Chapter 1

INTRODUCTION

1.1 Introduction

Due to the demand rise on new multimedia applications, the expectation of next generation wireless systems to support higher data rates has been increasing continuously. The efficient utilization of bandwidth is needed. In comparison with the previous generation systems, the universal terrestrial radio access (UTRA) long term evolution cellular system has to mainly provide a better spectral efficiency. One such useful technique is multiple-input multiple-output (MIMO), which performs spatial multiplexing and improves communication quality and spectral efficiency at no extra cost of spectrum.

From the study of research papers published in the previous years, it is observed that the MIMO capacity can be up to $\min(N_t, N_r)$ times greater than the capacity of single antenna, where $N_t$ and $N_r$ is the number of antenna elements at receiver. Accordingly, the expression MIMO incorporates spatial multiplexing techniques as well as traditional beam forming and diversity techniques. The ambitious target peak data rate of LTE can be achieved, when MIMO is exploited in terms of collaborative spatial multiplexing to increase the users peak data rate. A lot of study has been carried out in the field of array antennas to make antennas smart to distinguish interference signal and desired signal.

1.2 Smart Antenna

Smart Antenna[1] increases the capacity of the Mobile Communication System by making use of either Maximal Ratio Combining or Diversity combining techniques. Smart Antenna has to perform a duplex operation. It has to receive signals as well as transmits signals. The reception part mainly requires the detection of user directions. The transmission parts involve transmitting radiation into the look directions. A study of literature shows a lot of work done in direction of arrival algorithms. Each of the approaches have
their own way of determining the power spectrum in the network. In a similar way, there are many beam forming algorithms which are responsible for the transmission part.

Figure 1.1 shows a smart antenna system. This system consists of array elements, DSP processors, ADC/DAC units. The processor processes signals with the help of smart algorithms. The set of antenna elements and multiplexers perform the task of transmission and reception.

![Figure 1.1: Smart antenna system](image)

From figure 1.1, there are $N_n$ antennas arranged in a linear fashion. Each antenna considered here is of type diploe. These antennas receive electromagnetic waves. The antennas are connected to phase shifters and each antenna is assigned a unique phase shift $\phi_i$ in general i.e $\phi_1$ for first phase shifter and in the same fashion $\phi_n$ represents the phase shift applied to last antenna element $N_a$. The phase shifters values are then added up by using the summer $\sum_{i=1}^{N_a} \phi_i$ and after that they are multiplied with the received signal in order to obtain Array output $A_o$ and finally the difference is derived in between the training signal transmitted from mobile station and Array factor to obtain the error signal $e_v$. The phase shifters values are updated in such a way that $e_v$ is minimized. The ADC/DAC are used for conversion for the beam formed signals.

There are many multi-access techniques which are proposed in the literature namely space division multiple access (SDMA), Time Division Multiple Access (TDMA), Code Division Multiple Access (CDMA) and Frequency Division Multiple Access (FDMA).

In FDMA [2] technique the entire channel bandwidth is divided into multiple sub channels with guard band between the channels. Each channel is assigned to the Mobile Station whenever it enters into the coverage area of the Base Station. As the number of Mobile users increases the FDMA will not be able to handle by maintaining equal
Quality of Service for all the users in the network due to presence of Limited Capacity. A single carrier frequency division multiple accessing (SC-FDMA) technique is used for third generation partnership project long term evolution (3GPP-LTE) this finds application in uplink transmission. Orthogonal frequency division multiplexing uses SC-FDMA to produce a high throughput, high spectral efficiency and bit error rate.

In Time Division Multiple Access (TDMA) [3][4] technique the entire channel is divided into multiple time slots and each of the Mobile user is given a specify time slot. This will increase the capacity few percentage more than FDMA but TDMA suffers from Latency. There is possibility of co-channel interference in narrowband TDMA cellular networks. The gain in TDMA is achieved based on higher system capacity and lower network outage.

Code-division multiple access (CDMA) [5] is a channel access method in which unique code is used for creating a communication channel. The bandwidth is divided into several bands of frequencies which is allowed for several users. The radio environment is used for narrowband and wideband propagation.

