ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY SCHOOL OF ELECTRICAL AND COMPUTER ENGINEERING

DESIGN OF YAGI-UDA ANTENNA WITH IMPROVED RADIATION PATTERN

By

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Declaration

I the undersigned, declare that the thesis comprises my own work in compliance with internationally accepted practices; I have fully acknowledged from the work and referred all materials used in this thesis work

Bayissa Fufa ________________________

Name Signature

Place: **Addis Ababa University, Ethiopia**

Date of Submission: JULY,2018

This thesis has been submitted for examination with my approval as a university advisor.

Dr.Murad Ridwan ____________________

Adviser Signature

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List of abbreviation

PSO	*Particle swarm optimization*
BBO	*Bibliography based optimization*
GA	*Genetic algorithms*
EMS-GA	Emperor-Selective genetic algorithm
MOM	*Methods of moment*
FEM	*Finite element methods*
NEC	*Numerical electromagnetic code*
CI	*Computational intelligence*
CLPSO	*Comprehensive learning particle swarm optimization*
EA	*Evolutionary algorithms*
DE	*Driven element*
Ref	*Reflector element*
EMF	*Electromagnetic field*
HPBW	*Half power beam width*
FNBW	*First null beam width*

List of symbol

S	Element spacing
L	Element length
N	Element number
BL	Number of bits
GW	Geometry of wire
fi	fitness of individuals
Pi	Selection probability
CE	End of comment
GN	Ground card
EN	End of NEC file
LD	load of segment
GE	End of geometry
CM	Start of a comment
P_m	probability of mutation
EX	Excitation

ABSTRACT

Yagi-Uda antenna is used to transmit and receive electromagnetic waves. Yagi-Uda antenna also used for different applications in wireless communication systems,such as radio and television broadcasting, point-to-point radio communication, wireless local area network, radar, and space exploration. The main objective of this thesis is to discuss the design and performance factor of Yagi-Uda antenna. The design factor include antenna geometry,such as element length,element spacing and element diameters. The performance includes gain,voltage standing wave ratio, front to back ratio, impedance and radiation pattern. In this work Yagi-Uda antenna simulation was done by using Numerical electromagnetic code (NEC),comsol multiphysics and matlab software. The way of improving antenna performance is based on antenna geometry, such as element length, element spacing and element diameter. Numerical Electromagnetic Coding (4NEC2) is fast and efficient that used to simulate antenna parameters, such as voltage standing wave ratio, front-to-back ratio, input impedance, reflection coefficient and gain numerically and graphically with improved radiation pattern. Whereas comsol multiphysics is used to simulate electromagnetic field in two, three dimensions and mat lab is used to optimize gain and radiation pattern. Antenna designed at 100MHz for home television receiver and the performance was simulated conventional (by varying director length and spacing) and unconventional(by using multi-objective optimization methode). In the former the result couldnot meet the required solution or optimal solution,therefore unconventional (optimal design) would be important to get the optimal solution with high antenna performance. By using genetic algorithms with multi-objective optimization method the forward gain maximized and the real part impedance is adjusted to be 50Ω and imaginary part being different from zero. Finally the result was optimized with optimal element length and element pacing with element diameters held constant and the number of elements is set at N=4,6 and12 The gain of the designed antenna is compared with the conventional results. The unconventional design result was 6.74 dBi,9.97dBi and 10.98dBi for N=4,6 and12 respectively which is improved as compared to the conventional design with results in 6.71dBi,8.32dBi and 9.94dBi respectively, therefore as the result shows genetic algorithms can be used to increase forward gain for large number of elements.

Key words: Yagi-Uda antenna optimization, gain, front-to-back ratio, voltage stand wave ratio, radiation pattern, Numerical electromagnetic code and Genetic algorithms.

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First of all I would like to thank my advisor Dr. Murad Ridwan for his help and support during this work. His knowledge and understanding of design and improving radiation pattern of Yagi-Uda antenna have aided my work greatly. Also his willingness to make time for me when I had a question and concern for me were greatly appreciated. He is truly a good man. There are no words that describe how grateful I am to my parents for their support and encouragement through years.

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CHAPTER ONE

Introduction

Yagi-Uda Antenna is a device which is used to transmit and receive the electromagnetic waves, converting them into electric currents and vice versa. The simplest or minimal Yagi-Uda antenna has at least two parasitic elements behind the driven element (DE). The antenna with only one parasitic element as Reflector element (Ref) is generally called Yagi-Uda antenna.

The radiation capabilities of an antenna are characterized by the characteristics of an antenna such as the radiation pattern (including amplitude and phase patterns) polarization and gain. All these quantities are measured on the surface of a sphere with a constant radius. The radiation pattern is nothing but a graph which shows the variation of actual field strength of electromagnetic field at all the points equidistant from the antenna, antenna gain describes how well the antenna converts radio waves arriving from a specified direction into electrical power [1]. Also the gain of an antenna is directly related to its directivity and antenna gain is a measure that takes into account the efficiency of the antenna,which is, the fraction of the input power dissipated in losses due to many factors, such as a resistance. In contrast, directivity is defined as a measure that takes into account only the directional properties of the antenna, therefore it is only influenced by the antenna pattern, however for ideal antenna without losses then antenna gain will equal directivity as the antenna efficiency factor equals one. For real antennas (when efficiency factor less than one)the gain of an antenna is always less than its directivity [2]. Directional antenna or beam antenna is an antenna,which radiates greater power in one directions allowing for increased performance on transmit and receive and reduced interference from unwanted sources. Directional antennas like Yagi-Uda antennas provide increased performance over dipole antennas. The greater concentration of radiation in a certain direction is desired antenna commonly known as Yag-Uda antenna which consists an array of a dipole and additional closely coupled parasitic elements usually reflectors and one or more directors. The array is driven another element typically longer effectively operates as reflectors other elements shorter than the dipole and also directors added in front of the dipole Yagi-Uda antennas are directional along the axis perpendicular to the dipole in the plane of the element from the reflector through driven element.

The reflectors are arranged at approximately one quarter of wave length mutual spacing for all elements usually lie in the same plane supported on single boom as follows.

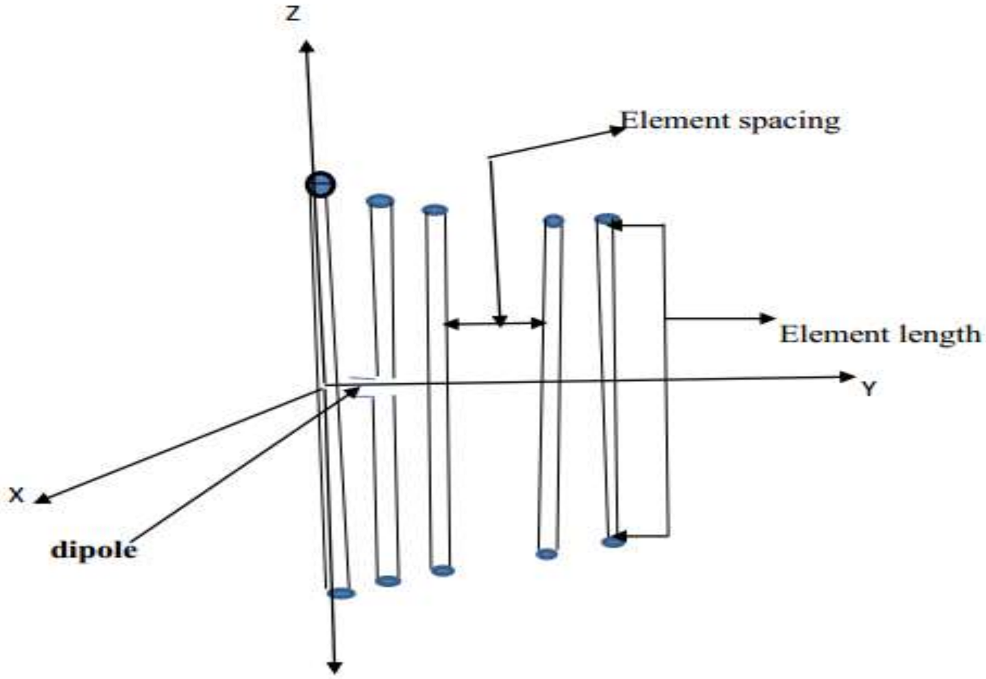


Fig 1.1 Antenna representation

1.1 Antenna elements

DRIVEN ELEMENT Driven element of a Yagi-Uda antenna is the feed point where the feed line is attached from the transmitter to the antenna. To perform the transfer of power from the transmitter to the antenna a dipole driven element will be resonant when its electrical length is half of the wavelength of the frequency applied to its feed point.

DIRECTOR Director is the shortest of the parasitic elements and this end of the Yagi-Uda It is resonant slightly higher in frequency than the driven element and its length will be about 5% shorter, progressively than the driven elements.The director length can vary depending upon the director spacing The desired pattern, bandwidth and element diameter the number of directors that can be used are determined by the physical size (length) of the supporting boom needed by the designer the directors are used to provide the antenna with directional pattern and gain. The amount of gain is directly proportional to the length of the antenna array and not by the number of directors used. The spacing of the directors can range from 0.1wavelength to 0.5 wavelength or depend upon the design specifications of the antenna.

REFLECTOR Reflector is the element that is placed at the rear of the driven element (the dipole) its resonant frequency is lower, and its length is approximately 5% longer than the driven element. Its length will vary depending on the spacing and the element diameter. The spacing of the reflector will be between 0.1 wavelength and 0.25 wavelength. Its spacing will little effect on the forward gain, bandwidth, F/B ratio, and side lobe pattern requirements of the final antenna design.

1.2 FEEDING YAGI UDA ANTENNA

1.2.1 Balanced feed system This may give a broader impedance bandwidth, but the main problem is that the driven element must in most cases be split in the center and insulated from the boom It is the better of the feed systems. The requirements of a balanced matching system is usually the main problem, but there are many methods available such as split the driven element and use a T match, which can be described as two gamma matches on each side of the center of the element. The main drawback is that it's difficult to adjust.

1.2.2 Unbalanced feed system used for low impedance feed points and a split element insulated from the boom, and is feed with a down-step wavelength sections of coaxial feed line. In parallel, attaching an equal length of insulated wire and connecting it to the center conductors at the feed point end and to the shields at the feed-line end. The impedance of this type should be at or near the mid-point value between the feed point impedance and the feed line impedance. The most common method is the gamma match. It will provide an easy and sure method of matching to the feed point without any loss of bandwidth [3].

