Chapter 1

Introduction

In every radio communication system the antenna is considered as the key element. In a wireless link, the transmitting and receiving antenna are directly involved to each other in order to achieve the desired performance. An antenna is a device that is made to efficiently radiate and receive radiated electromagnetic waves. An important feature of the antenna is the property of reversibility that is the same antenna can be used with the same characteristics as a transmitter or as a receiver antenna. An antenna is characterized by its center frequency, bandwidth (BW), polarization, gain, radiation pattern and impedance. Antennas are very important in the field of wireless communications. Some of such antennas are Parabolic Reflectors, Patch Antennas, Slot Antennas, and Folded Dipole Antennas etc. Antennas are the backbone of modern wireless communication systems without which the world could have not reached at this age of technology. Recently, the antennas arrays have been widely used to multiply the performances of the simple antennas in diverse domains such as the wireless communication, where the antenna array allows covering cellular communication coverage, also in the satellite systems.

A single-element antenna is usually not enough to achieve the better performance. An array of antennas that is the set of two or more elements does a superior job of receiving signals as compared to single antenna, leading to their widespread use in wireless applications. The concept of an antenna array was first introduced in military applications in the 1940s. Antenna arrays were significant in wireless communications because they improved the reception and transmission.

In the 1890s, there were only a few antennas in the world. Earlier antennas were used just as a part of experiments that demonstrated the transmission of electromagnetic waves. By World

War II, antennas had become so popular that their use had transformed the lives of every person via radio and television reception. By the early 21st century, the average person now carries one or more antennas on them wherever they go (cell phones can have multiple antennas, if GPS is used, for instance).

1.1 Microstrip Patch antennas:

Today in many commercial applications, such as mobile radio and wireless communications microstrip antennas are widely used because these applications require low profile antennas. Microstrip antennas are considered as low profile antennas because of their salient features such as ease of fabrication, good radiation control, low cost of production, light weight, reliability, reproducibility, compatibility with MMIC designs, simple and inexpensive to manufacture, mechanically robust etc.

A Microstrip Patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown below:

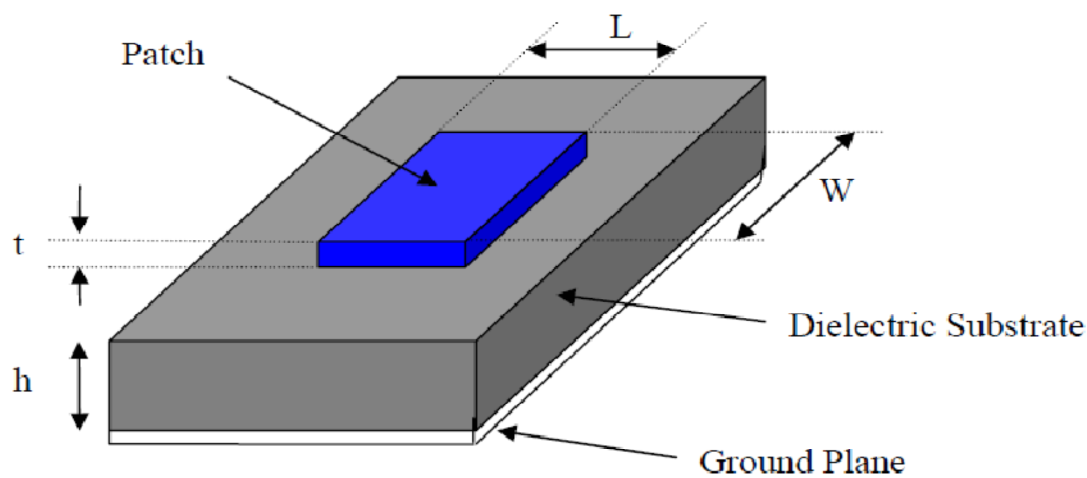

Fig 1.1 Structure of a Microstrip Patch Antenna (Parsad et al., 2012)

The patch is generally made up of some conducting material such as copper or gold and the patch can take any possible shape. The patch and the feeding lines are photo etched on the dielectric substrate. In order to simplify analysis and performance, the patch is generally taken square, rectangular, circular, triangular, and elliptical or some other common shape as shown below:

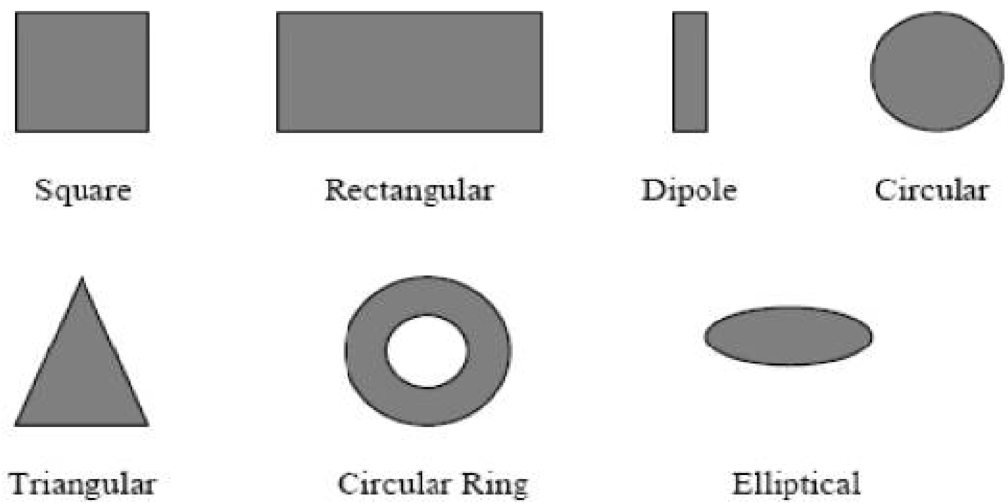

Fig 1.2 Common Shapes of Microstrip Patch Elements (Khatri et al., 2012)

A thick dielectric substrate having low dielectric constant is preferred for good antenna performance because this provides better efficiency, larger bandwidth and better radiation (Bahl, 2000). However, such a design leads to a larger antenna size. In order to design a compact microstrip patch antenna (MPA), substrates with higher dielectric constants must be used which are less efficient but result in narrower bandwidth. Hence a trade-off must be realized between the antenna dimensions and antenna performance. The telemetry and communication antennas on missiles need to be thin and conformal and are often in the form of microstrip patch antennas.

1.2 Advantages and Disadvantages

Today, Microstrip patch antennas are very popular in wireless applications due to their low profile structure. They are extremely compatible for embedded antennas in handheld wireless devices such as cellular phones, pagers etc. Another area where they have been used successfully is in satellite communication. Some of the advantages of microstrip patch antennas (Balanis, 1997) are given below:

- Light weight and low volume.
- Low profile planar configuration which can be easily made conformal to host surface.
- Low fabrication cost, hence they can be manufactured in large amount.
- Supports both, linear as well as the circular polarization.
- They can be easily integrated with the microwave integrated circuits (MICs).
- Mechanically robust when mounted on rigid surfaces.

Microstrip patch antennas suffer from some major disadvantages that are given below:

- Narrow bandwidth.
- Low efficiency.
- Low Gain.
- Extraneous radiation from feeds and junctions.
- Poor end fire radiator except tapered slot antennas.
- Low power handling capacity.
- Surface wave excitation.

1.3 Feed Techniques

Microstrip patch antennas can be fed by a variety of methods. These methods has two categories- contacting and non-contacting. In the contacting method, the RF power applied to the patch directly by using a connecting element such as a microstrip line. In the non-contacting method, power is transferred between microstrip line and patch by electromagnetic field coupling. There are four feed techniques that used to feed the microstrip patch antennas and these are microstrip line feeding, coaxial probe feeding, aperture coupling and proximity coupling.

1.3.1 Microstrip Line Feed

This method of feed to a patch antenna is a contacting method. It means, a conducting strip that is a feed line is connected directly to the edge of the microstrip patch as shown in Figure 1.3. The width of conducting strip is smaller as compared to the width of patch. The advantage of this feed technique is that it provides a planar structure because the feed can be etched on the same substrate.

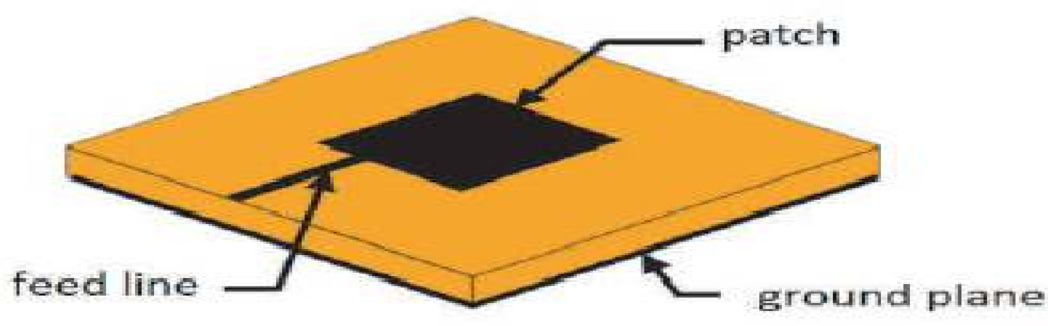

Fig 1.3 Microstrip Line Feed (Bugaj et al., 2012)

The inset cut in the patch is used to match the impedance of the feed line to the patch without the use of any additional impedance matching element. In order to achieve good impedance matching, designer has to control the inset position properly. This is an easy feeding technique. Ease of fabrication, simplicity in modeling and impedance matching are the advantages of this feeding method.

1.3.2 Coaxial Feed

The Coaxial feed also called probe feed is another very common feed technique for microstrip patch antennas. The inner conductor of the coaxial connector extends to the dielectric and it is attached to the patch and the outer conductor connected to the ground plane as shown below:

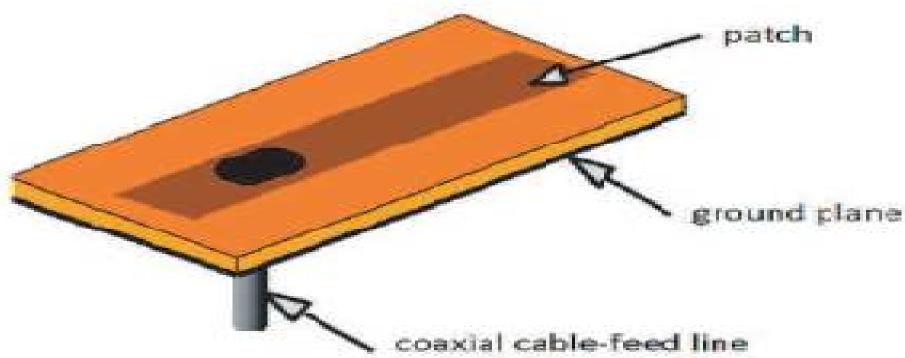

Fig 1.4 Probe fed Rectangular Microstrip Patch Antenna (Bugaj et al., 2012)

The main advantage of this feeding method is that the feed can be placed at any position inside the patch in order to match its impedance to the impedance of patch. This feeding method is very easy to fabricate and has low spurious radiation. Narrow bandwidth is the only major disadvantage of this feeding method.

1.3.3 Aperture Coupled Feed

This feed technique is a non contacting scheme. Non contacting means, the patch and the microstrip feed line are separated by a ground plane as shown in Figure 1.5. Coupling between the patch and the feed line is made with the help of a slot or an aperture in the ground plane.

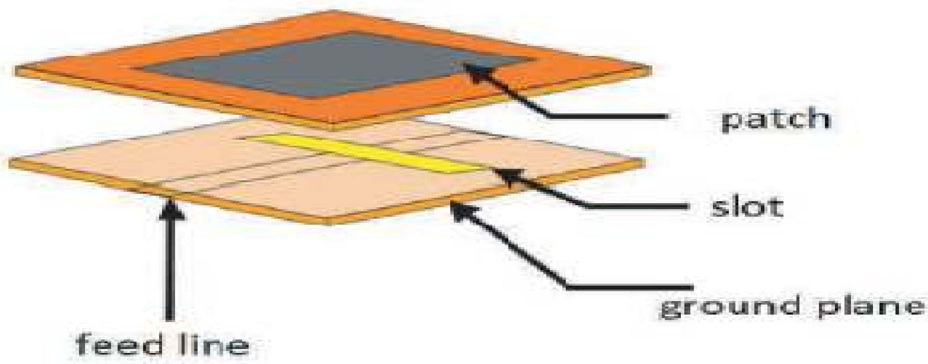

Fig 1.5 Aperture-coupled feed (Bugaj et al., 2012)

The coupling slot is centered under the patch and it leads to lower cross polarization. The amount of coupling from the feed line to the radiating patch is determined by the shape, size and location of the aperture or slot. Low spurious radiation is one of the advantages of this feeding method and this is due to the separation between the radiating patch and microstrip feed line by ground plane. The disadvantage of this feed technique is that it is difficult to fabricate because of multiple layers, and it also increases the antenna thickness. This feeding scheme also provides narrow bandwidth.

1.3.4 Proximity Coupled Feed

This type of feed technique is also called as the electromagnetic coupling scheme. In this non contacting scheme two dielectric substrates are used. In this scheme the feed line is inserted between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth.

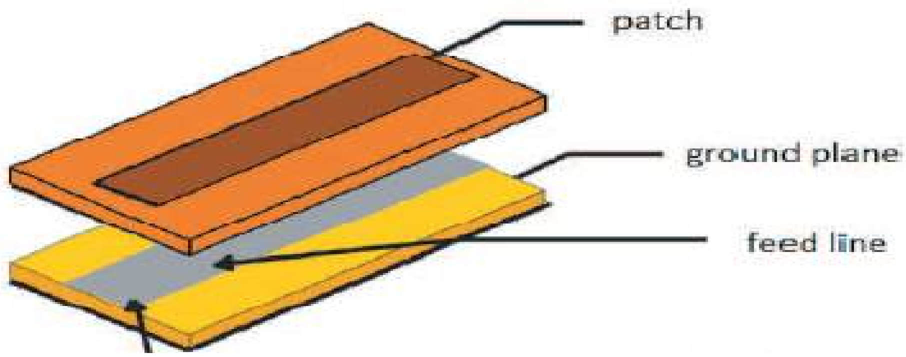

Fig 1.6 Proximity-coupled Feed (Bugaj et al., 2012)

The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers which need proper alignment. Also, there is an increase in the overall thickness of the antenna due to the use of two substrates.

1.4 Antenna Parameters

The basic antenna parameters are given below:

1.4.1 S-Parameters

S-parameters also called return loss describe the input-output relationship between two ports in an electrical system. For example, if we have 2 ports called Port 1 and Port 2, then S12 represents the power transferred from Port 1 to Port 2. Similarly, S21 represents the power transferred from Port 2 to Port 1. Since antennas are mostly designed to be low loss, the majority of the power delivered to the antenna is radiated. Return loss is the difference between forward and reflected power, and represented in dB.

