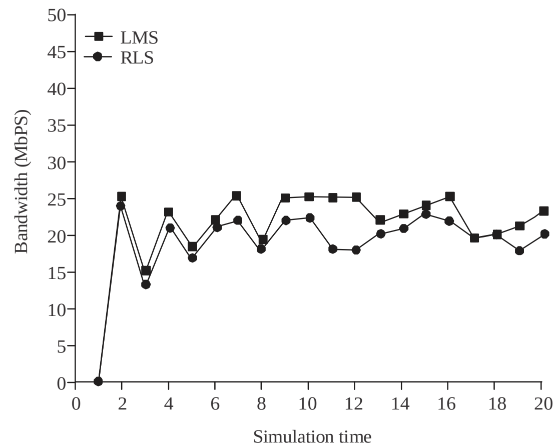

Fig. 7: Bandwidth LMS vs. RLSs

represent the simulation time in msec and the Y axis represents the Bandwidth in MHz show the variation of Bandwidth in LMS and RLS. It's clear that the value of Bandwidth increased in RLS case applied by 11.3% and this improvement was occurred due to the new communication channel that is provided by the RLS increases the bandwidth of the system.

CONCLUSION

In this project a focus on the increase demand on system capacity, that requires the usage of array antenna with a dedicated Quality of Service parameters (QoS), based on beamforming in order to focus on the target. With a main problem is non beamforming in MASSIVE MIMO can results a decreasing quality of service parameter.

The aim of the project focus on the study and analysis to multiple in multiple out MMO system of antenna, study and analysis MASSIVE MIMO of beamforming techniques and Study and analysis the mathematical model.

The simulation was done using Matlab 2016a and it was concluded that the usage of beamforming technique increase the coverage area and reduce the error rate with an increased capacity to the system.

A compare the performance of Adaptive beam forming algorithms LMS and RLS for smart antenna. First, we will implement three different geometries: linear, circular and planer, in next stage, we will implement the different algorithms for updating the weights of smart antenna system. Circular geometry not used for practical applications. Planar array geometry gives good array factor compare to other geometries. LMS algorithm used for fixed step size.

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