1.3 Statement of problem

Design and optimization of Yagi-Uda antennas are difficult due to the non-linear relationship between physical parameters of antennas. The gain of antenna is directly proportional to the length of the antenna array and inversely proportional to side lobes .The same spacing and the same length gives narrow band width. Were wide spacing will increase the bandwidth but the gain decreased To overcome such problems in this work different methods has been used. These are varying element length element spacing and genetic algorithms with multi-objective function optimization methods.

1.4 Objective

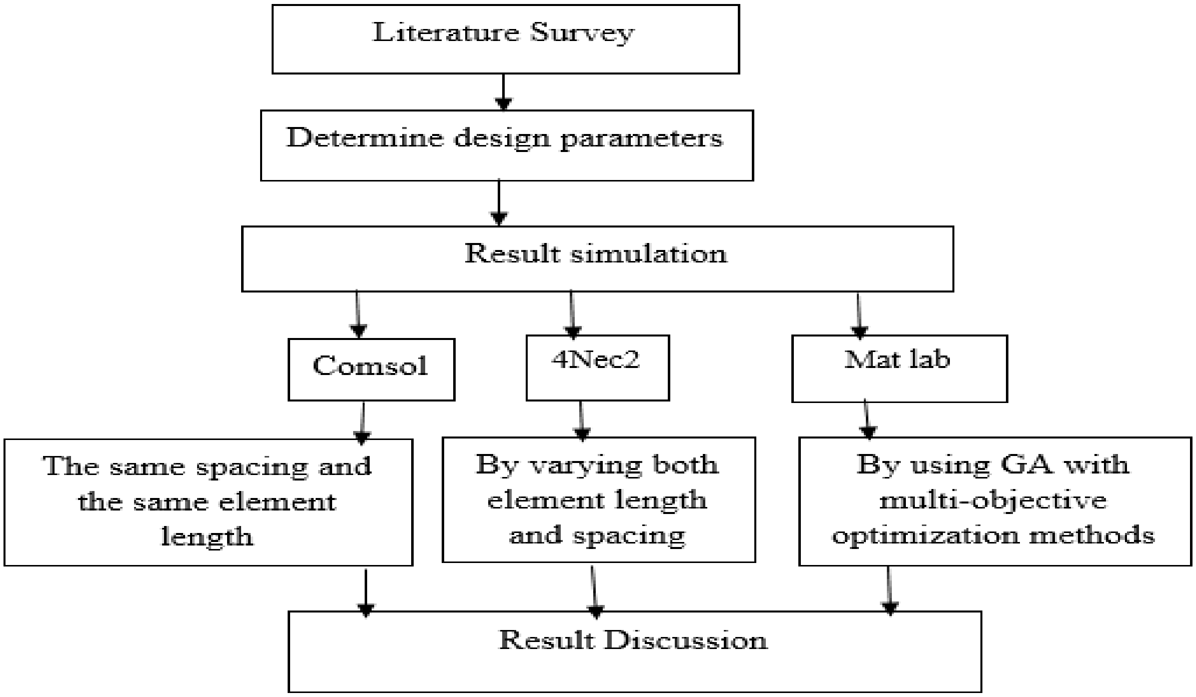
1.4.1 General objective

The aim of the thesis is to design Yagi-Uda antenna with improved radiation pattern at resonant frequency100MHz and gain of antenna will be optimized with genetic algorithms.

1.4.2 Specific objective

- To determine the antenna parameters such as front to back ratio, standing voltage wave ratio, input impedance and reflection coefficient.
- To simulate the far field 2D, 3D of radiation pattern at resonant frequency.
- To increase antenna efficiency by using genetic Algorithms and reduce Impedance mismatch.

1.5 Methodology This study involves four main procedures to achieve the objectives these are summarized as follows.



Flow chart of methodology

1.6 Literature review

Yagi-Uda antenna was invented in 1926 by Shintaro Uda of Tohoku Imperial University,Sendai, Japan,with the collaboration of Hidetsugu Yagi, at Tohoku Imperial University. Yagi published the first English-language reference on the antenna in a 1928, survey article on short wave research in Japan and it came to be associated the bandwidth of a Yagi-Uda antenna that refers to the frequency range over which its directional gain and impedance achieved a good performance. The Yagi-Uda antenna array is very narrow band,that compromised at frequencies that just a few Yagi-Uda antenna design. Several populations based optimization techniques are extensively used to optimize its sensitive physical dimensions resulting in desirable current distributions percent above or below its design frequency. Different methods and algorithms both mathematical and artificial techniques for designing and optimization of antenna have been presented in several literatures [5]. The objective was to achieve maximum gain and directivity of a Yagi-Uda antenna. Their method was based on computed and measured antenna currents and a graphical presentation was used to estimate optimum size of the antenna. Performance optimization of a Yagi-Uda antenna by varying the spacing between the directors of N element Yagi-Uda antenna, holding the reflector exciter spacing and elements length constant however varying spacing led to increase in gain. Optimum performance was achieved when the elements length were varied while keeping the optimum spacing constant. In genetic algorithm based automated antenna optimization technique that was applied on both fixed Yagi-Uda topology and a byte encoded antenna has an excellent gain with desirable impedance characteristic [6].

Genetic algorithms (GAs) is firstly adopted for the optimal design of Yagi-Uda antennas was done by Venkatarayalu and Ray. They solved the Yagi-Uda antenna optimization problems using computational intelligence method. Evolutionary algorithms such as comprehensive learning particle swarm optimization and biogeography based optimization Search routines that used to utilize numerical methods to provide the radiation properties of antennas,however consume a considerable amount of time, therefore, the great deal of work has been devoted by achieving optimization routines that rapidly and accurately search out an optimum solution. Recently,a unique optimization scheme based on genetic algorithms that maximize or minimize certain radiation properties and introduced for the optimal design of Yagi-Uda antennas was developed by many researchers [7].

Forward, backward, unidirectional, and bi-directional beams these tune able beams are achieved by simply adjusting the short-circuit position of the transmission line connected to the parasitic element and analytical method is developed for the maximization of the directivity of a Yagi-Uda array by adjusting the lengths of the dipole element. The effects of a finite dipole radius and the mutual coupling between the elements and size has always been the goal of antenna engineers. It is important for the antenna engineer to have the latest tools to effectively design antennas.That meet the given specifications optimization techniques are used to either synthesize an antenna from given radiation characteristics or simple improve existing antenna design [8].

Yagi-Uda antenna gain highly sensitive and depend upon numerous parameters,therefore it is difficult to optimize,however Simulated Annealing (SA) which is a powerful stochastic global search and optimization method used to optimize the element spacing and lengths of Yagi-Uda antennas was presented by Singh et al(2007). Frequency reconfigurable printed Yagi-Uda antennas was presented for the application of cognitive radio by Caietal (2012), continuous frequency tuning bandwidth is obtained by loading the driven dipole arms and four directors with varactor diodes. This configuration allows a high gain and almost constant end-fire pattern to be maintained while the antenna operating frequency is tuned. The introduction of an array of three-dimensional optical Yagi–Uda antennas, fabricated using top-down fabrication techniques,combined with layer by layer processing was done by Dregelyet al (2011). This involve future photonic circuit with the capability of high-speed data processing at optical frequencies. Bridging the size mismatch between optical radiation and sub wavelength emitters or detectors by optical nano antennas which subject of current research in the field of plasmonics an optimal design approach based on the popular realistic field simulator. Numerical Electromagnetic Code(NEC)and the effective real coded Emperor-Selective genetic algorithm (EMS-GA), for automatic antenna design optimization was done by Lu et al.(2011). The real engineering application is a special corner reflector antenna driven by a Yagi Uda array is designed by the NEC/EMS-GA approach Compared to the traditional Yagi-Uda the designed has much lower side lobe level with better immunity. To improve the interference and used for wireless communication and television reception Yagi-Uda antenna system consisting of a low noise amplifier and a reflector co-located on the same printed circuit board as the radiators and directors is disclosed (Hegen doerfer,2001).

The balun cable was replaced by surface mount devices whose feed line is implemented in micro strip technology,all co-located on the same printed on circuit board. The investigation of the use of a self-structuring antenna for television reception was done by Perry (2001). Information about the received signal strength is obtained from the automatic gain control circuit of the television and used to determine the appropriate antenna structure. For the purpose of comparison and benchmarking, equally spaced arrays, genetic algorithm optimized antenna design, computational intelligence optimized antenna design are considered CLPSO is a robust and useful optimization tool for designing Yagi-Uda antennas for the desired target specifications (Baskar,2005).

Yagi-Uda array is the only driven element with applied input/output source feed, all the others interact by mutual coupling since receive and radiate electromagnetic energy, they act as parasitic elements by the induced current Dubey and Zafar (2014). It is assumed that an antenna is a passive reciprocal device, then may be used either for transmission or for reception of the electromagnetic energy this well applies to Yagi-Uda also (Dubey and Zafar2014). These antennas are directional along the axis perpendicular to the dipole in the plane of the elements, from the reflector toward the driven element and the director(s). The Yagi-Uda Antenna which is to be optimized was taken from Murali et.al (2011), the purpose of this work is to optimize the same antenna and optimize it for UHF (DVBT2) application. The Yagi-uda antennas was optimized at frequency band centered on 500 MHz using genetic algorithm that used for DVB-T2 system. The Antenna used is a dipole having a length of 15cm and a radius of 0.03cm.The simulation results which were done using commercial software FEKO.

In this work Yagi-Uda antenna was designed at100MHz for home television receiver. Antenna can be simulated by using comsol multiphyscis,Numerical electromagnetic code and matlab software. The antenna used is single reflector and single folded dipole with fixed length and spacing. The director length and spacing ranges 0.45λ-0.3λ and 0.1λ -0.15 λ, respectively. The aim is to achieve improved radiation pattern, gain, front-to-back ratio, voltage standing wave ratio. As different methods and genetic algorithm has been used for the design This is done by are varying director length, director spacing with fixed director diameters and genetic algorithms (GAs) for the antenna gain optimization .

CHAPTER TWO

FUNDAMETALS OF ANTENNA PARAMETERS

2.1 Radiation pattern

The field patterns which associated antenna, that change with distance are two types energy radiating and reactive energy Hence, the space surrounding an antenna can be divided into three regions.