1.4.2 Radiation Pattern

A radiation pattern defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. A pattern is called "isotropic" only if the radiation pattern is the same in all directions. But, these antennas do not exist in actual practice. Such antennas sometimes discussed as a means of comparison with real antennas. Some antennas may also be described as "Omni directional", it means that the antenna is isotropic in a single plane. There is another type of antennas also called "directional", which do not have symmetry in the radiation pattern.

1.4.3 Directivity

The Directivity of an antenna is defined as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. The average radiation intensity is the total power radiated by the antenna divided by 4π.

1.4.4 Antenna Efficiency

There are a number of efficiencies related to antennas. The total efficiency of antenna, takes into account losses at the input terminals and with the structure of the antenna. Such losses may be due to reflections because of the mismatch between the transmission line and the antenna, and conduction and dielectric losses.

1.4.5 Antenna Gain

Antenna gain is another useful parameter describing the performance of an antenna. Antenna gain is closely related to the directivity. It is defined as the ratio of the intensity in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted (input) by the antenna divided by 4π.

In most cases, the gain is relative, which is defined as the ratio of the power gain in a given direction to the power gain of a reference antenna in its referenced direction. The reference antenna is usually a dipole or isotropic antenna.

1.4.6 Bandwidth

The bandwidth of an antenna is defined as the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard. In this range of frequencies, the antenna characteristics such as input impedance, radiation pattern, beam width, polarization, side lobe level, gain, and radiation efficiency are within an acceptable value at the center frequency. For broadband antennas, the bandwidth is usually expressed as the ratio of the upper-to-lower frequencies of acceptable operation. For example, a 10:1 bandwidth indicates the upper frequency is 10 times greater than the lower. For narrowband antennas, the bandwidth is expressed as a percentage of the frequency difference (upper minus lower) over the center frequency of the bandwidth. For example, a 5 percent bandwidth indicates that the frequency difference of acceptable operation is 5 percent of the center frequency of the bandwidth. By increasing the substrate thickness, the bandwidth of the antenna can be enhanced (Awida et al., 2011).

1.4.7 Polarization

Polarization is defined as the property of an electromagnetic wave describing the time-varying direction and relative magnitude of the electric-field vector. Vertical and horizontal polarizations are the simplest forms of antenna polarization and these both polarizations fall into a category known as linear polarization. Some antennas can also have circular polarization. Circular polarization occurs when two or more linearly polarized waves add up together. Circular polarization has a number of benefits for satellite applications. Circular polarization helps to overcome the effects of propagation anomalies, ground reflections and the effects of the spin that occur on many satellites. There is another type of polarization called elliptical polarization. It occurs when linear and circular polarizations mix together. Linearly polarized antennas are able to receive circularly polarized signals and vice versa. But, there is a 3 dB polarization mismatch between linearly and circularly polarized antennas.

1.4.8 Input Impedance

Impedance of antenna is defined as the ratio of voltage to current at the antenna terminals. In order to achieve maximum transfer of the energy, the input impedance of the antenna must identically match the characteristic impedance of the transmission line. If these two impedances do not match, then a reflected wave will be generated at the antenna terminal and it travels back towards the energy source. This reflection of energy results in reduction in the overall efficiency of antenna. The input impedance of an antenna is generally a function of frequency. The input impedance of the antenna also depends on many other factors such as antenna's geometry, its method of excitation, and its proximity to surrounding objects. For many other applications, the input impedance has been determined experimentally. The "impedance mismatch factor" is also called "mismatch efficiency" (Woestenburg et al., 2008).

1.4.9 Radiation Intensity

Radiation intensity in a given direction is defined as the power radiated from an antenna per unit solid angle. The radiation intensity is a far-field parameter, and it can be obtained by multiplying the radiation density by the square of the distance.

1.4.10 Beam Width

The beamwidth of an antenna is defined as the angular separation between two identical points on opposite sides of the radiation pattern maximum. In a given radiation pattern of antenna, there are a number of beam widths. One of the most commonly used beamwidth is Half-Power Beamwidth (HPBW), which is defined by IEEE as, “In a plane containing the direction of the maximum of a beam, the angle between the two directions in which the radiation intensity is one-half value of the beam”. Another important beamwidth is the angular separation between the first nulls of the pattern, and it is called the First-Null Beam width (FNBW). Other beamwidths are those where the pattern is -10 dB from the maximum, or any other value. However, in practice, the term beamwidth, with no other identification, usually refers to HPBW. The beamwidth of an antenna is an important parameter, and often is used to describe the resolution capabilities of the antenna to distinguish between two adjacent radiating sources or radar targets.

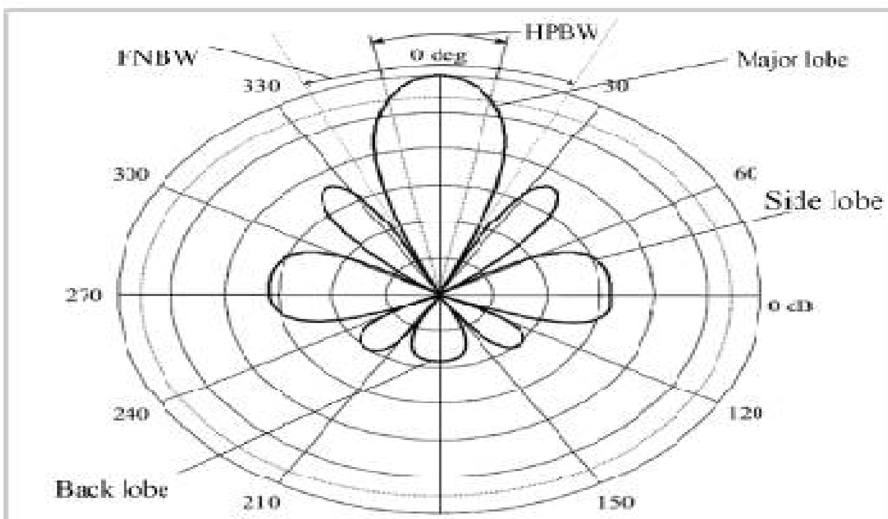

Fig 1.7 Radiation lobes and beam widths of an antenna pattern (Balanis, 1997)

1.4.11 Voltage Standing Wave Ratio (VSWR)

When there is a installing and tuning of transmitting antennas the most common case is to measure and examine the VSWR. When a transmitter is connected to an antenna by a feed line, then for maximum transfer of energy the impedance of the antenna and feed line must be match exactly. If there is any impedance mismatch between an antenna and feed line, then some of the electrical energy cannot be transferred from the feed line to the antenna. Energy not transferred to the antenna is reflected back towards the transmitter. This interaction of these reflected waves with forward waves results in standing wave patterns. Ideally, VSWR must lie in the range of 1-2 for a better antenna performance (Woestenburg et al., 2008).

1.5 Antenna Arrays

An antenna array is a set of N spatially separated antennas. Generally, an array of antennas does a superior job of receiving signals when compared with a single antenna, which leads to their widespread use in wireless applications. Arrays in practice can have as few as 2 elements, which is common for the receiving arrays on cell phone towers. In general, array performance improves with added elements; therefore arrays in practice usually have more elements. Arrays can have several thousand elements, as in the AN/FPS-85 Phased Array Radar Facility operated by U. S. Air Force (Ulaby, 2001).

The array has the ability to filter the electromagnetic environment it is operating in based on the spatial variation of the signals present. There may be one signal of interest or many, along with noise and interfering signals.

The concept of an antenna array was first introduced in military applications in the 1940s. This development was significant in wireless communications because it improved the reception and transmission patterns of antennas used in these systems. Different array configurations of microstrip antenna can give high gain, wide bandwidth and improved efficiency. The distribution of voltages among the elements of an array depends on feeding network. Suitable feeding network accumulates all of the induced voltages to feed into one point. The proper impedance matching throughout the corporate and series feeding array configurations provides high efficiency microstrip antenna. Power distribution among antenna elements can be modified by corporate feed network. The corporate feed network can steer beam by introducing phase change. The synthesis problem in array design consists of finding the excitation distribution of the antenna elements given a power - or field - pattern, with specified characteristics established by the designer (Pazos et al., 2002).

1.5.1 Need of Antenna Arrays

Many applications require desired radiation patterns and high gains that may not be achieved by using a single element antenna. In order to obtain the desired radiation characteristics and high gain several single antenna elements are combined together to form an antenna array (Ahmad, 2008). The arrangement of the array is in such a way that the radiation from each individual element adds up to produce a maximum radiation in a particular direction or directions. The overall radiation characteristics of array antennas can be influenced by many factors such as the number of elements, spacing, and radiating element properties. Unlike a single element antenna whose radiation pattern is fixed, the radiation pattern of array antennas, called the array pattern, can be changed upon exciting its elements with different currents. This provides a freedom to design a certain desired array pattern from an array without changing its physical dimensions (Kosta et al. 2009).

The radiation pattern of a single-element antenna is relatively wide, and the values of directivity, gain are relatively low. Applications such as remote sensing require a highly directive beam, high gain and low return losses, which can be obtained by increasing the size of the antenna. As the electrical size of the antenna increases the beam becomes narrower, but the sidelobes become larger, which limits the directivity. A way of enlarging the dimensions of the antenna without necessarily increasing the size of an individual element is to form an array. Combining antennas into an array allows for improved control over the radiation pattern and better focus of the radiated energy. Circular-array (CA) antennas are very popular due to their several advantages, such as an all-azimuth scan capability (i.e., the array can perform a 3600 scan around its center), and the ability to keep the beam pattern invariant. Circular ring arrays (CRA) contain many circular rings of different radii and with different numbers of elements. They have several advantages, including flexibility in array pattern synthesis and design, in both narrowband and broadband beam forming applications (Kamchouchi, 2010).

1.5.2 Advantages of Antenna Arrays

Antenna arrays are becoming increasingly important in wireless communications. Advantages of using antenna arrays are given below:

1. They can provide the capability of a steerable beam as in smart antennas.

2. They can provide a high gain by using simple antenna elements.

3. They provide a diversity gain in multipath signal reception.

4. They enable array signal processing.

5. They are light-weight and have small size.

6. Antenna arrays are low profile antennas having planar configuration.

1.5.3 Disadvantages

The main disadvantage of antenna arrays is increased complexity in its design compared to single element design. The system size becomes bulky and component costs are therefore high. Low efficiency, low power handling ability, high Q, poor polarization are some of the limitations of microstrip patch antenna array (Abdallah et al., 2011).

1.5.4 Applications

Antenna arrays have more advantages as compare to its disadvantages so it can be used in many applications. Its overall performance is better than single element antennas as it provides high directivity, high gain and low return losses. Some of the applications (Yuan et al., 2008), (Wang et al., 2013), (Parui et al., 2009) of antenna arrays are given below:

1. Wireless LAN

2. In Satellite communication

3. Mobile communication

4. Road/bridge deck inspection

5. Ideal for military uses

6. Global Positioning Systems (GPS)

7. Personal communication systems (PCS)

1.6 Introduction to Artificial Neural Networks

To model complex non linear systems, artificial neural network (ANN) has become a popular approach over the past two decades. . Neural networks are mainly used for modeling complex relationships between inputs and outputs or to find patterns in a data. Generally, neural networks can be properly trained to solve the problems that are difficult to solve for conventional computers or human beings. Currently, ANN model has been successfully applied in many areas, including automatic control, communication and information systems, fault diagnosis technique, non linear systems prediction, and so on. These artificial networks may be used for applications where they can be trained via a dataset. ANNs are trainable functional mappers for multi-input, multi-output functions. The ANN is a highly parallel, interconnected ensemble of simple computing elements termed neurons. Each neuron is a multi-input single output function interconnected to other neurons with adjustable weights. Since, we can say that artificial neural networks (ANNs) provide a functional approximation to a describing set of data (Lenhardt et al., 2001).

1.6.1 Brief historical review

ANN research has experienced three periods of extensive activity. The first peak in the 1940s was due to McCulloch and Pitts. The second occurred in the 1960s with Rosenblatt's perceptron convergence theorem (Rosenblatt, 1962) and Minsky and Papert's work showing the limitations of a simple perceptron (Minsky et al., 1969). Minsky and Papert's results dampened the enthusiasm of most researchers, especially those in the computer science community. Since the early 1980s, ANNs have received considerable renewed interest.

The major developments include Hopfield's energy approach in 1982 and the back-propagation learning algorithm for multilayer perceptrons (multilayer feed forward networks) first proposed by Werbos, reinvented several times, and then popularized by Rumelhart (Rumelhart et al., 1986). Anderson and Rosenfeld provide a detailed historical account of ANN developments.

1.6.2 Network architectures

ANNs can be viewed as weighted directed graphs in which artificial neurons are nodes and directed edges (with weights) are connections between neuron outputs and neuron inputs. Based on the connection pattern (architecture), ANNs can be grouped into two categories:

- feed-forward networks
- Recurrent (or feedback) networks

In the most common family of feed-forward networks, called multilayer perceptron, neurons are organized into layers that have unidirectional connections between them. Different connectivity's yield different network behaviors. Generally speaking, feed-forward networks are static, it means that, they produce only one set of output values rather than a sequence of values from a given input. Feed forward networks are memory-less in the sense that their response to an input is independent of the previous network state. These efficient networks are widely used to solve complex problems by modeling complex input-output relationships. A feed forward network is one whoso topology has no closed paths. Its input nodes are the ones with no arcs to them, and its output nodes have no arcs away from them. All other nodes are hidden nodes. When the states of all the input nodes are set, all the other nodes in the network can also set their states as values propagate through the network.

The operation of a feedforward network consists of calculating outputs given a set of inputs in this manner. A layered feedforward network is one such that any path from an input node to an output node traverses the same number of arcs. A hidden layer is one which contains hidden nodes. Layered feedforward networks have become very popular for a few reasons. They have been found in practice to generalize well, i.e. when trained on a relatively sparse set of data points, they will often provide the right output for an input not in the training set. A feed forward neural network is a biologically inspired classification algorithm. It consists of a number of simple neuron-like processing units, organized in layers .Every unit in a layer is connected with all the units in the previous layer. These connections are not all equal; each connection may have a different strength or weight. The weights on these connections encode the knowledge of a network. Often the units in a neural network are also called nodes. Data enters at the inputs and passes through the network, layer by layer, until it arrives at the outputs. During normal operation, that is when it acts as a classifier, there is no feedback between layers. Hence they are called feed forward neural networks.

The Levenberg Marquardt training algorithm is a widely used method for FFNN learning in many applications. It has the great advantage of simple implementation. They are famous learning algorithms among ANNs. Trainlm training algorithm is used mostly because it is very fast but it requires more memory. They have been widely and successfully applied in diverse applications, such as pattern recognition, location selection and performance evaluations (Rumelhart et al., 1986).

Recurrent, or feedback, networks, on the other hand, are dynamic systems. When a new input pattern is presented, the neuron outputs are computed. Because of the feedback paths, the inputs to each neuron are then modified, which leads the network to enter a new state. Different network architectures require appropriate learning algorithms.