In SDMA [6] technique the entire channel is divided into spatial slots. It increases the capacity of the system by a huge amount as it can provide the channel to multiple users at the same time with the same frequency but in different angular orientation. Optical cell is an alternative for angle diversity transmitter and the SDMA configuration can increase the bandwidth exponentially and it can also reduce inter cell interference.

1.3 Objectives

To provide optimal solution in terms of Quality of Service and spectral efficiency by making use of advanced antenna techniques (beam forming and direction of arrival algorithms).

a. To achieve efficient detection of mobile users with low bias and better resolution has compared to existing methods in the literature.

b. To direct the radiation in an efficient manner so that the desired user will get better radiation with low mean square error and better convergence.

1.4 Methodology

The methodology can be described as follows. One is for the detection of the user directions and other for directing the radiation towards users.
1.4.1 Detection approach

1. Amplitude Matrix Formation

In Amplitude Matrix Formation the amplitude of the signals are stored in the column matrix. Where each value represents the amplitude of specific signal.

2. Array Manifold Vector Computation

The Array Manifold Vector is the combination of steering vectors for a given set of angles in which the users are present. Each Steering Vector gives information about amount of time delay the electromagnetic wave undergoes as it hits the antenna elements.

3. Signal Correlation Matrix

The Signal Correlation Matrix will be the multiplication of signal amplitude with the Hermitian transpose of signal amplitude.

4. Noise Correlation Matrix

The Noise correlation matrix will be multiplication of noise signal with the Hermitian transpose of the noise signal. Each noise signal is represented as the Additive White Gaussian Noise (AWGN) which can be linear added with the signals.

5. Total Correlation Matrix

The Total Correlation Matrix is the formation of two additive matrices which contains the information of signal space and noise space. The Signal space will have array manifold vector, signal vector, Hermitian of array manifold vector and then the noise correlation matrix is additively added.

6. Eigen Value Decomposition

Eigen Value Decomposition is used to find the Eigen values and then find the Eigen vectors for all the Eigen values.

7. Subspace Formation

The signal and noise subspaces are found using subspace formation in which the Eigen values of small magnitude are used to find Noise Subspace and that with high magnitude are used to find Signal Subspace.

8. LU Factorization

LU Factorization is responsible for finding the Lower Upper triangular matrix so that most of the noise is eliminated.
9. Power Spectrum Computation
   The power spectrum computation equation consists of LU factor and its Hermitian transpose of LU factor along with steering vector.

10. Bias Computation
    The Bias computation is performed by taking the difference between the true value of direction and estimated value of direction.

11. Resolution Computation
    The ability to distinguish two equal energy sources with nearly equal angles.

12. Comparison with existing DOA Methods
    The proposed LU Factor based DOA method is compared with existing methods namely Normalized Power method, Maximum Entropy Method (MEM), Multiple Signal Classification (MUSIC) Method and QR Decomposition Method.

1.4.2 Beam forming approach

1. Compute the Desired Steering Vector
   This module is responsible for computing the steering vector for the desired angle where the actual radio user is present.

2. Compute the Jammer Steering Vectors
   This module is responsible for computing the steering vectors for the direction of jammers. The jammers can be a single jammer or multiple jammers across different directions.

3. Generation of training, Noise and Interference Signal
   The Training signal is responsible for generation of wave at the mobile station with a certain sampling period. Noise and Interference signal are the signals which are generated randomly.

4. Compute the received signal
   The received signal is the combination of signal at the mobile station, interference signal and noise signal.

5. Compute the hermitical transpose of received signal
   The received signal transpose is found out by taking the transpose and then applying the conjugate of each of the values.
6. Compute the auto correlation matrix

   The auto correlation matrix is used to find the relation between the signal and its delayed version. It is defined as the multiplication of signal and its hermitical transpose.

7. Compute the Array Output

   The Array Output is computed by adding all the electromagnetic waves and its delayed version with the phase shifts.

8. Compute the error signal

   The error signal is defined as the difference between the actual signal and array output.

9. Compute the weight vector

   The weight vector is the phase shifts which is applied to individual antenna elements and is responsible for forming the radiation.

10. Compute the Array Factor

    The array factor is responsible for finding the radiation pattern of antenna array. It is computed, in two ways one is using polar coordinates and then using Cartesian coordinates.

11. Radiation Formation

    The radiation formation is performed based on the MATLAB usage.