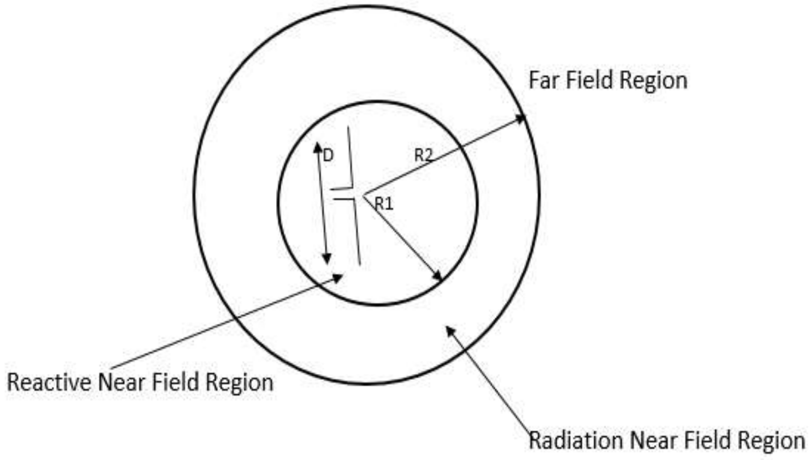


Fig 2.1 Field Region around the antenna [8]

2.1.1 Reactive near-field region: In this region the reactive field dominates the reactive energy oscillates towards and away from the antenna, thus appearing as reactance. In this region, energy is only stored and no energy is dissipated. The outermost boundary for this region is at a distance where *R*1 is the distance from the antenna surface, *D* is the largest dimension of the antenna.

2.1.2 **Radiating near-field region** (Fresnel region) It is the region which lies between the reactive near field region and the far field region. Reactive fields are smaller in this field as compared to the reactive near field region in the field of antenna design In this region, the angular field distribution is a function of the distance from the antenna. The outermost boundary for this region is at a distance. In this region, the reactive fields are absent and only the radiation fields exist. The angular field distribution is not dependent on the distance from the antenna in this region and the power density varies as the inverse square of the radial distance in this region.

2.1.3 Far field region is the region which the radiation pattern most commonly refers to the directional (angular) dependence of radiation from the antenna. Whereas radiation pattern is defined as a mathematical function or a graphical representation. The radiation properties of the antenna as a function of space and coordinates. Mostly it is determined as a function of directional coordinates the two or three-dimensional spatial distribution of radiated energy. It include power flux density, radiation intensity, field strength, directivity or polarization the radiation pattern plays a major role in the performance of the Yagi-Uda antenna [9].

The spatial variation of electric or magnetic field is called field pattern. The isotropic radiator is a theoretical point source of waves, which exhibits the same magnitude or properties when measured in all directions. It has no preferred direction but radiates uniformly in all directions over a sphere centered on the source. Directional antenna or beam antenna is an antenna,which radiates greater power in one or more directions allowing for increased performance on transmit and receive and reduced interference from unwanted sources. Directional antennas like Yagi-Uda antennas provide increased performance over dipole antennas that greater concentration of radiation in a certain direction. The desired omn-directional antenna is an antenna,which radiates power uniformly in one plane with a directive pattern shape in a perpendicular plane.

Half power beam width is an angle between two vectors, originating at the pattern's origin passing through these points of the major lobe and where the radiation intensity is half its maximum. **First null beam width** is the angle between two vectors, originating at the pattern's origin tangent to the main beam at its base. It is very often approximately FNBW≈ 2HPBW [10]. These lobes represent the radiation in undesired directions. The level of minor lobes is usually expressed as a ratio of the power density in the lobe that of the major lobe. This ratio is called as the side lobe level (expressed in decibels). Back lobe is the minor lobe opposite the main lobe,side lobes are the minor lobes adjacent to the main lobe and are separated by various nulls. Side lobes are generally the largest among the minor lobes. In most wireless systems, minor lobes are undesired,hence a good antenna design should minimize the minor lobes since all antennas will radiate more in some direction that in others,therefore the gain is the amount of power that can be achieved in one direction at the expense of the power lost in the others directions.

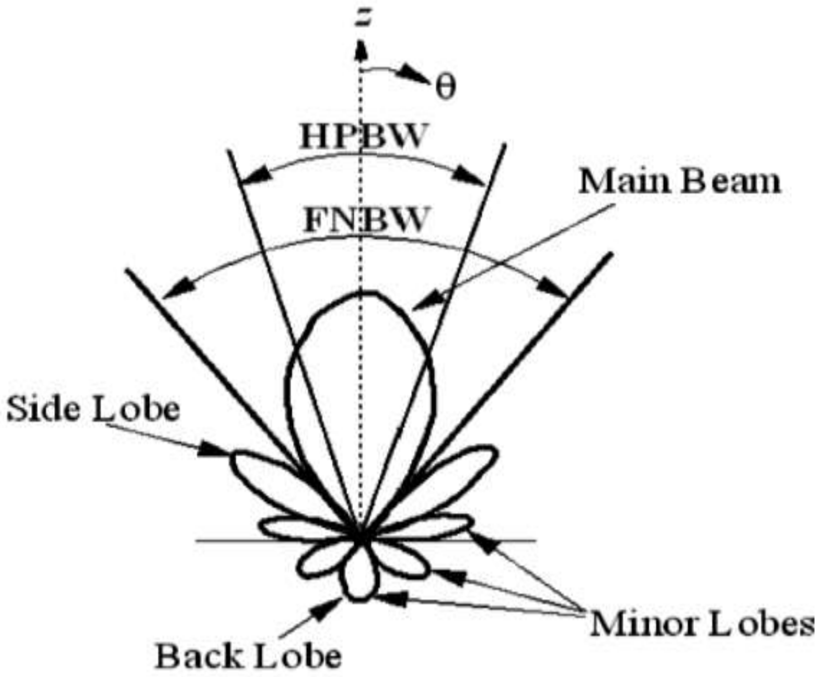


Fig 2.2 Parts of radiation patterns [9]

2.2 *IMPEDANCE OF YAGI UDA ANTENNA*

The impedance of an element is the value of pure resistance at the feed point plus any reactance (capacitive or inductive) that is present at that feed point. Primary importance in Yagi-Uda design is the impedance of driven(dipole)element, where the transfer of radiofrequency from the feed line takes place. Maximum energy transfer of radio frequency at the design frequency occurs when the impedance of the feed point is equal to the impedance of the feed line in most antenna design.

The feed line impedance will be 50 ohms,but usually the feed point impedance of the Yagi is rarely 50 ohms.In most cases it can vary from approximately 40ohms to around 10ohms which depending upon the number of elements, their spacing and the antenna's bandwidth. If the feed line impedance does not equal the feed point impedance,the driven element can not transfer radio frequency energy effectively from the transmitter,thus reflecting it back to the feed line resulting in voltage standing wave ratios. Therefor impedance matching devices are highly recommended for getting the best antenna performance[14]. The impedance and bandwidth of the driven elements is the range of frequencies above and below the center or design frequency. The antenna that the driven elements feed point will accept maximum power.

2.3 Time-average Poynting is given the electric and magnetic field patterns of an antenna,the vector,also known as the power density equation, can be obtained using the following formulas.

$$S_{av} = \frac{1}{2}R\ (E.H)$$

Where **E** and **H** are the electric and magnetic field equations

2.4 Gain The directional gain of a Yagi-Uda antenna is typically 7-9dB per λ (wavelength) of overall antenna length (given as a multiple of wavelengths) There is little or no gain by the addition of more than one reflector. Adding directors however,does increases the overall directivity and gain of the antenna, but not indefinitely after some number of elements the effects insignificance.

2.6 bandwidth Yagi-Uda antennas, which is usually defined as the frequency range for which the antenna provides a good match to the transmission line to which it attached,determined by the length,diameter and spacing of the elements. For most designs, bandwidth is low, typically only a few percent of the design frequency.

2.7 Directivity Yagi-Uda is directional antenna which commonly referred to as beam antennas or high gain antenna. It is directional along the axis perpendicular to the dipole in the plane of the elements from the reflector through the driven element and out via the directors.

Mathematical Analysis

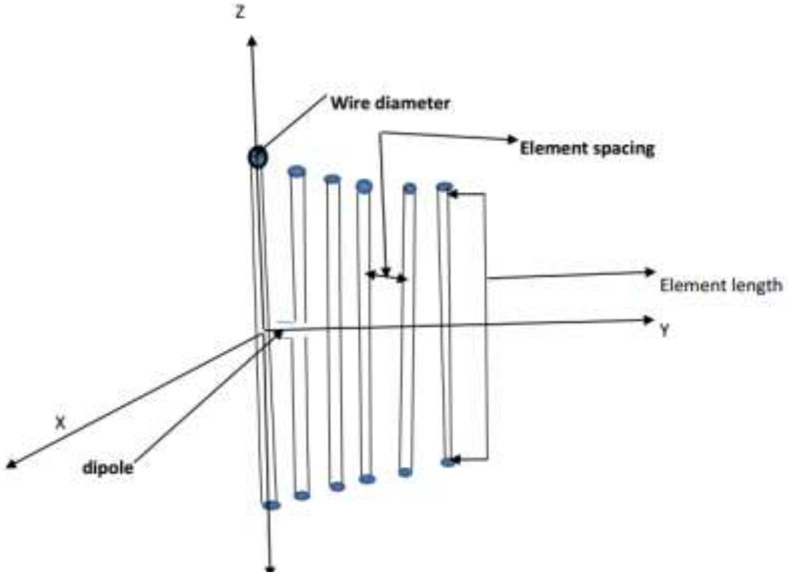


Fig 2.3 Element design

The method of solving Yagi-Uda antenna problem is based on an integral equation for the electric field of the array. The point-matching technique is then used to satisfy the integral equation at discrete points on the axis of each element, rather than attempting to satisfy the equations every where on the surface of elements. Thus a system of linear algebraic equations is generated in terms of the complex coefficients. The Fourier series expansion of the currents on the elements, therefore it is not easily solvable [11]. In the case of linear elements it has been found that an efficient representation for the current on element n is given by

$$I_n (Z') = \sum_{m=1}^{m} I_{mn} \cos\, [2m-1]\frac{\pi * z}{ln} \ldots\ldots 2.1$$

I_{nm} represent the complex current coefficient of mode m on element n and l_n represents the corresponding length on the n elements. This series of odd-ordered even modes is chosen such that the current goes to zero at the ends of elements n this is a suitable approximation for elements whose diameter is small in terms of the wavelength [12]. The theory is based on Pocklington's integral equation for total field generated be an electric current source radiating in an unbounded space as given by the following mathematical analysis.

$$\int_{-\frac{l}{2}}^{\frac{l}{2}} I(z') \left[\frac{\partial^2}{\partial Z^2} + k^2\right] * \frac{e^{-jkR}}{R} d_{z'} = j4\pi\omega\varepsilon o E \ldots\ldots 2.2$$

Where

R= $[(x - x')^2 + (y - y')^2 + (z - z')^2]$ Since

$$\left(\frac{\partial^2}{\partial z^2}\right) * \left[\frac{e^{-jKR}}{R}\right] = \left(\frac{\partial^2}{\partial z'^2}\right) * \left[\frac{e^{-jKR}}{R}\right]$$

$$\int_{-l/2}^{l/2} I(z') * \left[\frac{e^{-jkR}}{R}\right] \frac{\partial^2}{\partial z'^2} + k^2 \int_{-l/2}^{l/2} I(z') * \left[\frac{e^{-jkR}}{R}\right] dz' = j4\pi\omega\varepsilon o E$$