1.6.3 Applications of ANN

The utility of artificial neural network models lies in the fact that they can be used to infer a function from observations. This is particularly useful in applications where the complexity of the data or task makes the design of such a function by hand impractical. Applications (Belavkin, 2003) of ANN include:

- Function approximation
- Pattern classification
- Object recognition (e.g. character recognition)
- Data compression
- Security (credit card fraud)

1.6.4 Advantages of Neural Networks

• Can be applied to many problems, as long as there is some data.

• Can be applied to problems, for which analytical methods do not yet exist

• Can be used to model non-linear dependencies.

• Always gives some answer even when the input information is not complete.

1.6.5 Applications of ANN in antennas

The ANN can be successfully used in different smart antenna array (SAA) applications in communication systems. The use of SAA in communication systems not only improves system performance but also extends its functions and hence its broad applications in communication systems (Rawat et al., 2012). Some other applications of ANN in antennas given below:

- Optimization of antenna parameters: ANN based approach is used for calculating the resonant frequency, return loss, directivity, bandwidth and gain of antenna. For the training of neural networks, feed forward back propagation training algorithm is mostly used because it provides good performance by decreasing inaccuracy and its implementation is also very simple.
- Designing of antennas: ANN models are used for designing and synthesis of antennas. ANN models are used to find the dimensions of antenna for given parameters such as height of substrate, dielectric constant and resonant frequency. They can also be used to predict gain, return loss for a given design of antenna.

1.7 Introduction to Genetic Algorithms

Genetic algorithms (GA) are population based algorithms that have proven to be successful in solving a variety of difficult problems. There are various benefits of using GA like GA concept is easy to understand and genetic algorithms are modular and separate from application. Genetic algorithms are good for noisy environments. Genetic algorithms applications in various domains like in Control, Design, Robotics, and Machine learning domain, Signal Processing, Game Paying, and Optimization. Genetic algorithms are an increasingly popular method of optimization being applied to many fields motivated by Darwin's theories of evolution and the concept of "survival of the fittest" (Werner and Boeringer, 2004).

1.7.1 History of Genetic Algorithm

Genetic algorithms were first introduced by Holland in the early 1970's and have been widely successful in optimization problems, especially in the binary domain. GA'S are often viewed as function optimizers, although the range of problems to which GA'S have been applied is quite broad. Genetic algorithms are original systems based on the supposed functioning of the Living. The method is very different from classical optimization algorithms in the following manner:

1. Work on a population of points, not a unique one.
2. Use the only values of the function to optimize, not their derived function or other auxiliary knowledge.
3. Use probabilistic transition function not determinist ones.

1.7.2 Advantages of Genetic Algorithm

1. They efficiently search the model space, so they are more likely (than local optimization techniques) to converge toward a global minima.
2. It can solve every optimization problem which can be described with the chromosome encoding.
3. It solves problems with multiple solutions.
4. Structural genetic algorithm gives us the possibility to solve the solution structure and solution parameter problems at the same time by means of genetic algorithm.
5. Genetic algorithm is a method which is very easy to understand and it practically does not demand the knowledge of mathematics.

1.7.3 Disadvantages of Genetic Algorithm

1. They show a very fast initial convergence, followed by progressive slower improvements.
2. In presence of lots of noise, convergence is difficult and the local optimization technique might be useless.
3. Models with many parameters are computationally expensive.
4. The fitness of all the models may be similar, so convergence is slow.
5. Like other artificial intelligence techniques, the genetic algorithm cannot assure constant optimization response times. Even more, the difference between the shortest and the longest optimization response time is much larger than with conventional gradient methods. This unfortunate genetic algorithm property limits the genetic algorithms' use in real time applications.

Chapter 2

Literature review

Oberhart et al. (1987) described a simple microstrip line feed network for an array module comprising four microstrip elements. The advantages and disadvantages of the network are discussed as well as a theoretical explanation for the radiation characteristics of array modules using the network.

Lee et al. (1995) discussed a coaxially-fed single-layer single-patch wideband microstrip antenna in the form of a rectangular patch with a U-shaped slot. Measurements showed that this antenna can attain 10-40% impedance bandwidth without the need of adding parasitic patches in another layer or in the same layer.

Lee et al. (1996) studied a two-element array of U-slot rectangular patches experimentally. The array has an impedance bandwidth of 29.5%, centered around 4.5GHz, with good pattern characteristics.

Branner et al. (1999) described a new approach to synthesis of unequally spaced arrays for performance improvement utilizing a simple inversion algorithm to obtain the element spacing from prescribed far-zone electric field and current distribution, or current distributions from prescribed far-zone electric field and element spacing.

Song et al. (2001) concerned with the design of a Ku-band active transmit-array module of transistor amplifiers excited by either a pyramidal horn or a patch array. Optimal distances between the active transmit array and the signal-launching/receiving device, which is either a passive corporate-fed array or a horn, are determined to maximize the power gain at a design frequency. Having established these conditions, the complete structure is investigated in terms of operational bandwidth and near-field and far-field distributions measured at the output side of the transmit array. The experimental results show that the use of a corporate-fed array as an illuminating/receiving device gives higher gain and significantly larger operational bandwidth. An explanation for this behavior is sought.

Lau et al. (2001) presented the design and measured results of a wideband antenna array of four U-slot rectangular patches. The U-slot patches are proximity coupled by a microstrip feed line terminating with novel Π-shaped stubs. By using a foam layer of thickness t - 5.5mm as the supporting substrate, an impedance bandwidth (SWR < 2) of 27% ranging from 3.4GHz to 4.5GHz is achieved. It has an average gain of 13dBi and a cross-polarization of less than -20dB.

Wong et al. (2003) presented the design and characteristics of a wide-beamwidth, wide-bandwidth patch antenna fed by an L-shaped probe. The novelty in this design is the incorporation of a folded patch with a U-shaped cross section, the dimensions of which can be optimized to achieve an impedance bandwidth of 20% (SWR 1.5) and a H-plane beamwidth of 103. The antenna finds application as a cellular base station antenna covering both CDMA and GSM bands from 824–960 MHz.

Khuntia et al. (2003) presented a simple and accurate method for calculating the resonant frequency of a rectangular microstrip patch antenna with a single shorting post by using the artificial neural networks. Genetic algorithm is used to select the initial weights of artificial neural networks. The calculated resonant frequency is compared with experimental results. The results are in very good agreement with experimental results with decreased computational time.

Neog et al. (2003) presented a novel method of optimization by coupling the genetic algorithm (GA) and artificial neural network (ANN). A trained artificial neural network is taken as objective function in GA for optimization. By utilizing this technique the optimized dimensions of patch antenna on thick substrate has been calculated. It is seen that the results obtained by this method are closer to experimental value compared to earlier results obtained by curve fitting method. To validate this, the results are compared with experimental values for fabricated antenna. The results are in very good agreement with experimental findings.

Yoon et al. (2005) presented a wide-band aperture coupled 2 into 4 microstrip array antenna using inverted feeding structures for serving both Personal Communications Services and International Mobile Telecommunications- 2000 services simultaneously. The measured bandwidth for 10 dB return loss at each port is 19.84% and 28.25%, respectively, which cover both services.

Honma et al. (2005) proposed a highly efficient multilayer parasitic microstrip antenna array that is constructed on a multilayer Teflon substrate for millimeter-wave system-on-package modules. The proposed antenna achieves a radiation efficiency of greater than 91% and an associated antenna gain of 11.1 dBi at 60 GHz. The antenna size is only 10 mm into 10 mm. Additionally, author describes a 60-GHz-band prototype antenna employing a multilayer Teflon substrate that is well suited to achieving high gain and a wide bandwidth. The measured performance of the prototype antenna is also presented.

Werner et al. (2007) presented the developments which address the challenge of determining the optimal element positions in non uniformly spaced broadband phased-array antennas in order to best meet desired performance criteria. Specifically, this is accomplished by introducing a new nature-based design technique that couples a robust genetic-algorithm (GA) optimizer with rapid neural-network (NN) estimation procedures. These provide performance criteria as functions of the element positions over the entire scanning range and bandwidth of operation. The objective of this GA-NN technique is to determine the optimal element positions for a broadband aperiodic linear phased-array antenna in order to minimize element VSWRs and sidelobe levels. The NN estimation procedures circumvent the need for computationally intensive full-wave numerical simulations during the optimization process, which would ordinarily render such an optimization task impractical. The effectiveness of the new GA-NN design synthesis technique is demonstrated by considering an example where a non uniformly spaced linear phased array of ten stacked patch antennas is optimized for operation within a given bandwidth and scanning range.

Fang et al. (2007) designed a new 2 into 2 microstrip antenna array. The element used in this array is a tooth-like-slot patch. This patch is electromagnetically coupled by a microstrip feed line. In addition to the easy feeding, the proposed structure possesses the advantages of being wide bandwidth, high gain and the low cross-polarization level. The patch element has the peak gain 10.2 dBi and the cross-polarization is lower than 23 dB within the impedance bandwidth. The measured VSWR of 2 into 2 array show that the impedance bandwidth is 34%. The gain of the array is 14–16.3 dBi at 4.8–6.1 GHz. And the cross-polarization level of the array is lower than 20 dB within the impedance bandwidth.

Huang et al. (2008) presented the design and measured results of a 2 into 2 microstrip line fed U-slot rectangular antenna array. The U-slot patches and the feeding network are placed on the same layer, resulting in a very simple structure. The advantage of the microstrip line fed U-slot patch is that it is easy to form the array. An impedance bandwidth of 18% ranging from 5.65 GHz to 6.78 GHz is achieved. The radiation performance including radiation pattern, cross polarization, and gain is also satisfactory within this bandwidth. The measured peak gain of the array is 11.5 dBi. The agreement between simulated results and the measurement ones is good. The 2 into 2 arrays may be used as a module to form larger array.

Wang et al. (2008) proposed a compact switched-beam antenna. The antenna is composed of a four-element antenna array based on L-shaped quarter-wavelength slot antenna elements. Such an antenna element is a planar structure and presents a directional radiation pattern in the azimuth plane. Its maximum radiation direction is toward near the direction of the open end of the slot. The experiment results fully demonstrate the performance of the proposed design. Due to the compact size and low manufacture cost, such a design can be a promising solution for digital home applications to overcome multipath problems and increase the transmission data rate.

Sambell et al. (2008) described a design procedure for a circularly polarized 2 times 2 patch antenna array. The structure involves 22 design parameters with associated constraints, and a multi-objective genetic algorithm is developed to determine the parameter values. This approach removes the requirement for quarter-wave transformers associated with the conventional method, and achieves a more compact configuration. In addition, the proposed design reduces step discontinuities and hence reduces spurious radiation. The related constraints were the lengths, characteristic impedance values of the array feed network and the phase-shifting between the radiating elements of the array. The return loss and axial ratio for a 5.8 GHz array were investigated and good agreement was obtained between calculated, simulated, and measured measurements.

Stankovic et al. (2009) introduced the efficient neural networks model of slotted patch antenna. The model calculates the resonant frequency and minimum value of S_{11} parameters considering both antenna dimensions and dielectric characteristics. The proposed neural model has similar accuracy as detailed electromagnetic (EM) methods while its simulation speed is significantly greater.

Mishra et al. (2009) described the analysis and synthesis design of square and rectangular microstrip antenna by using ANN. The feed forward back propagation algorithm of ANN is used to design the parameters of square and rectangular patch antenna. Neural results of trained and tested data are in very good agreement with the experimental results available in the literature. Both models have been used in the field of computational electromagnetics of patch antenna as the most powerful optimizing tools. With the help of analysis model, we get the accurate value of resonant frequency while synthesis model helps to get the accurate value of width W and length L of MSA.

Hassani et al. (2010) introduced a combination of slots and series-fed patch antenna array leading to an array antenna with wide bandwidth, low sidelobe level (SLL), and high front-to-back ratio (F/B). Three structures are analyzed. The first, the reference structure, is the conventional series-fed microstrip antenna array that operates at 16.26 GHz with a bandwidth of 3%, SLL of -24 dB, and F/B of 23 dB. The second is similar to the reference structure, but a large slot that covers the patch array is removed from the ground plane. This results in a wide operating bandwidth of over 72%, with a 3 dB gain bandwidth of over 15.9%. The SLL of this structure is improved. This structure has a bi-directional radiation pattern. To make the pattern uni-directional and increase the F/B, a third structure is analyzed. In this structure, rather than one single large slot, an array of slots is used and a reflector is placed above the series-fed patch array. This increases the F/B to 40 dB. The simulated and measured results are presented and discussed.

Dhaliwal et al. (2011) presented a dual band elliptical fractal patch antenna .Artificial Neural Networks (ANN) based approach is used for calculating the resonant frequency, return loss and gain of antenna. The back propagation algorithm is used to train the network. The results obtained by using this ANN approach are in agreement with the simulated results obtained using IE3D software.

Wang et al. (2011) presented a planar waveguide-slot array antenna with a centre hole. Throughout analyzing the effects on patterns sidelobes in the waveguide-slot array antenna with a centre hole, the array's pattern is optimized by Genetic Algorithm method. The results of design are good and compare very well with ones analyzed by the emulational software of the electromagnetic fields. The array antennas are widely applied in the fields of the complex detectors especially ones with radio and optics on aircraft.

Dhaliwal et al. (2012) described that Artificial Neural Networks have been recently used for the design and analysis of fractal antennas. The performance of various types of networks has not been yet explored for these antennas. This paper evaluates the performance of three types of neural networks: Back Propagation Neural Network (BPNN), Radial Basis Function Neural Network (RBFNN), and Generalized Regression Neural Networks (GRNN) for parameter estimation of Microstrip Fractal Antenna. Depending on the values of mean percentage error and time taken for training of each type, it has been concluded that the GRNN has best performance among these three networks.

Sohal et al. (2012) introduced Genetic Algorithms (GA) that has been applied to calculate the optimized parameters of Elliptical Microstrip antenna. The inputs to the problem are thickness of the substrate, eccentricity, dielectric constant and even mode frequency. The output obtained is the optimized semi-major axis length `a' from which the other parameters i.e. semi-minor axis length and odd mode frequency are calculated. The results obtained by GA are compared with the targeted results. The results are in good agreement. GA results are also compared with IE3D simulation results. These results are also comparable and thus validate the GA based code.

Zhang et al. (2012) presented a novel class of low-cost, small-footprint and high-gain antenna arrays for W-band applications. A 4 into 4 antenna arrays is proposed and demonstrated using substrate-integrated waveguide (SIW) technology for the design of its feed network and longitudinal slots in the SIW top metallic surface to drive the array antenna elements. Dielectric cubes of low-permittivity material are placed on top of each antenna array to increase the gain of the circular patch antenna elements. This new design is compared to a second 4 into 4 antenna array which, instead of dielectric cubes, uses vertically stacked Yagi-like parasitic director elements to increase the gain. Measured impedance bandwidths of the two 4 into 4 antenna arrays are about 7.5 GHz (94.2–101.8 GHz) at 18 dB gain level, with radiation patterns and gains of the two arrays remaining nearly constant over this bandwidth. While the fabrication effort of the new array involving dielectric cubes is significantly reduced, its measured radiation efficiency of 81 percent is slightly lower compared to 90 percent of the Yagi-like design.