Let U = I (z')

du = $\left[\frac{dI(z')}{dz'}\right]$dz' V= $\left(\frac{\partial}{\partial z'}\right) * \left[\frac{e^{-jKR}}{R}\right]$

dv = $\left(\frac{\partial^2}{\partial z^2}\right) * \left[\frac{e^{-jKR}}{R}\right] \partial z = \left(\frac{\partial^2}{\partial z'^2}\right) * \left[\frac{e^{-jKR}}{R}\right]$dz

Then the equation reduced to

$$\int_{-l/2}^{l/2}(\frac{\partial^2}{\partial z'^2})*\frac{e^{-jKR}}{R}]\partial z' = \mathrm{I}(z')(\frac{\partial}{\partial z\prime}) * [\frac{e^{-jKR}}{R}] - \int_{-l/2}^{l/2}(\frac{\partial}{\partial z\prime})[\frac{e^{-jkR}}{R}] \frac{dI(z')}{dz\prime}$$

Where $I(z' = \pm l/2)$ *is zero*

equation reduced to

$$\int_{-l/2}^{l/2}(\frac{\partial^2}{\partial z'^2}) * [\frac{e^{-jKR}}{R}]dz' = \int_{-l/2}^{l/2}(\frac{\partial}{\partial z\prime})[\frac{e^{-jKR}}{R}]dz'(\frac{dI(z')}{dz}$$

By using integration by parts

$U = \frac{dI(z')}{dz\prime}$ $du = [d^2I(z')/dz^{2\prime}]dz'$ $V = \frac{e^{-jkR}}{R}$ $dv = (\frac{\partial}{\partial z\prime})[\frac{e^{-jkR}}{R}]dz'$

$$\int_{-l/2}^{l/2}(\frac{\partial^2}{\partial z\prime^2}) * [\frac{e^{-jKR}}{R}]dz' = [\frac{dI(z)}{dz\prime}][\frac{e^{-jkR}}{R}] + \int_{-\frac{l}{2}}^{\frac{l}{2}}[k^2I(z') + dI^2(z')/dz'][\frac{e^{-jkR}}{R}]dz' = j4\pi\omega\varepsilon oE$$

A wire with small diameter the current on each element can be approximated by a finite series of odd-ordered even modes Thus, the current on nth element can be written as a Fourier series expansion of following form.

$$\mathrm{I}_n(Z') = \sum_{m=1}^{m} Imn\cos[2m-1]\frac{\pi * z}{In}$$

The radiation pattern bandwidth is the range of frequencies above and below the design frequency in which the radiation pattern remains consistent. The degree of non-consistency that can be tolerated is subjective, and limits such as minimum front-to-back ratio and side lobe levels are mainly a matter of choice. Equal spaced equal length directors may give higher gain at a particular frequency, but the band with is narrow and unacceptable side lobe levels are common, and while wide spacing will increase the bandwidth, the side lobes become quite large by varying both the spacing and director lengths the pattern and the pattern bandwidth may be controlled. More directors within a given boom length will not increase the gain by any large measure, but will allow better control of the pattern over a wider frequency range. By reducing the length of each succeeding director by a set factor, while increasing the spacing of each succeeding director by another factor, a very clean pattern with a good pattern bandwidth can be obtained [13].

CHAPTER THREE

YAGI-UDA ANTENNA DESIGN BY USING COMSOL MULTIPHYSICS SOFTWARE

3.1 INTRO DUCTION

Comsol multiphysics software is a powerful finite element, partial differential equation solution engine. The basic comsol multi physics software modules are listed below.

- Wave optics
- Radio frequency
- Semiconductor
- AC/DC
- MEMS
- Plasma

The Radio frequency module is used by engineers and scientists to understand, predict, and design electromagnetic wave propagation. In high-frequency applications simulations of this kind result is more powerful and efficient products. In engineering areas it allows its users to quickly and accurately predict the electromagnetic field distributions transmission line,reflection and power dissipation when Compared to traditional prototype.

It offers the benefits of lower cost and the ability to evaluate and predict entities that are not directly measurable in experiments. It also allows the exploration of operating conditions that would destroy a real prototype or be hazardous [15]. This module covers electromagnetic fields and waves in two-dimensional and three dimensional spaces along with traditional circuit based modeling of passive and active devices. The modeling formulations are based on the basic concept Maxwell’s equations and special cases of these together with material laws for propagation in various media. The modeling capabilities are accessed via predefined physics interfaces referred to as radiofrequency interfaces. The latter means that it covers the modeling of devices that are about 0.1 electromagnetic Wavelength in size. Thus, it may be used to model micro scale optical devices or for human size devices operating at frequencies above 10MHz.

3.2 software procedure

Study It is the beginning of setting up the models that selected a stationary study which implies that comsol will use a stationary solver.

Geometry is describe how the object to be designed with a given geometry.

Materials the material nodes stores the material properties for all physical and all domains in a component node.

Parameters is where the input variables or design specification determined.

Domain physics and Boundary condition where the geometry and material defined the boundary condition can be set.

Mesh The mesh setting determine the resolution of the finite element mesh used to discretize the models.

Result

Design specification

Frequency =100MHz

Reflector length=0.6 λ

Driven element length=0.5λ

Director length =0.45λ

Element spacing =0.15λ

Constant wire diameter=0.1mm

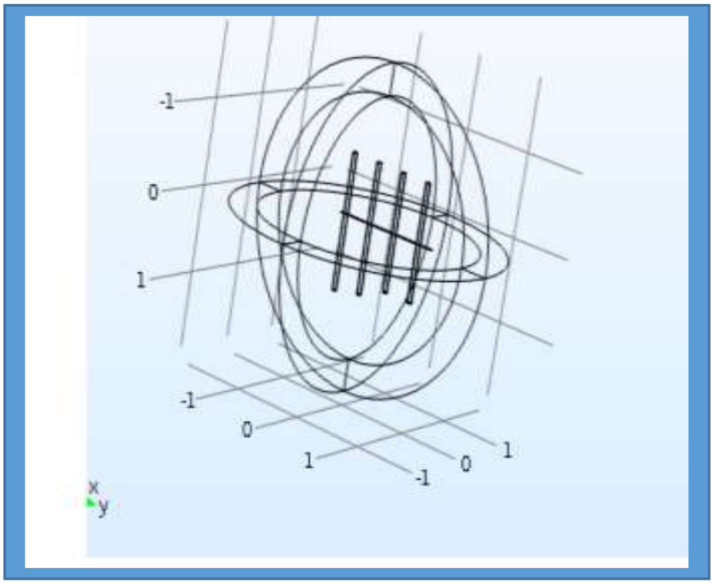
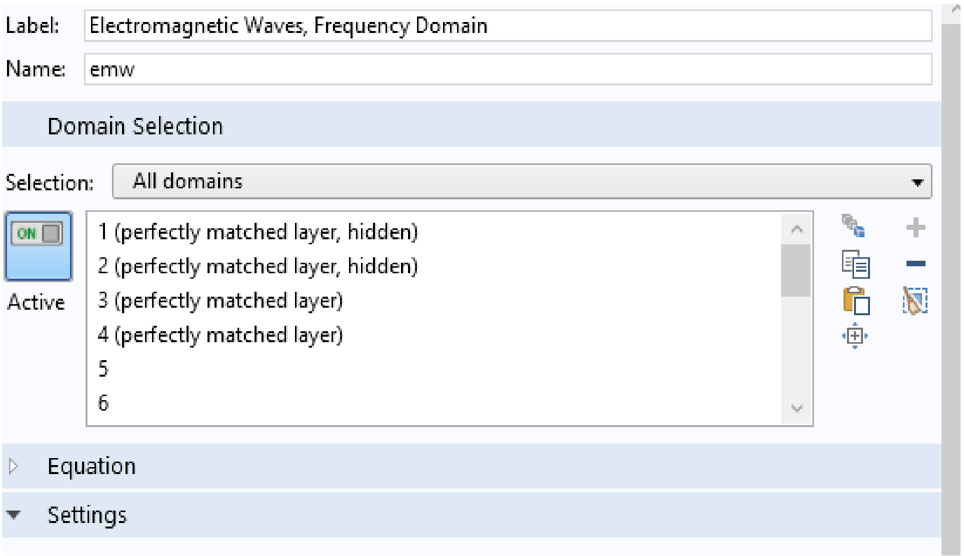


Fig 3.1 antenna element configuration



Label: Electromagnetic Waves, Frequency Domain

Name: emw

Domain Selection

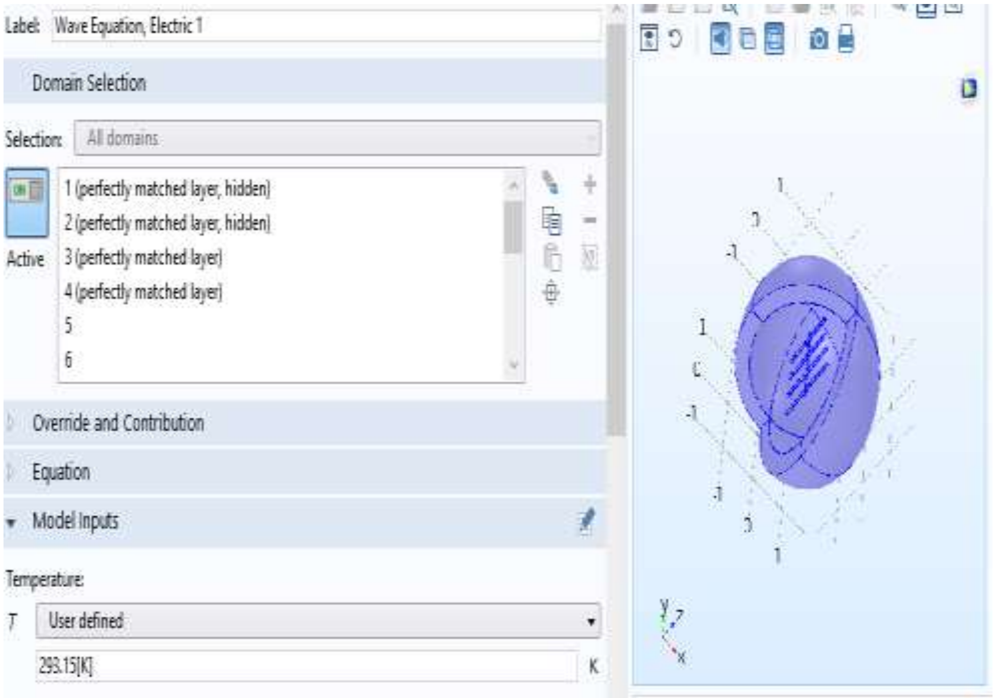
Selection: All domains

Active

1 (perfectly matched layer, hidden)
2 (perfectly matched layer, hidden)
3 (perfectly matched layer)
4 (perfectly matched layer)
5
6

Equation

Settings



Label: Wave Equation, Electric 1

Domain Selection

Selection: All domains

Active

1 (perfectly matched layer, hidden)
2 (perfectly matched layer, hidden)
3 (perfectly matched layer)
4 (perfectly matched layer)
5
6

Override and Contribution

Equation

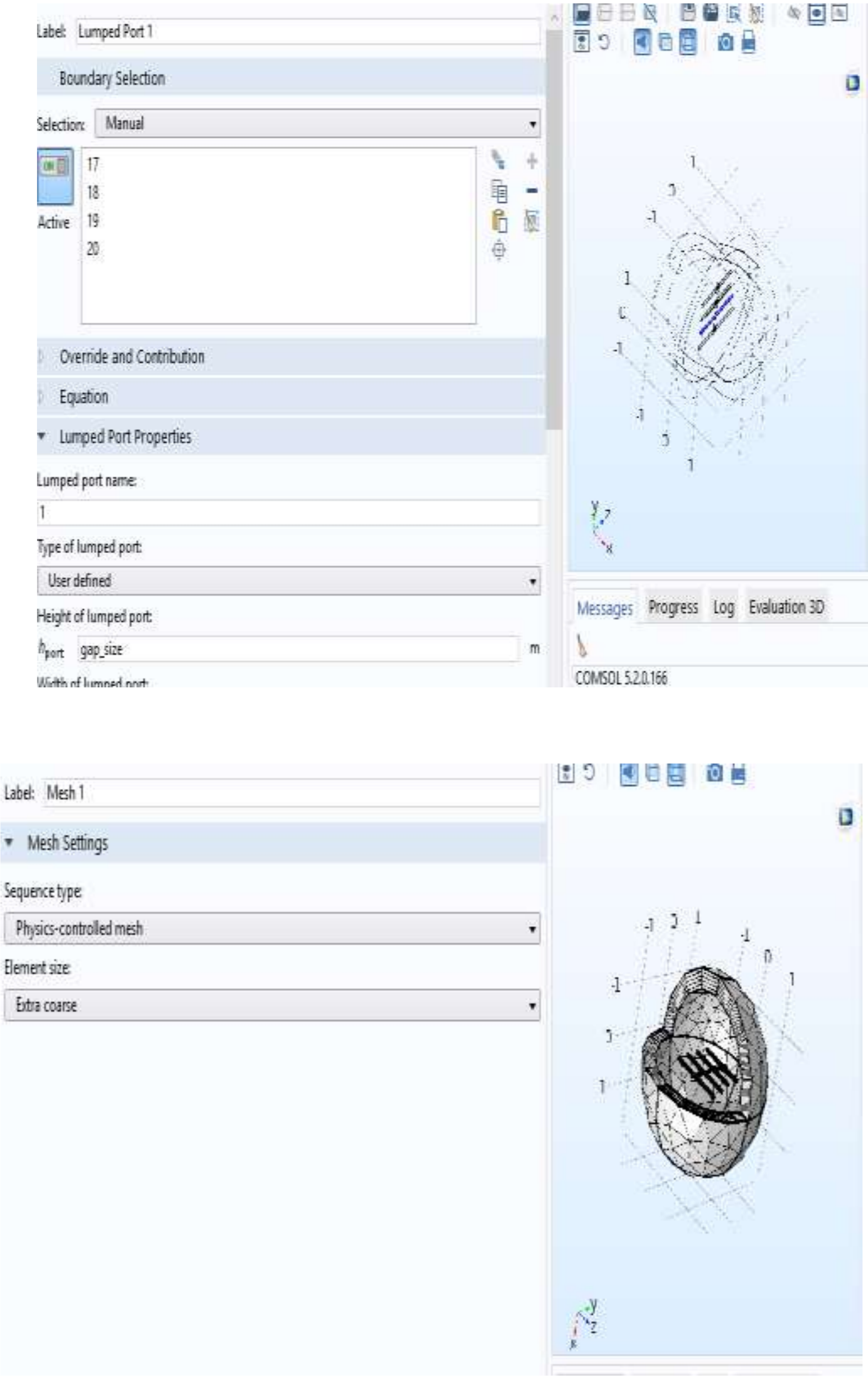
Model Inputs

Temperature:

T User defined

293.15[K] K

Fig 3.2 perfectly matched layer domains



Label: Lumped Port 1

Boundary Selection

Selection: Manual

Active

17
18
19
20

Lumped port name: 1

Type of lumped port: User defined

Height of lumped port:

h_{port} gap_size m

COMSOL 5.2.0.166

Label: Mesh 1

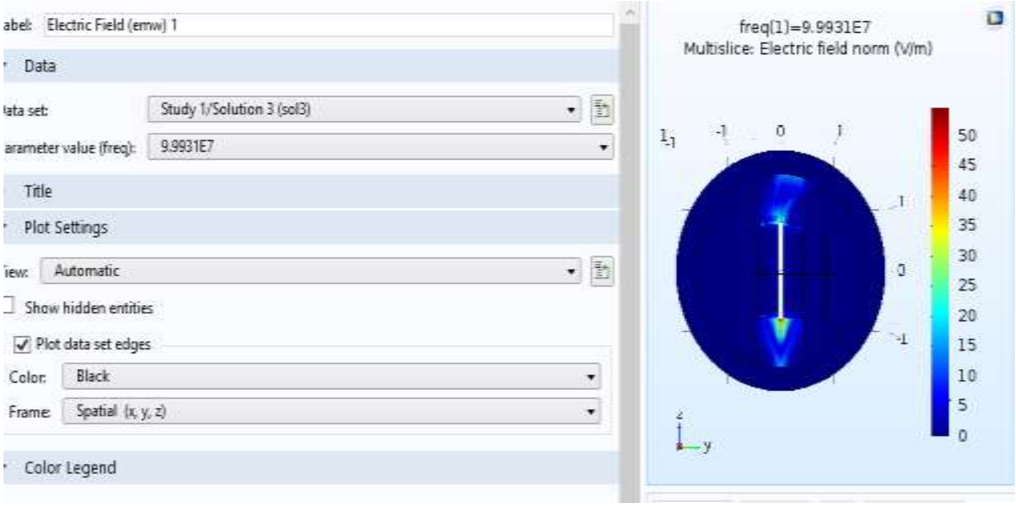
Mesh Settings

Sequence type: Physics-controlled mesh

Element size: Extra coarse

Fig 3.3 antenna meshing

3.3 Four element Yagi-Uda antenna result analysis


abel: Electric Field (emw) 1

Data

ata set: Study 1/Solution 3 (sol3)

arameter value (freq): 9.9931E7

Title

Plot Settings

iew: Automatic

☐ Show hidden entities

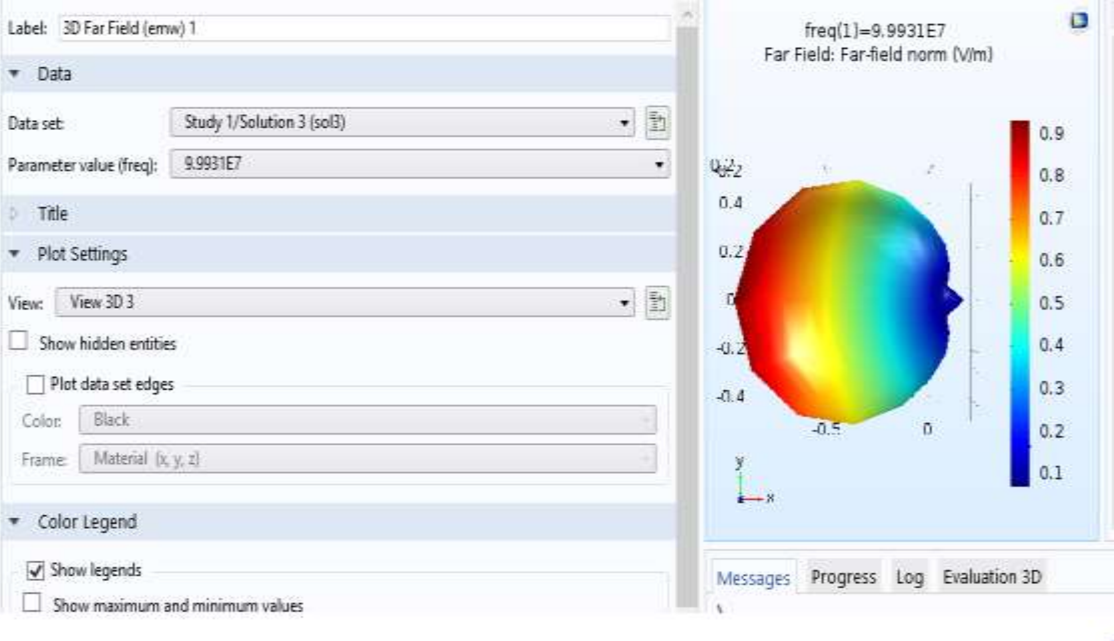
☑ Plot data set edges

Color: Black

Frame: Spatial (x, y, z)

Color Legend

Fig 3.4 Near-field Region Radiation four element Yagi-Uda


Label: 3D Far Field (emw) 1

Data

Data set: Study 1/Solution 3 (sol3)

Parameter value (freq): 9.9931E7

Title

Plot Settings

View: View 3D 3

☐ Show hidden entities

☐ Plot data set edges

Color: Black

Frame: Material (x, y, z)