Wang et al. (2012) introduced a compact dual-port, multiple input-multiple output (MIMO) antenna arrays for handheld devices. The antenna structure consists of two quarter wavelength monopole slots etched on the ground plane of a printed circuit board (PCB) and a meandered slot cut between them. The meandered slot not only reduces the coupling between the two slot antennas, but also improves the bandwidth and efficiency of the array by acting as a radiating parasitic element. Simulated and measured results show that the meandered isolating slot allows the antennas to achieve wider bandwidth, higher efficiency, higher isolation and better diversity performance, compared to other types of isolating slots.

Chapter 3
Problem Formulation

3.1 Need and Significance of proposed research work

Antenna arrays have many applications in communication field. The need and significance of the thesis work is to get optimized value of return loss using ANN and an optimizer. Optimization technique which is used is GA optimizer means genetic algorithm optimizer. Generally, the dimensions of slot are given by X and Y coordinates. For different combinations of slot dimensions, the return loss is obtained using IE3D software to prepare a data set for the training of neural networks. To get the optimized value of return loss, we use ANN and genetic algorithm together.

3.2 Objective

The objective of this research work is as under:

(1) To optimize the return loss of a U-slot antenna array using ANN and Genetic Algorithm.

3.3 Methodology/ Planning of work

The procedure adopted to achieve the required objective is given below:

1. Firstly, IE3D software has been used to design an antenna array and then prepare a data set for the training of ANN. The slot dimensions have been given by the X and Y coordinates. The various combinations of slot dimensions have been taken as the input parameters for the training of ANN. The return loss for the corresponding combination of dimensions has been taken as output.

2. The data set prepared has been used to train the ANN in Matlab. Sufficient number of training samples has been used to train the artificial neural networks. In this research work, there are 100 training samples that used to train the neural network efficiently.

3. Then, both the genetic algorithm and ANN have been used to get optimal return loss i.e. minimum return loss.

4. The optimum value of return loss given by genetic algorithm has been then compared with the results obtained from IE3D software for the same slot dimensions. The results have a good match with each other.

Chapter 4

Present work

4.1 Introduction to U- slot Antenna Array Design

In the design of an antenna array, there is a basic patch antenna element which can be of any shape i.e. rectangular, circular, square, elliptical and so on. By combining these elements by a proper feed network we get an antenna array. A single-element antenna is usually not enough to achieve high gain, directivity and low return losses. To overcome this problem, a set of discrete elements, which constitute an antenna array, is designed. The objective of my work is to design a U-slot antenna array using IE3D software and then find optimum return loss using ANN and genetic algorithm.

4.2 Basic parameters and Antenna dimensions

The antenna array geometry is designed using IE3D toolbox of Zealand Software with base geometry of a rectangular patch having U-slot in it. The basic parameters used for the design of an antenna array are given below:

Table 4.1 Basic parameters and Antenna dimensions

Height of substrate	3.5 mm
Dielectric constant	2.7
Loss tangent	0.0002
Length of patch	19.3 mm
Width of patch	12.8 mm

4.3 Design of U-slot antenna array using IE3D

Firstly, we designed basic rectangular patch with given dimensions. Then we design a U shaped slot in this rectangular patch with the following dimensions. Compared to the conventional rectangular patch antenna, slot loading antennas give the better performance in resonant frequency, return loss in the cost of bandwidths (Bhunia, 2012).

- Length of vertical rectangle in slot = 0.5 mm
- Width of vertical rectangle in slot = 10.4 mm
- Length of horizontal rectangle in slot= 7.65 mm
- Width of horizontal rectangle in slot = 0.7 mm

The designed structure obtained is a single layer structure, resulting in a simple structure. Steps to design antenna array using IE3D are shown below:

1. Double click on MGRID

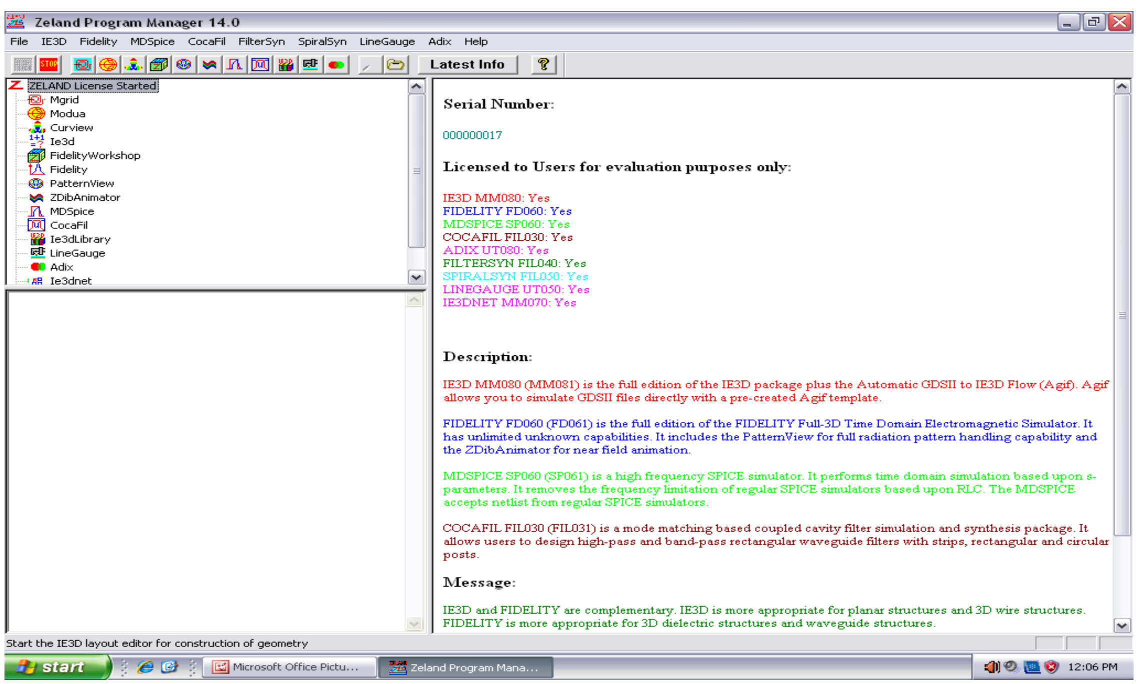

Fig 4.1 MGRID Block

2. Click on File→ open New file

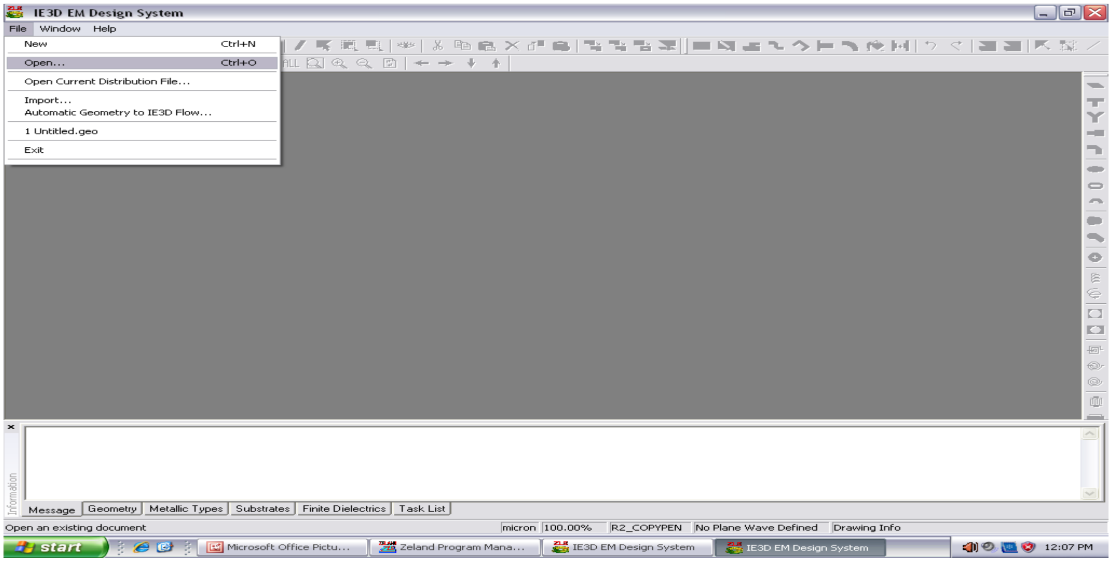

Fig 4.2 IE3D EM Design System

3. Make Grid size = 0.025 mm

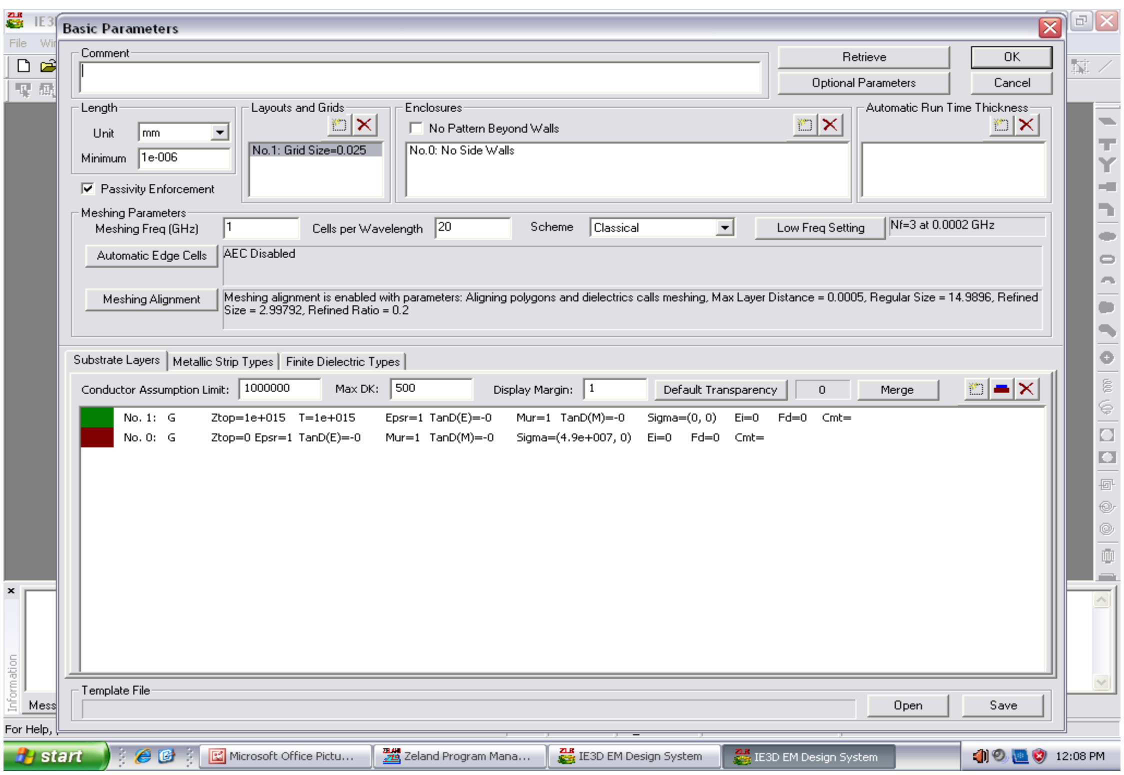

Fig 4.3 Basic Parameters

4. Define substrate parameters

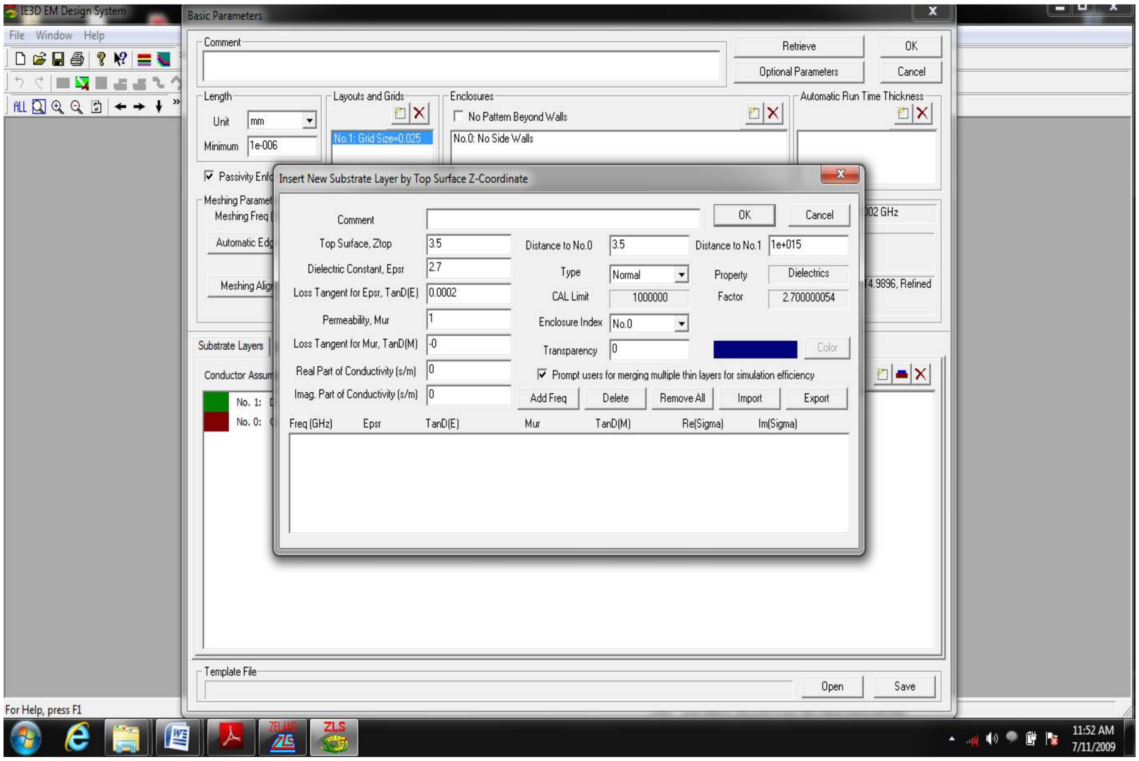

Fig 4.4 Basic parameters used in IE3D for designing antenna array

5. Click on entity →Rectangle

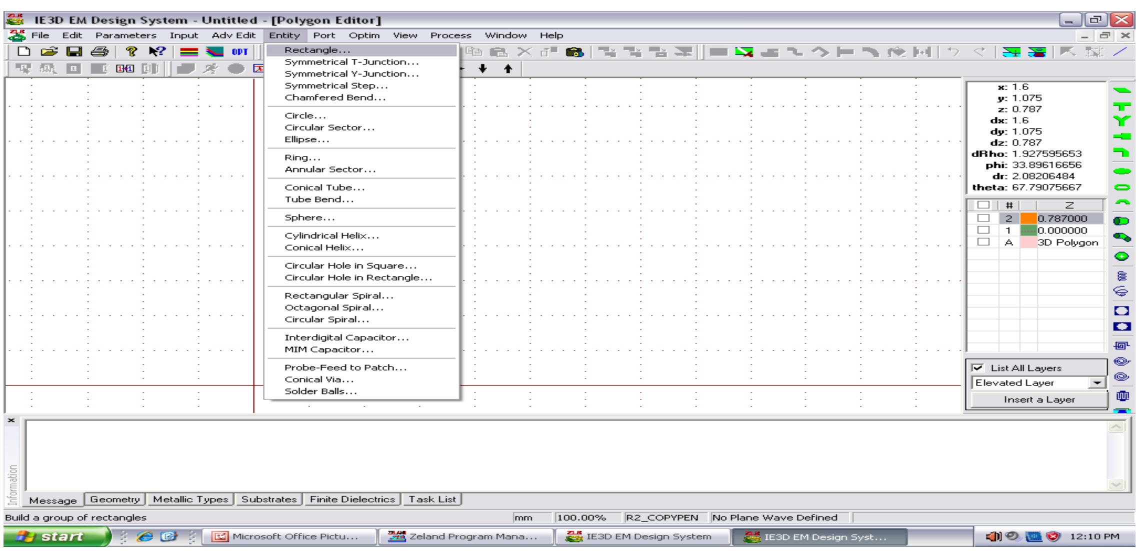

Fig 4.5 Polygon Editor

6. Fill the dimensions of rectangle

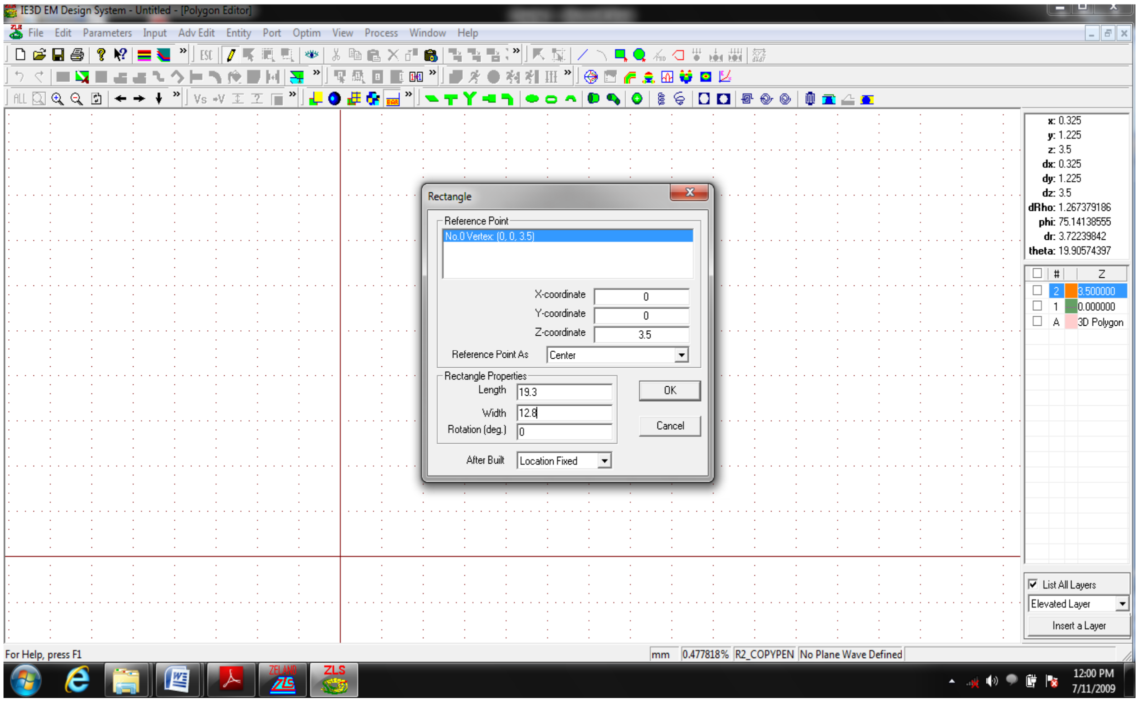

Fig 4.6 Dimensions of rectangular patch

7. Design an antenna array

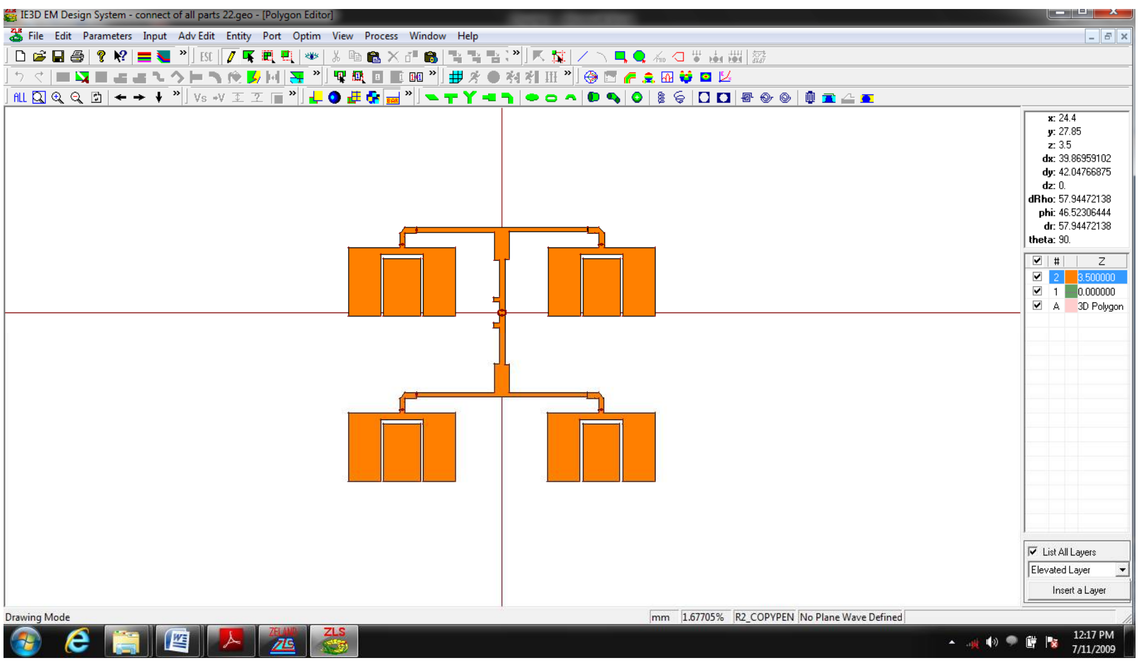

Fig 4.7 Design of U-slot antenna array

8. Click on entity → Probe feed to patch

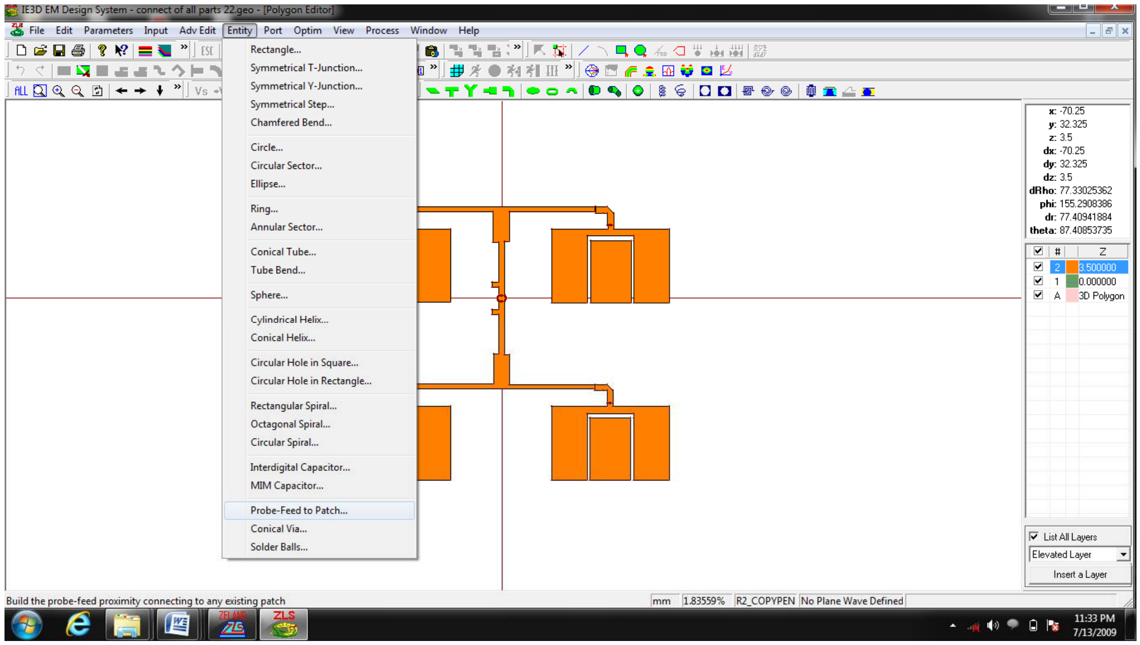

Fig 4.8 Feed to antenna array

9. Give location of feed point (X, Y) = (0.2, -0.1)

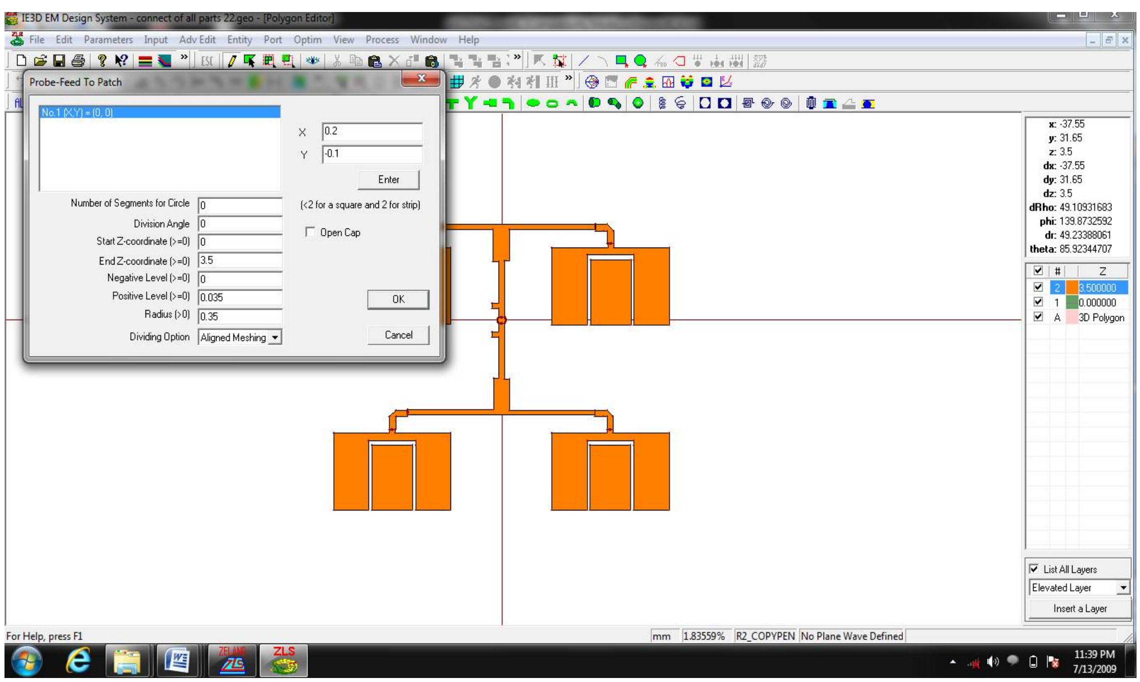

Fig 4.9 Feed Point Location

10. Click on process → Simulate

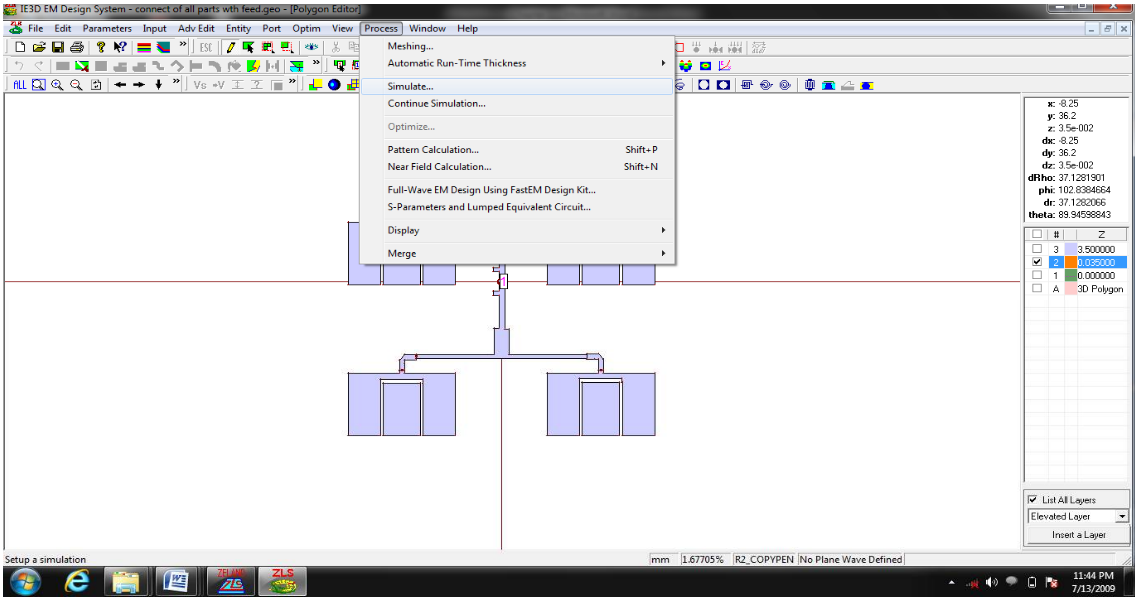

Fig 4.10 Simulation of array design

11. Enter Frequencies

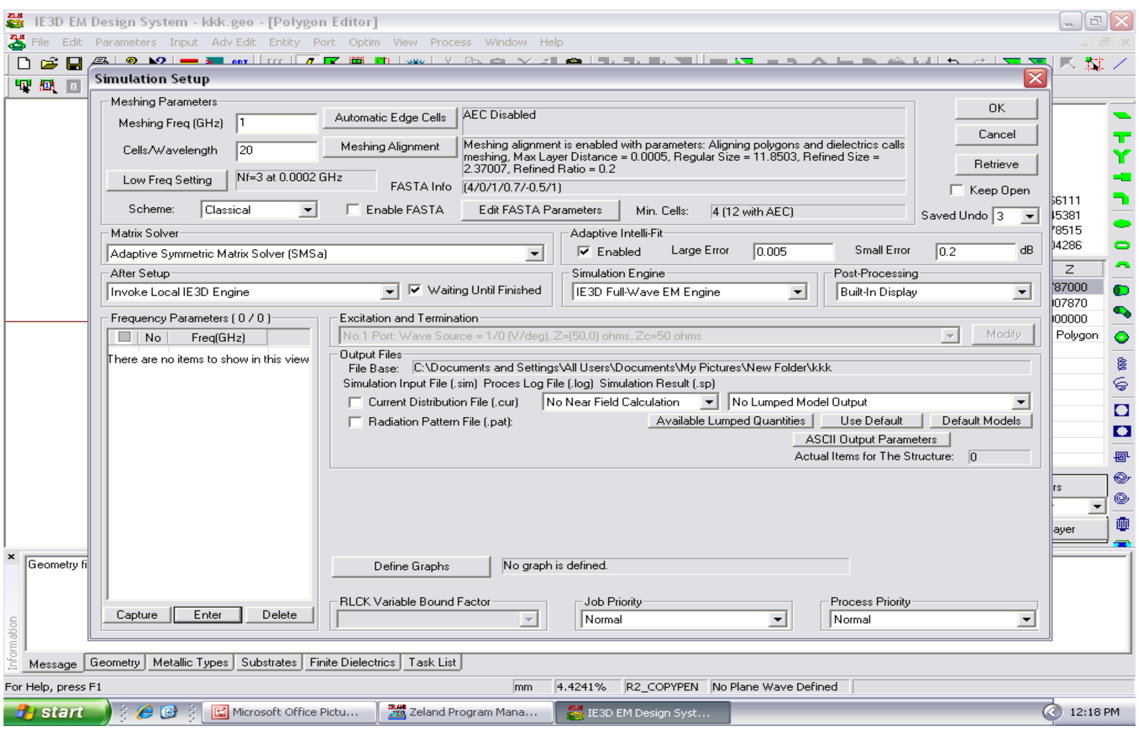

Fig 4.11 Simulation Setup

12. Press OK

13. Simulation starts and after simulation we get results.

14. During simulation, current and radiation pattern should be marked to activate the process → Pattern Calculation.

15. After Simulation, we can obtain value of return loss -14 dB for corresponding antenna array design.

After performing simulation using IE3D, we have to use ANN and GA. Before using ANN we have to prepare a data set using IE3D for the training of neural networks. The trained artificial neural networks used as an objective function for the optimization in GA.

4.4 Artificial Neural Networks

The greatest advantage of ANN is their ability to be used as an arbitrary function approximation mechanism that learns from observed data. The utility of ANN models lies in the fact that they can be used to infer a function from observations. This is particularly useful in applications where the complexity of the data or task make the design of such a function by hand in practical. ANN's ability to automatically learn from examples make them attractive and exciting. They learn input output relationships from given collection of representative examples.

4.4.1 Artificial Neural Network Training

Feed forward neural network is a type of artificial neural networks that has been used for finding optimum return loss using genetic algorithm. Trainlm training function is used for the training of feed forward network because it is very fast. Number of combinations of slot dimensions have been chosen and calculate the return loss for each combination. In this way, a data set has been prepared by simulating it across IE3D software to obtain return loss as output. Then this data set has been used for the training of ANN. Then this trained ANN is taken as objective function in GA for optimization.

4.4.2 Training data set

The training data set for the training of artificial neural networks is given below in table 4.2 where X and Y represent slot dimensions.

Table 4.2 Data set for training of ANN

Sr. No.	X (in mm)	Y (in mm)	Return Loss (S_{11}) (in dB)
1	0.4	0.6	-11
2	0.6	0.7	-23
3	0.8	0.8	-23
4	0.9	0.6	-22.5
5	1	0.8	-14
6	1.5	1	-12
7	0.2	0.5	-14
8	2	1	-28
9	2	0.9	-12
10	0.3	0.5	-10
11	2.5	1	-21
12	0.4	0.7	-22
13	0.5	0.8	-23

14	2.5	0.5	-34
15	2	0.5	-13
16	3	1.5	-27
17	0.7	0.8	-23
18	1.2	0.9	-12
19	1.3	0.6	-12
20	0.9	0.8	-12
21	2.5	0.6	-30
22	2.2	0.4	-10
23	0.3	0.4	-21
24	0.4	0.4	-23
25	0.6	0.4	-20
26	0.7	0.4	-22
27	0.6	0.6	-10
28	0.7	0.6	-23
29	0.8	0.9	-21
30	0.9	0.9	-22.5
31	1	0.9	-22
32	1	1	-11
33	1.5	0.9	-22.5
34	1.5	0.8	-11
35	0.4	0.5	-9.5
36	0.1	0.1	-21

37	0.1	0.2	-13
38	0.1	0.3	-10
39	0.1	0.4	-22.5
40	0.1	0.5	-23
41	0.1	0.6	-28
42	0.2	0.1	-13
43	0.2	0.2	-22.5
44	0.2	0.3	-8.5
45	0.2	0.4	-9.5
46	0.2	0.6	-11
47	0.3	0.3	-8.9
48	0.3	0.1	-13
49	0.3	0.2	-21
50	0.3	0.6	-23
51	0.3	0.8	-12
52	0.3	0.9	-26
53	0.3	1	-34
54	0.4	0.1	-8
55	0.4	0.2	-8.2
56	0.4	0.3	-9
57	0.4	0.8	-23

58	0.4	0.9	-30
59	0.4	1	-24
60	0.6	0.1	-23
61	0.6	0.2	-23
62	0.6	0.3	-9
63	0.6	0.5	-10
64	0.6	0.8	-11
65	0.6	0.9	-14
66	0.6	1	-15
67	0.7	0.1	-8
68	0.7	0.2	-9
69	0.7	0.3	-21
70	0.7	0.5	-22
71	0.7	0.8	-12
72	0.7	0.9	-22.5
73	0.8	1	-26
74	0.8	0.1	-20

75	0.8	0.2	-9
76	0.8	0.3	-21
77	0.8	0.4	-10
78	0.8	0.5	-23
79	0.8	0.6	-17
80	0.9	0.1	-21
81	0.9	0.2	-21
82	0.9	0.3	-9.5
83	0.9	0.4	-15
84	0.9	0.5	-21
85	0.9	1	-12
86	1	0.1	-21
87	1	0.2	-8
88	1	0.3	-21
89	1	0.4	-20
90	1	0.5	-10
91	1	0.6	-23
92	2	0.1	-13

93	2	0.2	-21
94	2	0.3	-21
95	2	0.4	-21
96	2	0.6	-23
97	2	0.8	-11
98	1.5	0.2	-20
99	1.5	0.3	-20
100	1.5	0.4	-20

4.5 Genetic Algorithm

Genetic Algorithm is inspired from natural life. Genetic Algorithms are the heuristic search and optimization techniques that mimic the process of natural evolution. Genetic algorithms implement the optimization strategies by simulating evolution of species through natural selection. The GA most often requires a fitness function that assigns a score (fitness) to each chromosome in the current population. The fitness of a chromosome depends on how well that chromosome solves the problem at hand. Particularly well suited for hard problems where little is known about the underlying search space. It is widely-used in business, science and engineering and some other applications. GA'S are often viewed as function optimizers, although the range of problems to which GA'S have been applied is quite broad.

4.5.1 The flow chart of the standard genetic algorithm (SGA)

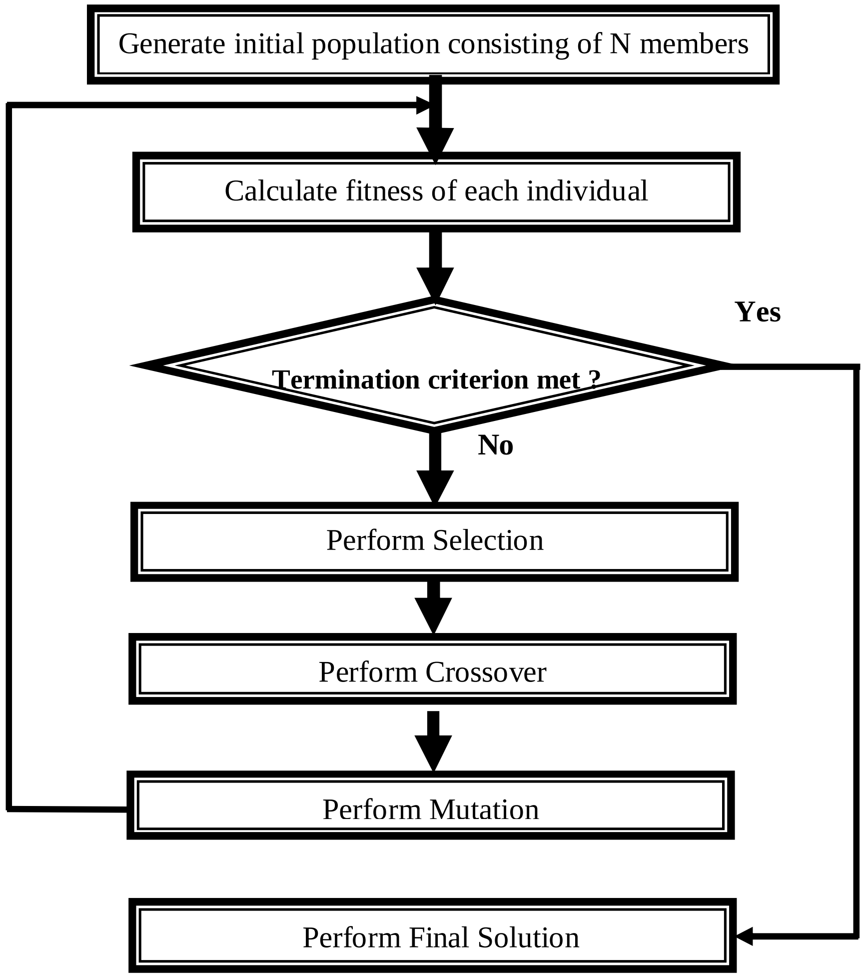

Fig 4.12 Flow chart of SGA

Step 1: Before the search starts, a set of chromosomes is randomly chosen from the search space to form the initial population consisting N members.

.**Step 2:** After that through computations the individuals are selected in a competitive manner, based on their fitness as measured by a specific objective function.

Step 3: Check termination criterion, if termination criterion is not met then goes for genetic search operators and if met then go to final solution.

Step 4: The genetic search operators such as selection, mutation and crossover are then applied one after the other to obtain a new generation of chromosomes in which the expected quality over all the chromosomes is better than that of the previous generation.

Step 5: This process is repeated until the termination criterion is met, and the best chromosome of the last generation is reported as the final solution.

Chapter 5

Results and Discussions

The data set obtained from IE3D software has been used for the training of feed forward back propagation neural network. Then the trained neural network has been used as an objective function for the optimization algorithm GA. The genetic algorithm provides the slot dimensions at which an optimum return loss is obtained. When design array using slot dimensions provided by genetic algorithm using IE3D, the results of return loss has a good match with the results provided by GA.

5.1 Simulation Results

5.1.1 Simulation results of antenna array configuration before applying ANN and GA

The configuration of U-slot antenna array is firstly designed and then simulated by using IE3D software. The configuration of antenna array is shown below:

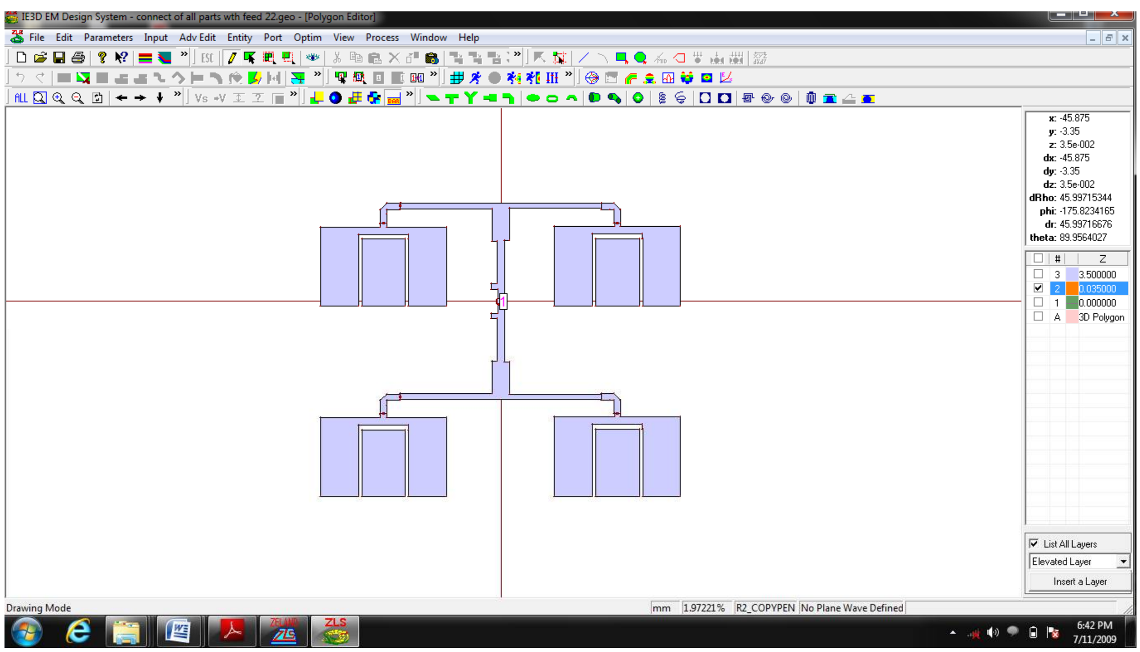

Fig 5.1 Configuration of U-slot antenna array before applying ANN and GA

After simulation of the configuration shown in fig 5.1, the return loss is obtained is -14 dB shown below in fig 5.2. The resonance frequency used for the geometry is 4.1 GHz. Return Loss is a parameter which defines the amount of power that is lost to the load and does not return as a reflection. It is also defined as the ratio of the reflected back power to the incident power. For good antenna its value should be more negative then -10dB.