Color Legend

☑ Show legends

☐ Show maximum and minimum values

Fig 3.5 3D far field radiation pattern of Yagi-Uda with four elements

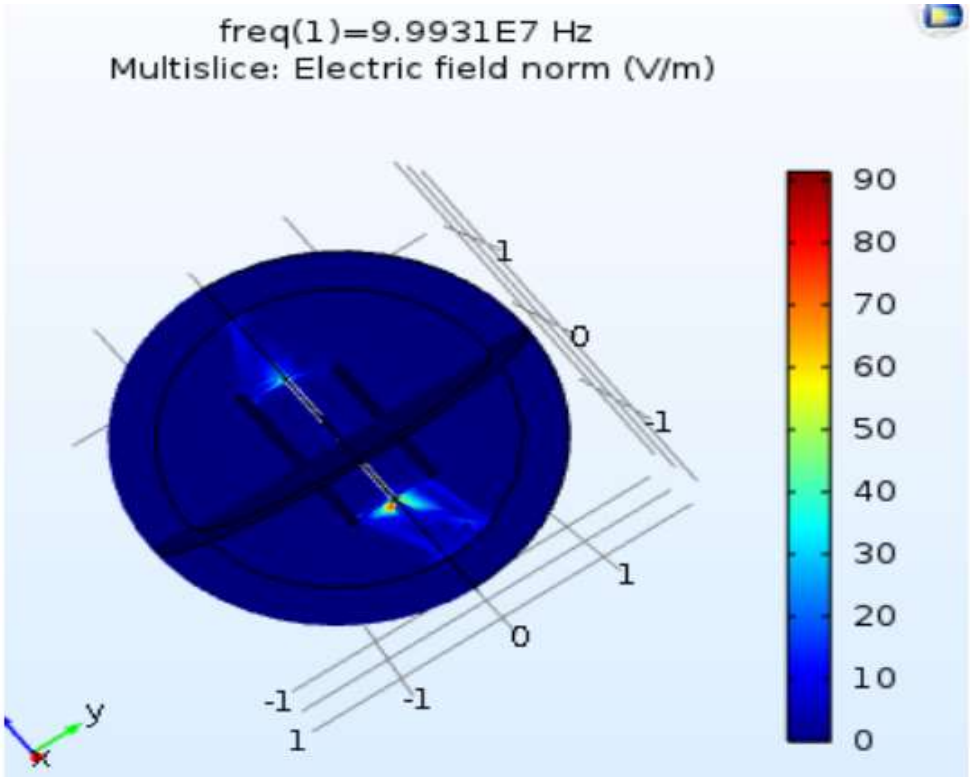


Fig 3. 6 Near field region radiation for three element Yag-Uda

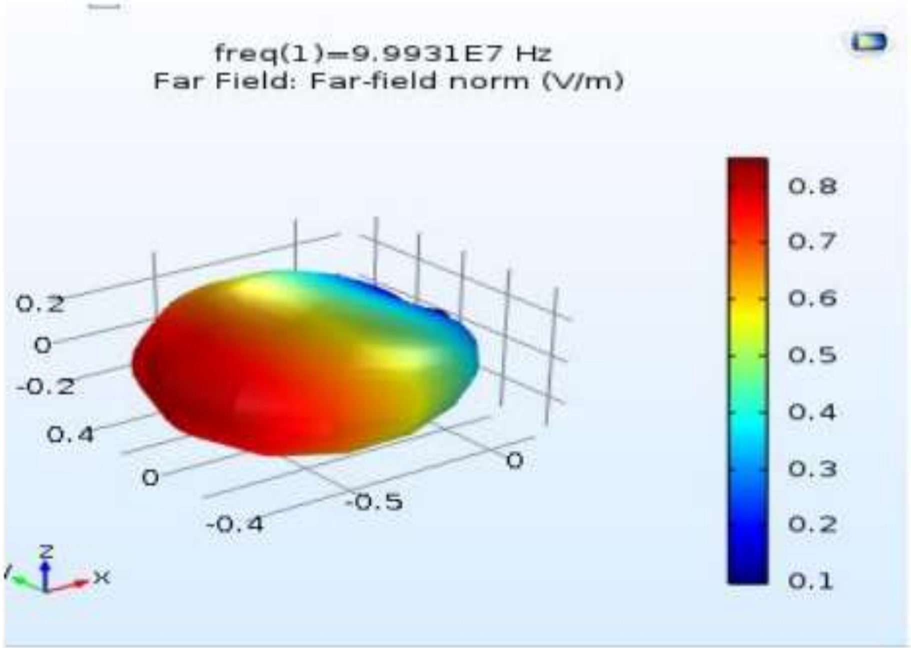


Fig 3.7 3D far field radiation pattern of Yagi-Uda with three elements

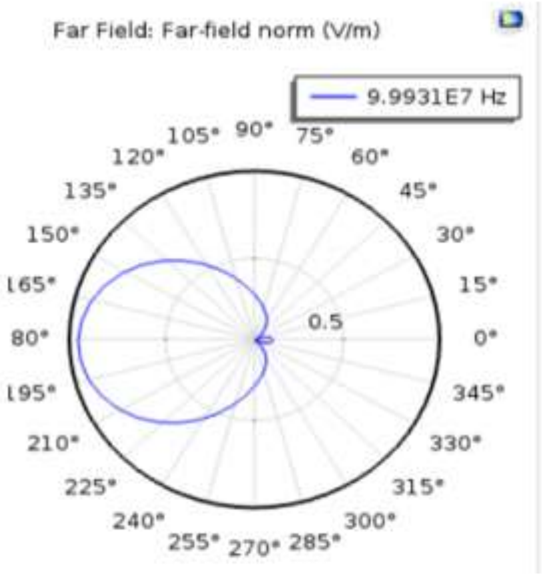


Fig 3.8 2D far field radiation pattern of four element Yagi-Uda antenna

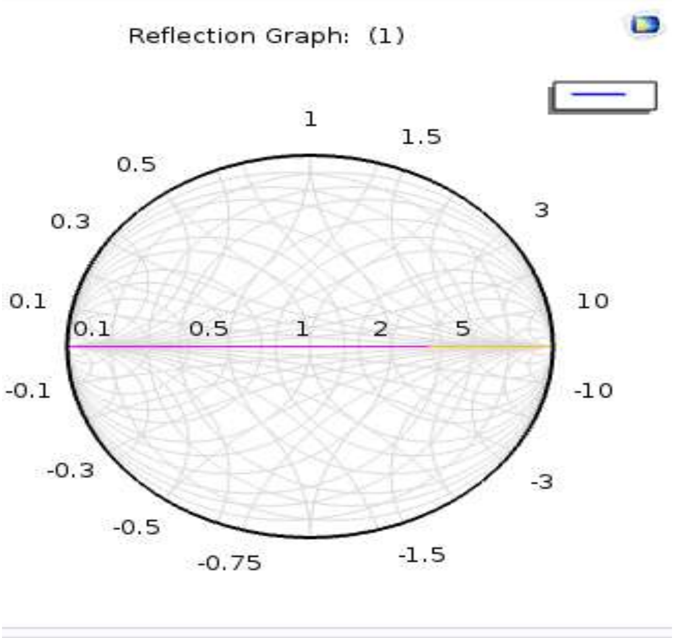


Fig 3.9 Reflection graph of four element Yagi-Uda antenna

CHAPTER FOUR

DESIGN OF YAGI-UDA ANTENNA WITH NUMERICAL ELECTRO MAGNETIC CODE

4.1 Introduction

Numerical Electromagnetic code is a windows based tool. For creating, viewing, optimizing and checking 2D and 3D style antenna geometry structures can be display and compare near and far-fiel radiation patterns for both starting and experienced antenna model [16]. In this thesis 4NEC2 ver 5.8.16 was used, which has the following features graphical 2D,3D visualization of far and Near-field data and geometry structures sophisticated real time 3D geometry and pattern viewer showing real wire-radius interactive smith chart visualization for frequency-sweeps. Geometry builder to create cylinder, patch, plane, box, helix and parabola shaped structures using auto-segmentation or equal-area rules the user is expected.

To draw the structure, specify material characteristic for each object and identify ports,sources and special characteristics. The system then generates the necessary field solutions and describes the various steps to be followed in order to design Yagi-Uda antenna with different elements.

4.2 Application of 4NEC2

- To plot near and far fields electric field strength
- To plot 3D, 2D radiation patterns and
- To optimize antenna parameters

4NEC2 software has extensive features related to antenna modeling. Many predefined functions from the 4NEC2 library are also available.In this thesis built in optimizer in 4NEC2 helps in getting the good antenna performance.

4.3 Yagi-Uda antenna simulation

Yagi-Uda antenna is a type of dipole antenna. The gain and directivity of Yagi-Uda is higher than dipole antenna. By starting from a single dipole antenna and adding the parasitic elements Yagi-Uda antenna simulation result can be obtained by using different techniques to get a good solution.