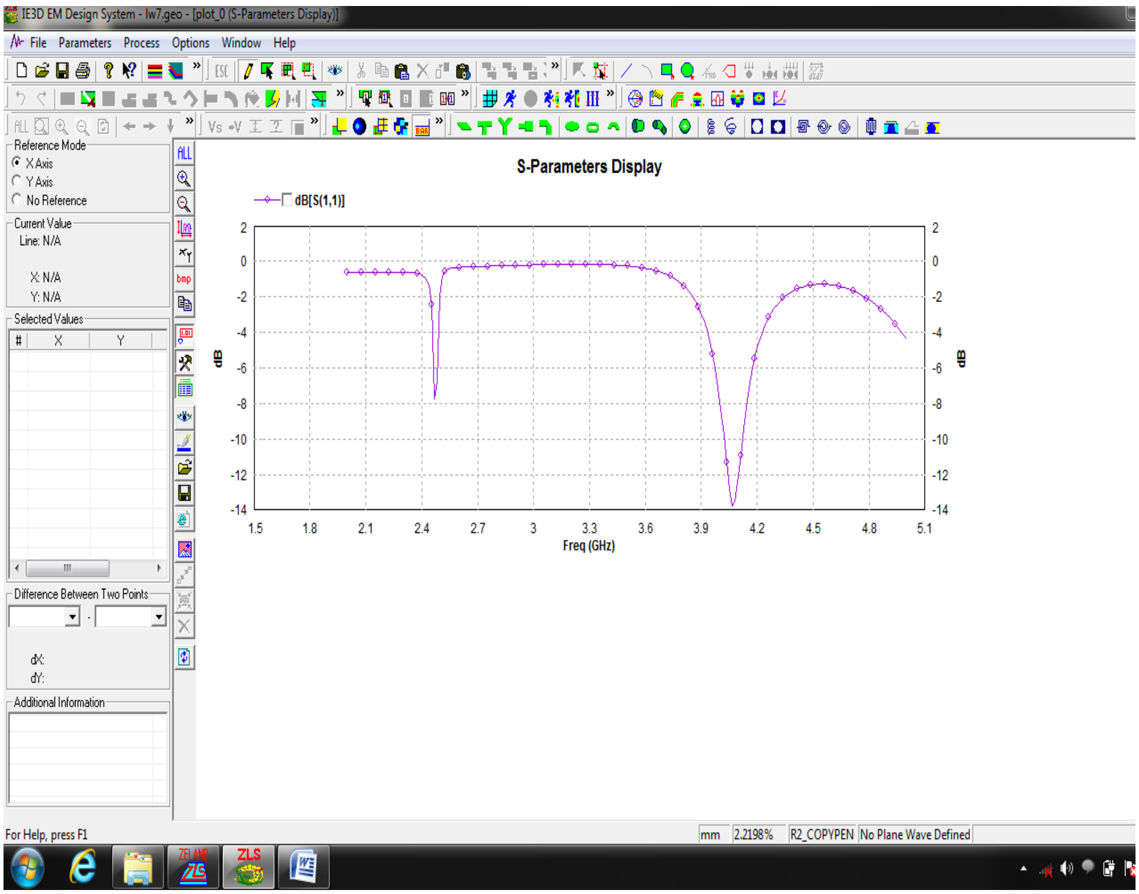

Fig 5.2 Return loss of antenna array configuration before applying ANN and GA

5.1.2 Simulation results of antenna array using values of slot dimensions provided by ANN and GA

By using training data set obtained from IE3D we have to train artificial neural networks. Process of capturing the unknown information hidden in data is called training of neural networks. Neural network training is shown below:

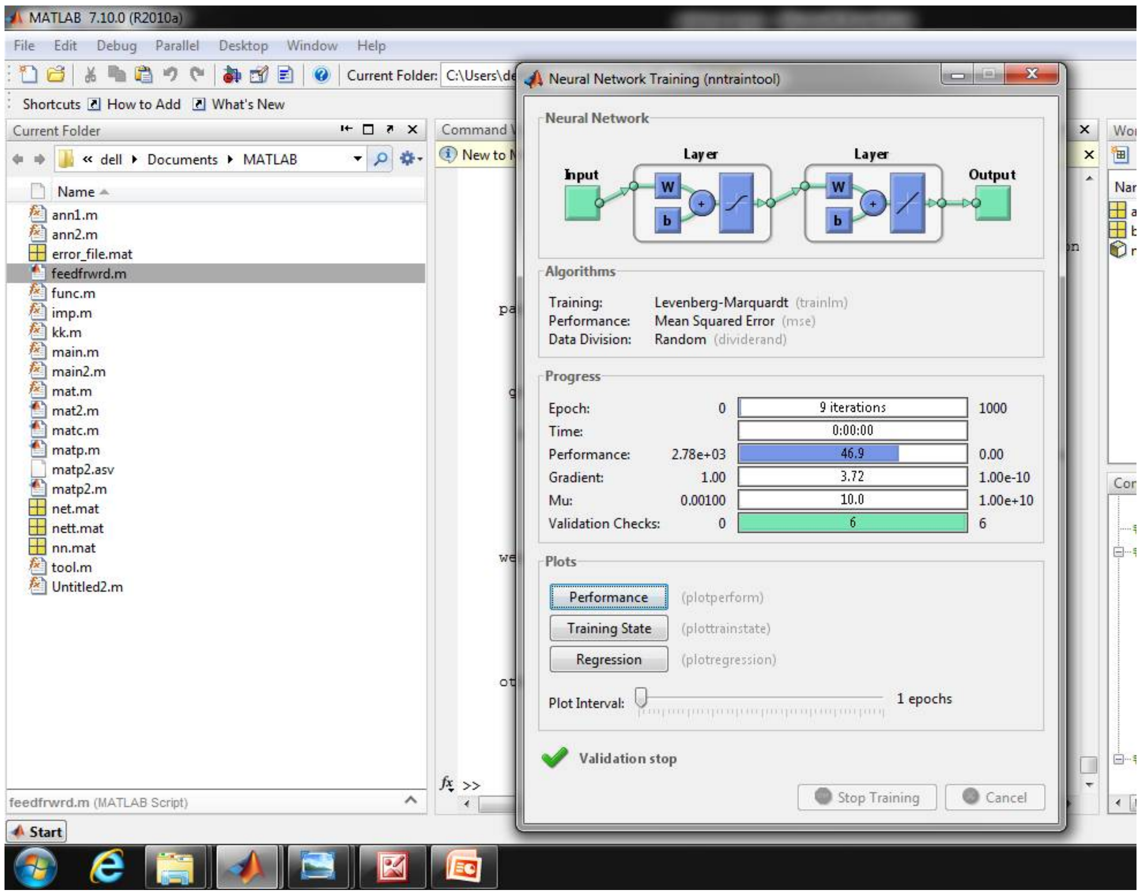

Fig 5.3 Neural Network Training

A trained ANN is taken as objective function in GA for optimization. ANN's ability to automatically learn from examples makes them attractive and exciting. They learn input-output relationships from given collection of representative examples.

Objective function is the fitness function you want to minimize. A Fitness function shown in Fig 5.4 below:

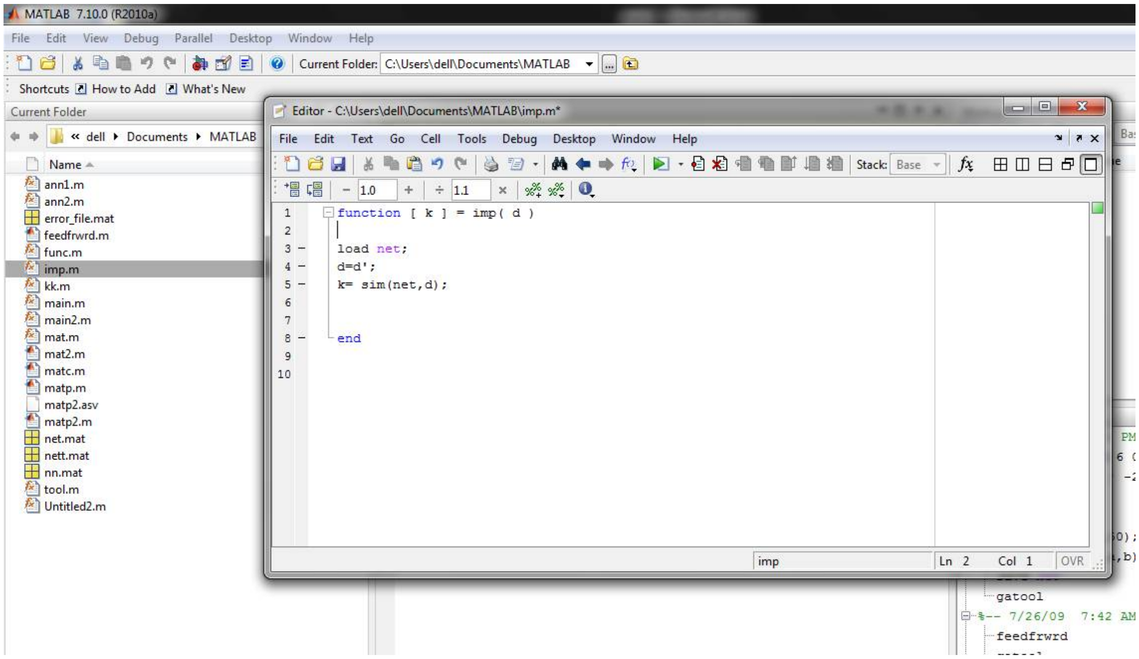

Fig 5.4 Fitness function in MATLAB

After performing the training of neural networks, apply the optimization tool GA. It provides optimum value of return loss i.e. -34.29 dB. The slot dimensions provide by GA tool are given below in table 5.1. Using these dimensions of slot, design the array using IE3D and after simulation we obtain the value of return loss -35 dB shown in fig 5.4 that are match with the results of genetic algorithm.

Table 5.1 Values of slot dimensions provided by ANN and GA

Length of vertical rectangle in slot	1.58
Width of horizontal rectangle in slot	0.103

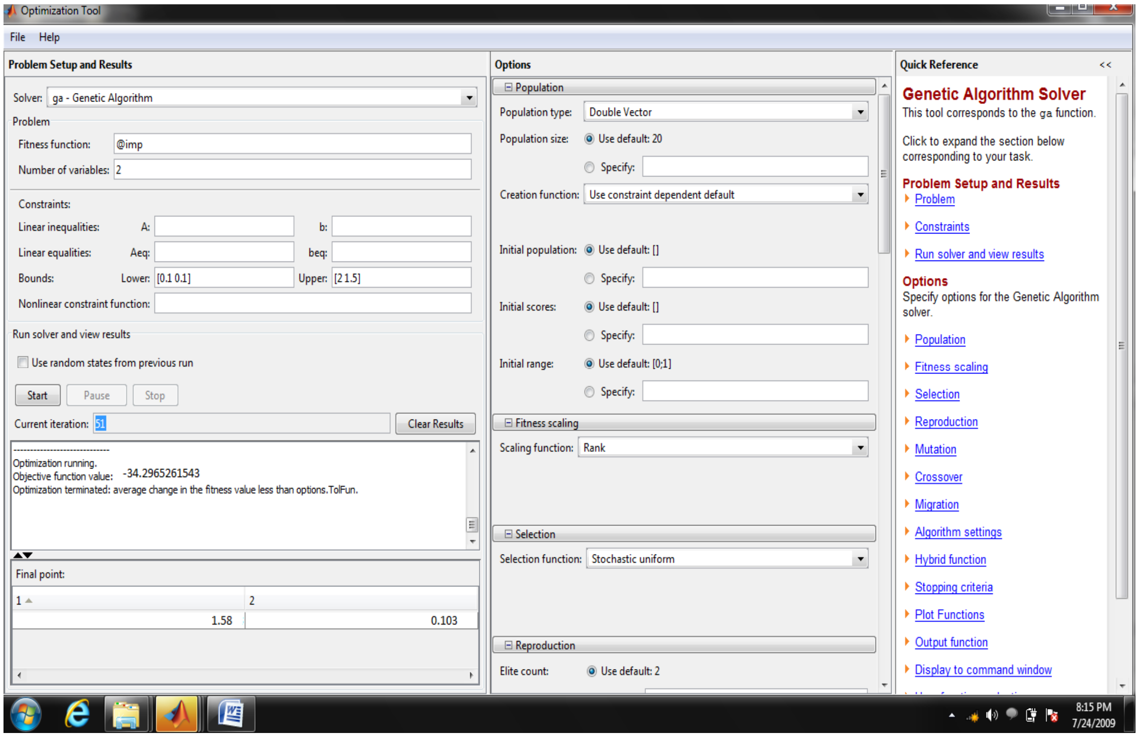

Fig. 5.5 Optimized value of return loss given by GA tool

The configuration of U-slot antenna array using values of slot dimensions provided by ANN and GA shown in fig 5.4 below:

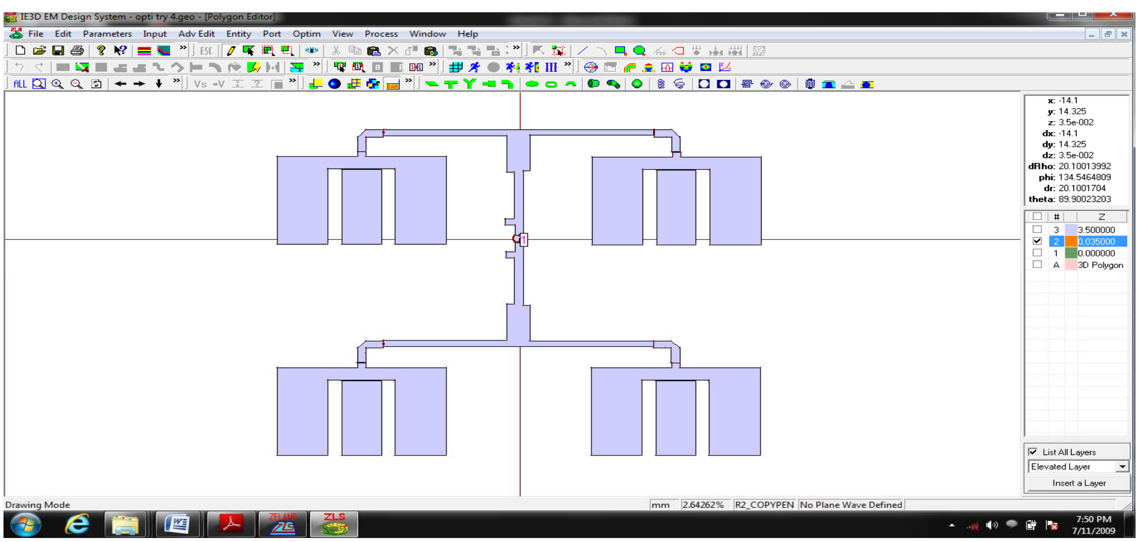

Fig 5.6 Simulation of U-slot antenna array using dimensions provided by ANN and GA

The simulated results obtained using IE3D software with the slot dimensions provided by genetic algorithm gives the optimized return loss of -35 dB shown in fig 5.5 below:

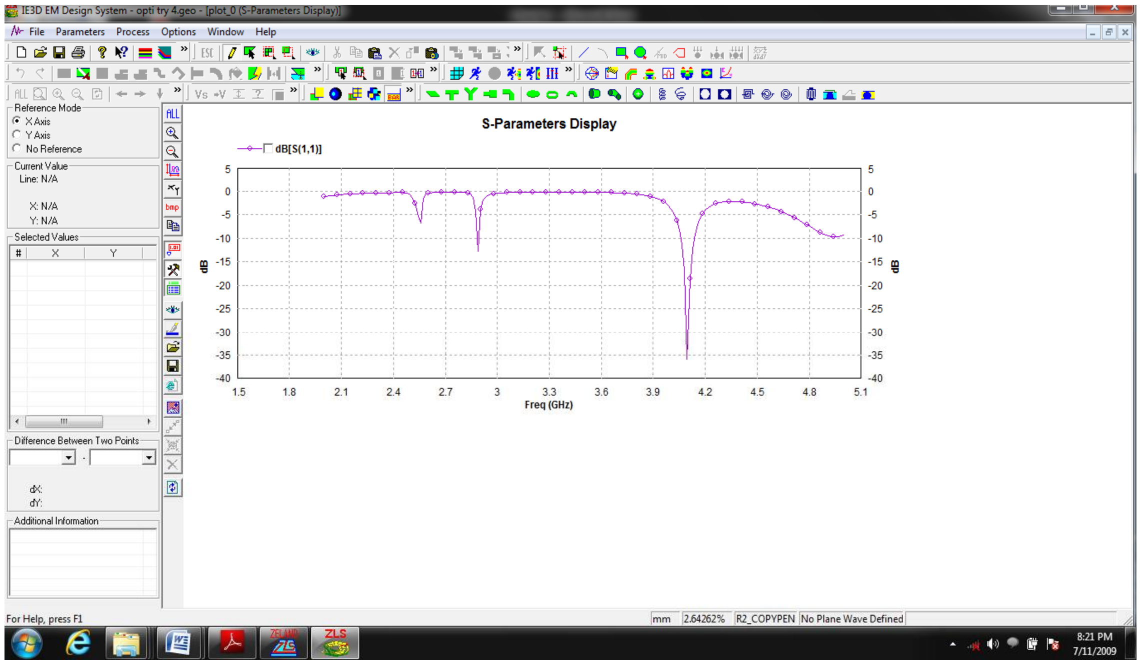

Fig 5.7 Optimized return loss of array using slot dimensions provided by ANN and GA

The results obtained by simulation using IE3D toolbox of Zeland software are in good agreement with results obtained from GA, hence providing a novel approach for getting optimum value of return loss for antenna arrays using ANN and genetic algorithms that result in maximum power transmission from the antenna array with minimum return loss.