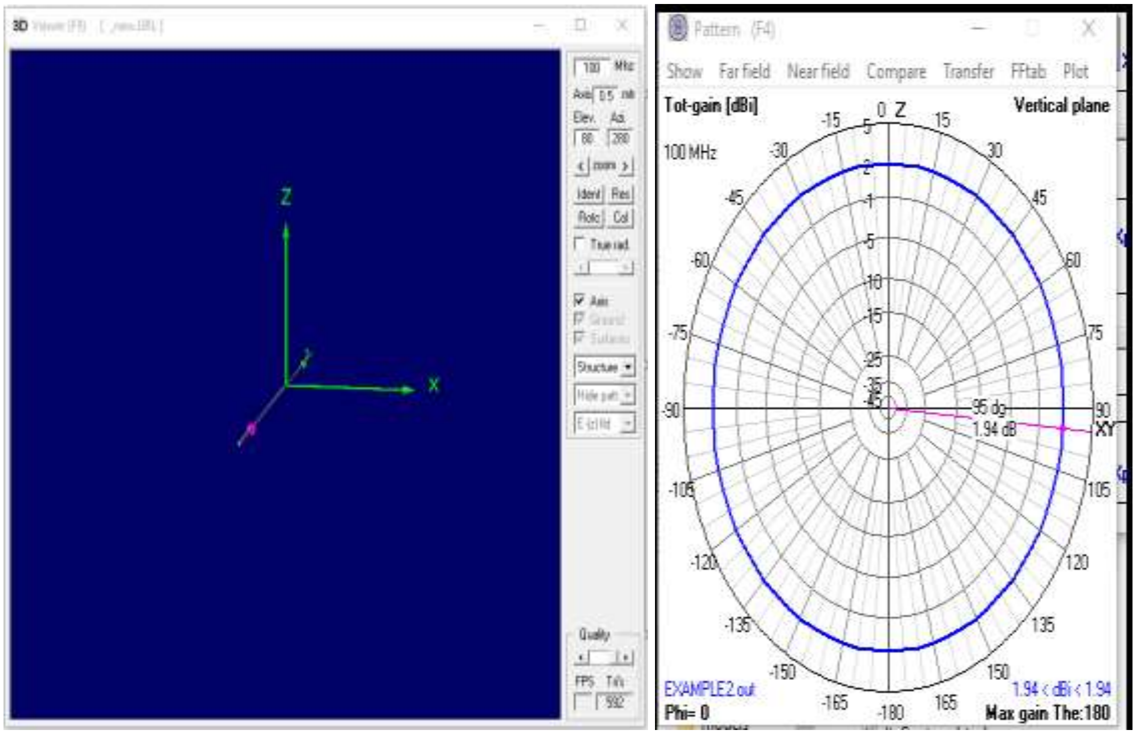


Fig 4.1 Dipole antenna

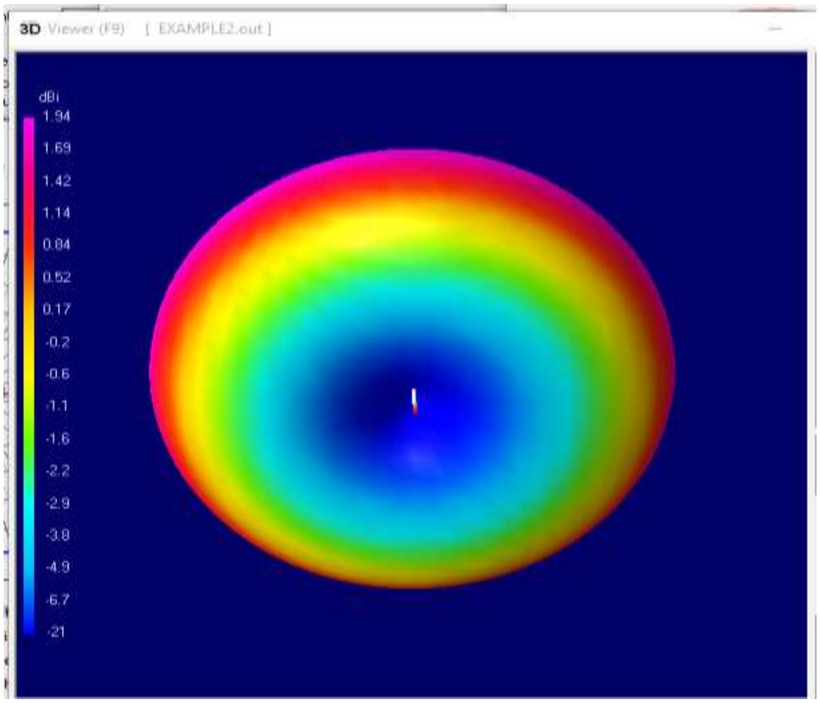


Fig 4.2 3D Radiation pattern of dipole antenna

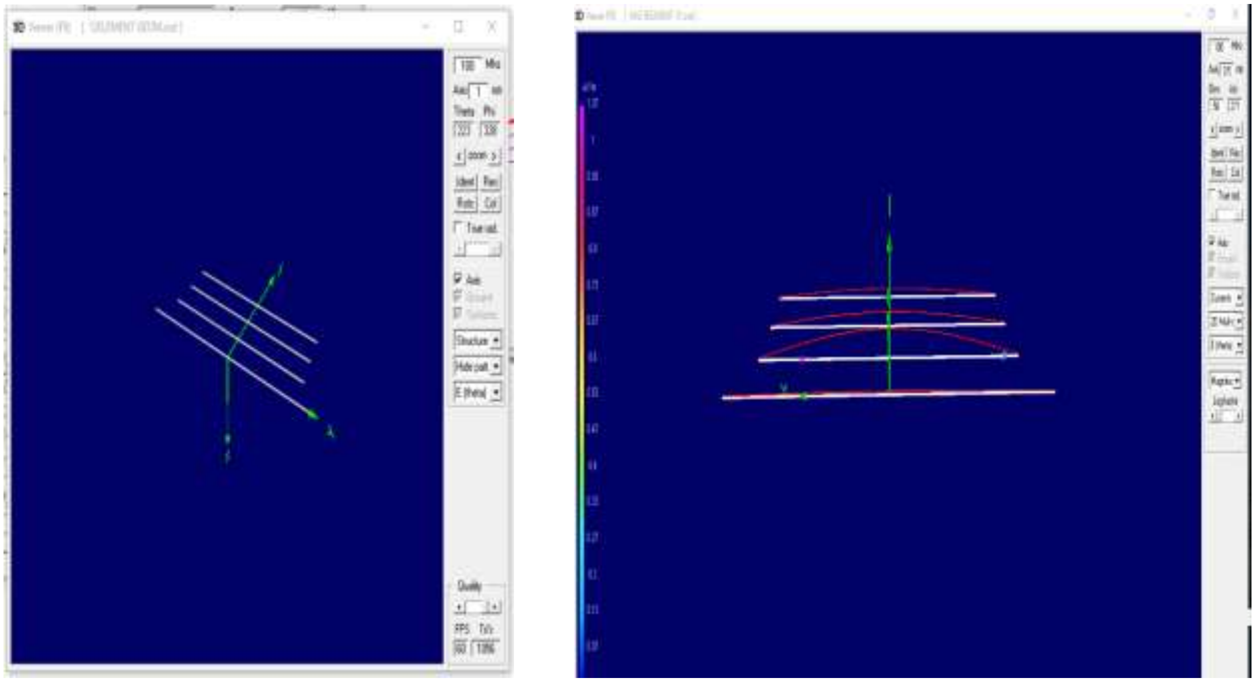


Fig 4.3 Magnitude of current on each elements

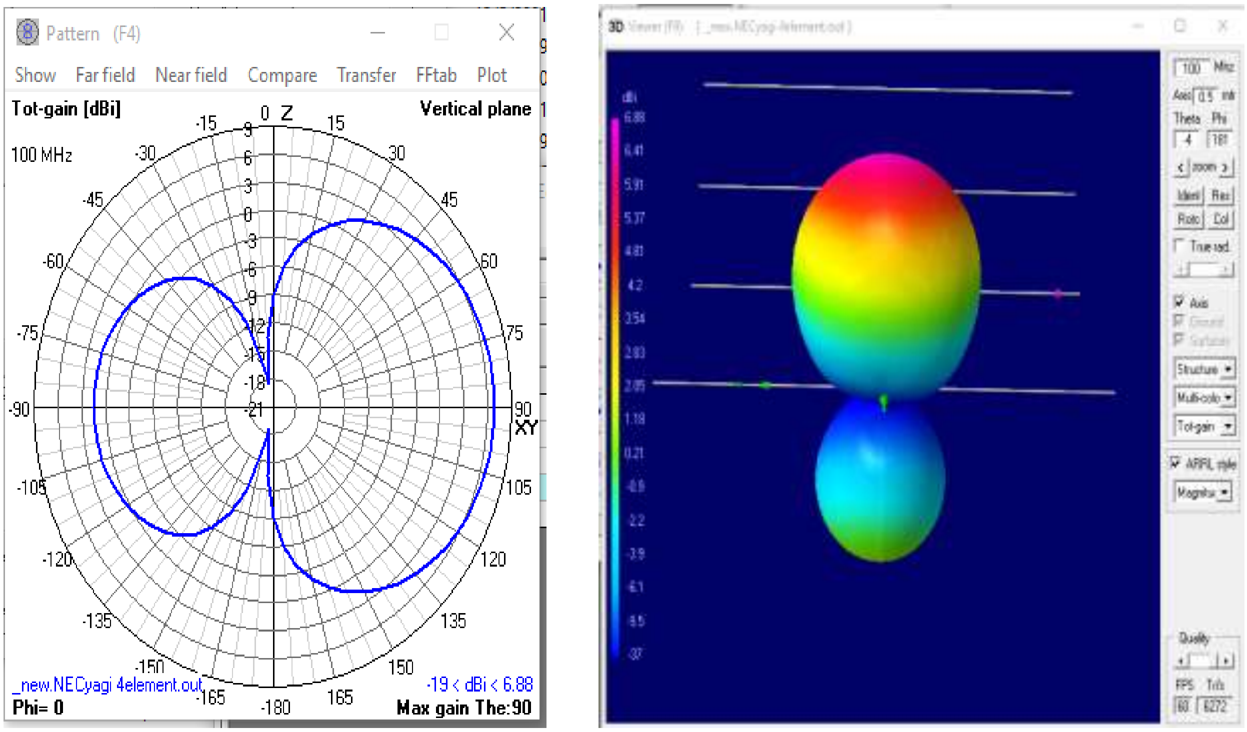


Fig 4.4 2D,3D Radiation pattern for four element Yagi-Uda with fixed element spacing element spacing

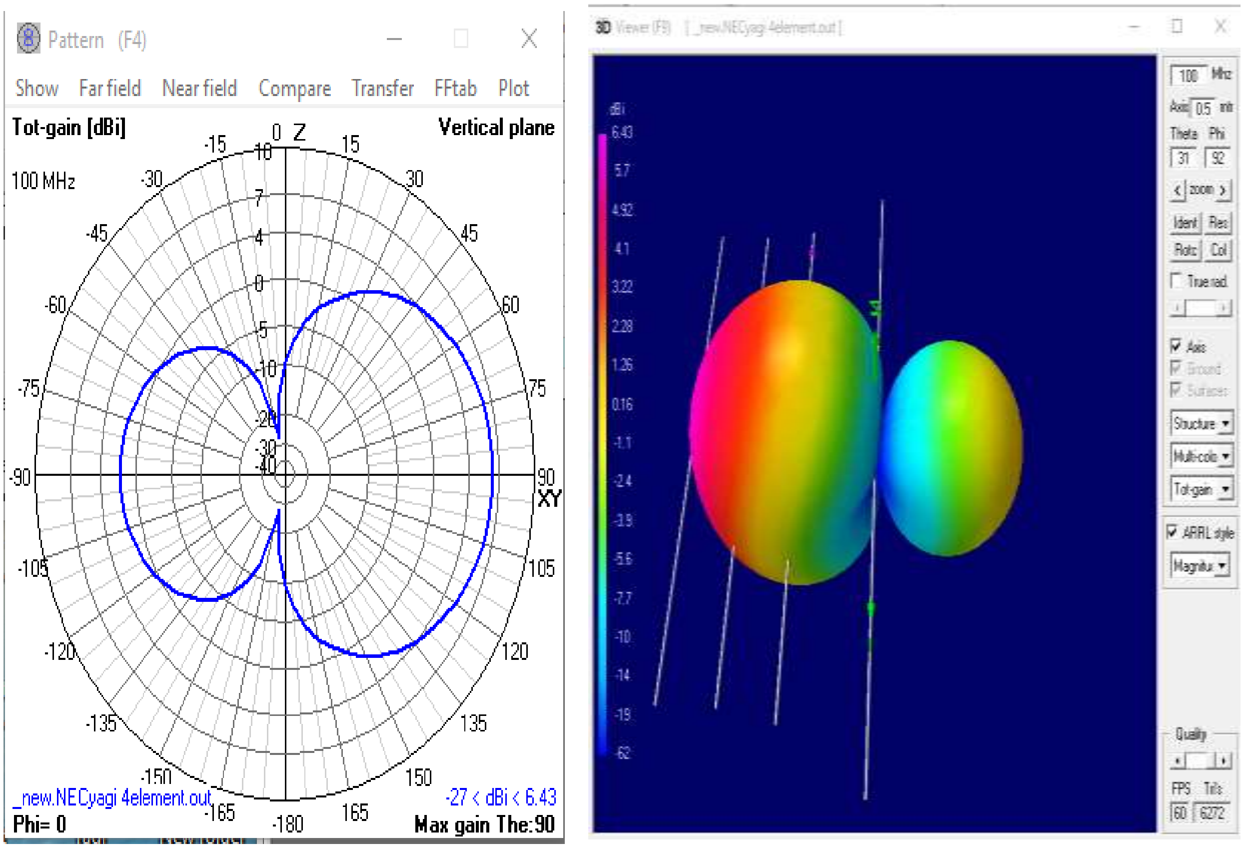


Fig 4.5 2D,3D Radiation pattern for four element Yagi-Uda with fixed Element length