Chapter 6

Conclusion and Future Scope

Conclusion

The following conclusions can be drawn from the presented work:

- A single element microstrip patch antenna has very narrow impedance bandwidth, low directivity, gain and high return loss. To overcome these problems, a U-slot antenna array is designed. This antenna array is a simple single layer structure easy to design and manufacture.
- A novel approach for finding optimum value of return loss for antenna array has been proposed.
- An artificial neural network (ANN) and Genetic algorithm (GA) has been used successfully to find the optimum value of return loss for an antenna array.
- The value of optimum return loss obtained by using ANN and GA are in good match with the value of return loss obtained from IE3D software for same slot dimensions.

Future Scope

- The performance of an antenna array can be more better by expanded this array into a larger array. An array can be expanded by increasing its antenna elements.
- The dimensions of the basic rectangular patch can also be optimized using different optimization techniques.
- The other optimization techniques can also be used like Ant colony optimization and Bacterial Foraging optimization (BFO).
- The fabrication of antenna array can also be done to get the experimental results.

- We can also apply firefly algorithm to this data set and then compare the results of GA and FA.

References

[1] Awida, M.H., Suleiman, S.H., and Fathy, A.E., (2011), "*Substrate-Integrated Cavity-Backed Patch Arrays: A Low-Cost Approach for Bandwidth Enhancement*", IEEE Transactions on Antennas and Propagation, Vol. 59, No. 4, pp. 1155-1163.

[2] Abdallah, E.A., Nashaat, D., Elsadek, H.A., Iskander, M.F., and Hennawy, H.M.E, (2011), "*Ultrawide Bandwidth 2 into 2 Microstrip Patch Array Antenna Using Electromagnetic Band-Gap Structure (EBG)*", IEEE Transactions on Antennas and Propagation, Vol. 59, No. 5, pp. 1528-1534.

[3] Ahmad, G., (2008), "*Design, Optimization and Development of X-Band Microstrip Patch Antenna Array for High Gain, Low Sidelobes and Impedance Matching*", Proceedings of IEEE International Conference on Electrical Engineering, University of Surrey, U.K.

[4] Aljibouri, B., Sambell, A.J., and Sharif, B.S., (2008), "*Application of genetic algorithm to design of sequentially rotated circularly polarised dual-feed microstrip patch antenna array*", IEEE Electronics Letters, Vol. 44, No. 12, pp. 708 – 709.

[5] Branner, G.R., and Kumar, B.P., (1999), "*Design of Unequally Spaced Arrays for Performance Improvement*", IEEE Transactions on Antennas and Propagation, Vol. 47, No. 3, pp. 511-523.

[6] Bhagile, V.D., Mishra, A., Nandgaonkar, A.B., and Mehrotra, S.C., (2009), "*Design of square and rectangular microstrip antenna with the use of FFBP algorithm of artificial neural network*", Proceedings of IEEE International Conference on Applied Electromagnetics, Kolkata, India, pp. 1-4.

[7] Bugaj, M., Przesmycki, R., Nowosielski, L., and Piwowarczyk, K., (2012), "*Analysis Different Methods of Microstrip Antennas Feeding for Their Electrical*

Parameters", Proceedings of Progress In Electromagnetics Research Symposium, KL, Malaysia, pp. 62-66.

[8] Deluccia, S., and Werner, D.H., (2007), "*Nature-Based Design of Aperiodic Linear Arrays with Broadband Elements Using a Combination of Rapid Neural-Network Estimation Techniques and Genetic Algorithms*", IEEE Antennas and Propagation Magazine, Vol. 49, No. 5, pp. 13-23.

[9] Dhaliwal, B.S., and Pattnaik, S.S., (2012), "*Performance evaluation of Artificial Neural Networks in microstrip fractal antenna parameter estimation*", Proceedings of IEEE International Conference on Communication Systems (ICCS), Singapore, pp. 135-139.

[10] Dhaliwal, B.S., Sohal, J.S., and Josan, S.K., (2012), "*Design of elliptical microstrip patch antenna using genetic algorithms*", Proceedings of IEEE International Conference on Communication Systems (ICCS), Singapore, pp. 140-143.

[11] Dhaliwal, B.S., and Arora, P., (2011), "*Parameter Estimation of Dual Band Elliptical Fractal Patch Antenna Using ANN*", Proceedings of IEEE International Conference on Devices and Communications (ICDeCom), Mesra, pp. 1-4.

[12] Fang, D.G., Wang, H., and Huang, X. B., (2008), "*A Single Layer Wideband U-Slot Microstrip Patch Antenna Array*", IEEE Antennas and Wireless Propagation Letters, Vol. 7, pp. 9-12.

[13] Fang, D.G., Wang, H., Huang, X. B., and Han, G.B., (2007), "*A Microstrip Antenna Array Formed by Microstrip Line Fed Tooth-Like-Slot Patches*", IEEE Transactions on Antennas and Propagation, Vol. 55, No. 4, pp. 1210-1214.

[14] Ghassemi, N., Wu, K., Claude, S., Zhang, X., and Bornemann, J., (2012), "*Low-Cost and High-Efficient W-Band Substrate Integrated Waveguide Antenna Array*

made of Printed Circuit Board Process", IEEE Transactions on Antennas and Propagation, Vol. 60, No. 3, pp. 1648-1653.

[15] Hassani, H.R., and Bayderkhani, R., (2010), "*Wideband and Low Sidelobe Slot Antenna Fed by Series-Fed Printed Array*", IEEE Transactions on Antennas and Propagation, Vol. 58, No. 12, pp. 3898-3904.

[16] Itipiboon, A., Garg, R., Bhartia, P., and Bahl, I., (2000), "*Microstrip antenna design handbook*", Artech House, Boston, London.

[17] Jeng, S.K., Lai, M.I., Wu, T.Y., Hsieh, J.C., and Wang, C.H., (2008), "*Compact Switched-Beam Antenna Employing a Four-Element Slot Antenna Array for Digital Home Applications*", IEEE Transactions on Antennas and Propagation, Vol. 56, No. 9, pp. 2929-2936.

[18] Kamchouchi, H.I., (2010), "*Ultra-Low-Sidelobe-Level Concentric-Ring Array Pattern Synthesis Using Bessel Neural Networks*", IEEE Antennas and Propagation Magazine, Vol. 52, No.4, pp. 102-105.

[19] Khuntia, B., Devi, S., Panda, D.C., and Pattnaik, S.S., (2003), "*Initializing artificial neural networks by genetic algorithm to calculate the resonant frequency of single shorting post rectangular patch antenna*", Proceedings of IEEE International Symposium on Antennas and Propagation Society, Columbus, OH, USA, Vol. 3, pp. 144-147.

[20] Kosta, Y.P., and Rathod, J.M., (2009), "*Development of Feed for Parabolic Reflector Antenna*", International Journal of Engineering and Technology, Vol.1, No.1, pp.1793-8236.

[21] Lee, K.F., and Huynh, T., (1995), "*Single-layer single-patch wideband microstrip antenna*", IEEE Electronics Letters, Vol. 31, No. 16, pp. 1310-1312.

[22] Lau, K.L., Luk, K.M., and Lee, K.F., (2001), "*Wideband U-slot microstrip patch antenna array*", Proceedings of IEEE on Microwave Antennas Propagation,Vol.148, No. 1, pp. 41-44.

[23] Leong, M.S., Ng, C.H., and Uysal, S., (1999), "*Bowtie Patch Antennas and Simple Arrays for Wireless Indoor Communications*", IEEE Transactions on Microwave Theory and Techniques, Vol. 47, No. 6, pp. 738-745.

[24] Lenhardt, B. M., Belfore, L. A., and Arkadan, A.A., (2001), "*ANN Inverse Mapping Technique Applied to Electromagnetic Design*", IEEE Transactions on Magnetics, Vol. 37, No. 5, pp. 3584-3587.

[25] Maaskant, R., Ivashina, M.V., and Woestenburg, B., (2008), "*Equivalent System Representation to Model the Beam Sensitivity of Receiving Antenna Arrays*", IEEE Antennas and Wireless Propagation Letters, Vol. 7, pp. 733-737.

[26] Miliji, M., Stankovic, Z., and Milovanovic, B., (2009), "*Efficient model of slotted patch antenna based on neural networks*", Proceedings of IEEE International Conference on Telecommunication in Modern Satellite, Cable, and Broadcasting Services, Nis, pp. 384-387.

[27] Neog, D.K., Panda, D.C., Pattnaik, S.S., and Khuntia, B., (2003), "*Coupling of ANN with GA for effective optimization of dimensions of rectangular patch antenna on thick substrate microstrip patch antenna on thick substrate*", Proceedings of IEEE International Symposium on Antennas, Propagation and EM Theory, Beijing, China, pp. 720-725.

[28] Oberhart, M.L., Lo, Y. L., and. Lee, R.Q.H., (1987), "*New simple feed network for an array module of four microstrip elements*," IEEE Electronics Letters, Vol. 23, No. 9, pp. 436–437.

[29] Parui, S.K., and Ghosh, C.K., (2009), “*Design of Triple Frequency Compact Microstrip Patch Antenna Array for MIMO Application*”, Proceedings of IEEE.

[30] Pazos, A., Bregains, J. C., Dorado, J., Gestal, M., Rodrjguez, J. A., and Ares, F., (2002), “*Avoiding Interference in Planar Arrays Through the use of Artificial Neural Networks*”, IEEE Antennas and Propagation Magazine, Vol. 44, No.4, pp. 61-65.

[31] Papert, S., and Minsky, M., (1969), “*Perceptrons: An Introduction to Computational Geometry*”, MIT Press, Cambridge.

[32] Qiu, M., and Eleftheriades, G.V., (2002), “*Efficiency and Gain of Slot Antennas and Arrays on Thick Dielectric Substrates for Millimeter-Wave Applications*”, IEEE Transactions on Antennas and Propagation, Vol. 50, No. 8, pp.1088-1098.

[33] Rao, Q., Ayatollahi, M., and Wang, D., (2012), “*A Compact, High Isolation and Wide Bandwidth Antenna Array for Long Term Evolution Wireless Devices*”, IEEE Transactions on Antennas and Propagation, Vol. 60, No. 10, pp. 4960-4963.

[34] Rawat, A., Yadav, R.N., and Shrivastava, S.C., (2012), “*Neural network applications in smart antenna arrays*”, International Journal of Electronics and Communications, Science Direct, pp. 903-912.

[35] Song, H.J., and Bialkowski, M.E., (2001), “*A Ku-Band Active Transmit-Array Module with a Horn or Patch Array as a Signal Launching/Receiving Device*”, IEEE Transactions on Antennas and Propagation, Vol. 49, No. 4, pp. 535-541.

[36] Seki, T., Honma, N., Nishikawa, K., and Tsunekawa, K., (2005), “*Millimeter wave high efficiency multilayer parasitic microstrip antenna array on Teflon substrate*”, IEEE Transactions on Microwave Theory and Techniques, Vol. 53, No. 6, pp. 2101-2106.

[37] Sun, H., Guo, Y.X., and Wang, Z., (2013), "*60-GHz Circularly Polarized U-Slot Patch Antenna Array on LTCC*", IEEE Transactions on Antennas and Propagation, Vol. 61, No. 1, pp. 430-435.

[38] Tong, K.F., Lee, K.F., Luk, K.M., Yung, Y.L., and Huynh, T., (1996), "*Experimental study of a two-element array of U-slot patches*", IEEE Electronics Letters, Vol. 32, No. 5, pp. 418-420.

[39] Ulaby, F.T., (2001), "*Fundamentals of Applied Electromagnetics*", Prentice Hall, New Jersey.

[40] Wong, T. P., and Luk, K. M., (2003), "*A Wideband L-Probe Patch Antenna Array with Wide Beamwidth*", IEEE Transactions on Antennas and Propagation, Vol. 51, No. 10, pp. 3012-3014.

[41] Werner, D.H., and Boeringer, D.W., (2004), "*Particle Swarm Optimization versus Genetic Algorithms for Phased Array Synthesis*", IEEE Transactions on Antennas and Propagation, Vol. 52, No. 3, pp. 771-779.

[42] Wang, J., Wang, Z., and Li, W., (2011), "*Design of new planar waveguide-slot array antennas with a centre hole using genetic algorithm*", Proceedings of IEEE International Conference on Electronics, Communications and Control (ICECC), Ningbo, pp. 214-217.

[43] Yuan, T., Yuan, N., and Li, L.W., (2008), "*A Novel Series-Fed Taper Antenna Array Design*", IEEE Antennas and Wireless Propagation Letters, Vol. 7, pp. 362-365.

[44] Yun, W., and Yoon, Y.J., (2005), "*A Wide-band Aperture Coupled Microstrip Array Antenna Using Inverted Feeding Structures*", IEEE Transactions on Antennas and Propagation, Vol. 53, No. 2, pp. 861-862.

.