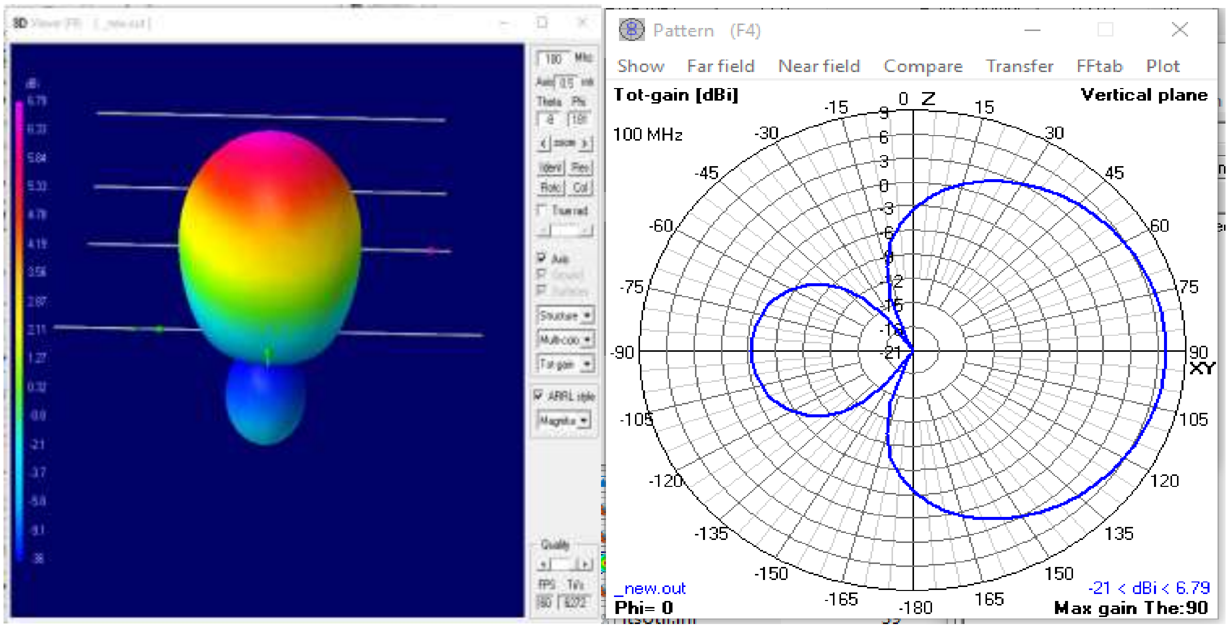


Fig 4.6 3D,2D Radiation pattern for four element Yagi-Uda by varying Spacing and length

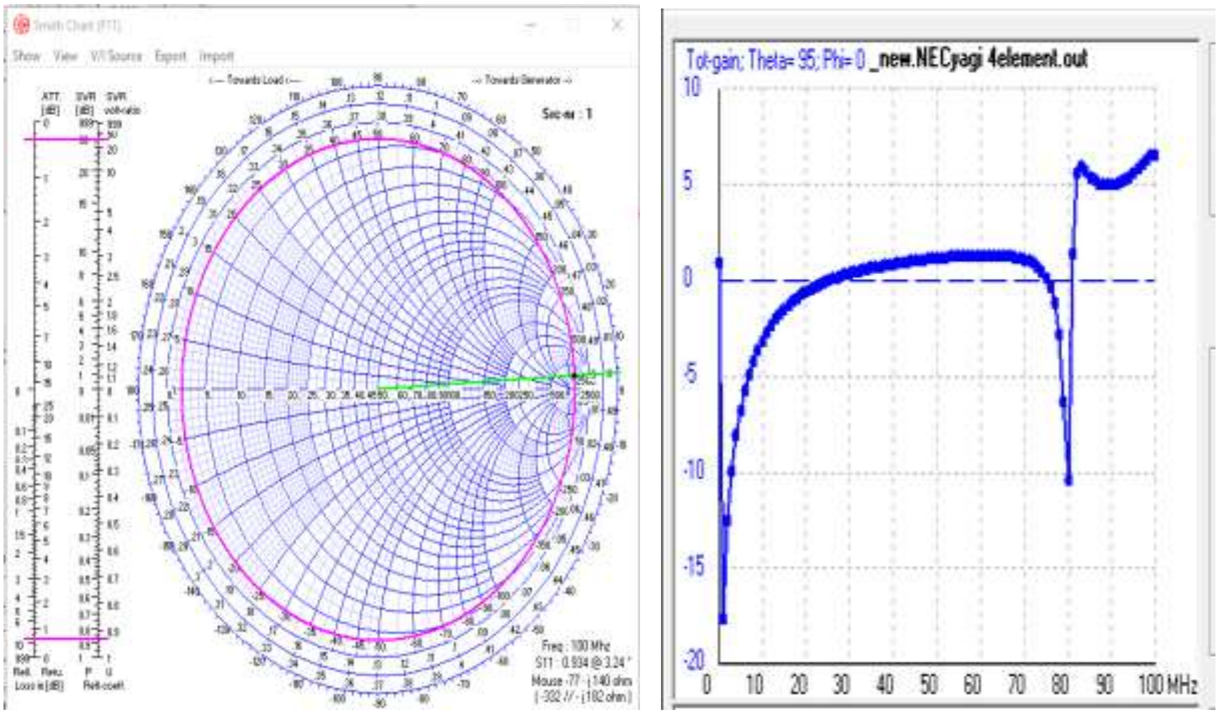
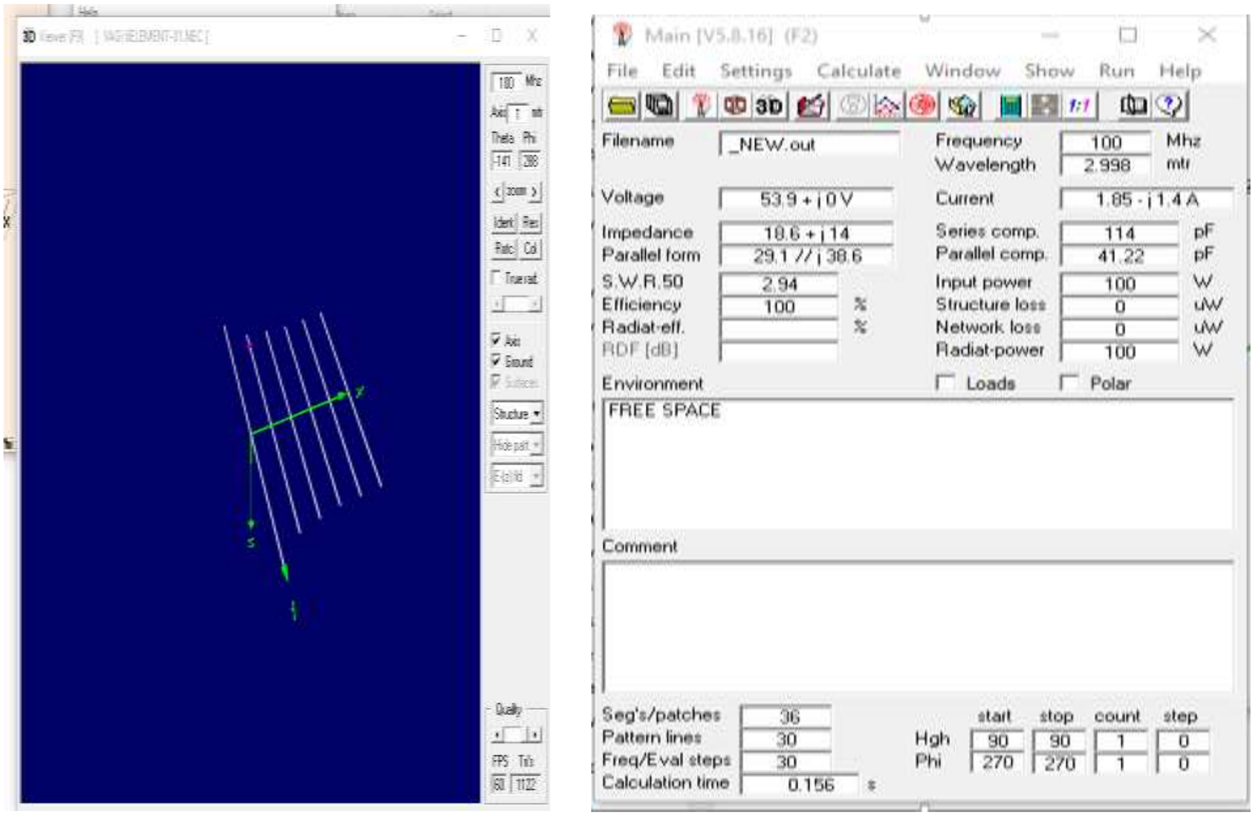


Fig 4.7 impedance at100 MHz for four element &gain by varying Spacing and length



Filename _NEW.out

Frequency 100 Mhz

Wavelength 2.998 mtr

Voltage 53.9 + j 0 V

Current 1.85 - j 1.4 A

Impedance 18.6 + j 14

Parallel form 29.1 // j 38.6

Series comp. 114 pF

Parallel comp. 41.22 pF

S.W.R.50 2.94

Efficiency 100 %

Radiat-eff. %

RDF [dB]

Input power 100 W

Structure loss 0 uW

Network loss 0 uW

Radiat-power 100 W

Environment ☐ Loads ☐ Polar

FREE SPACE

Comment

Seg's/patches 36

Pattern lines 30

Freq/Eval steps 30

Calculation time 0.156 s

	start	stop	count	step
Hgh	90	90	1	0
Phi	270	270	1	0

Fig 4.8 3D Geometry of six element Yagi-Uda antenna

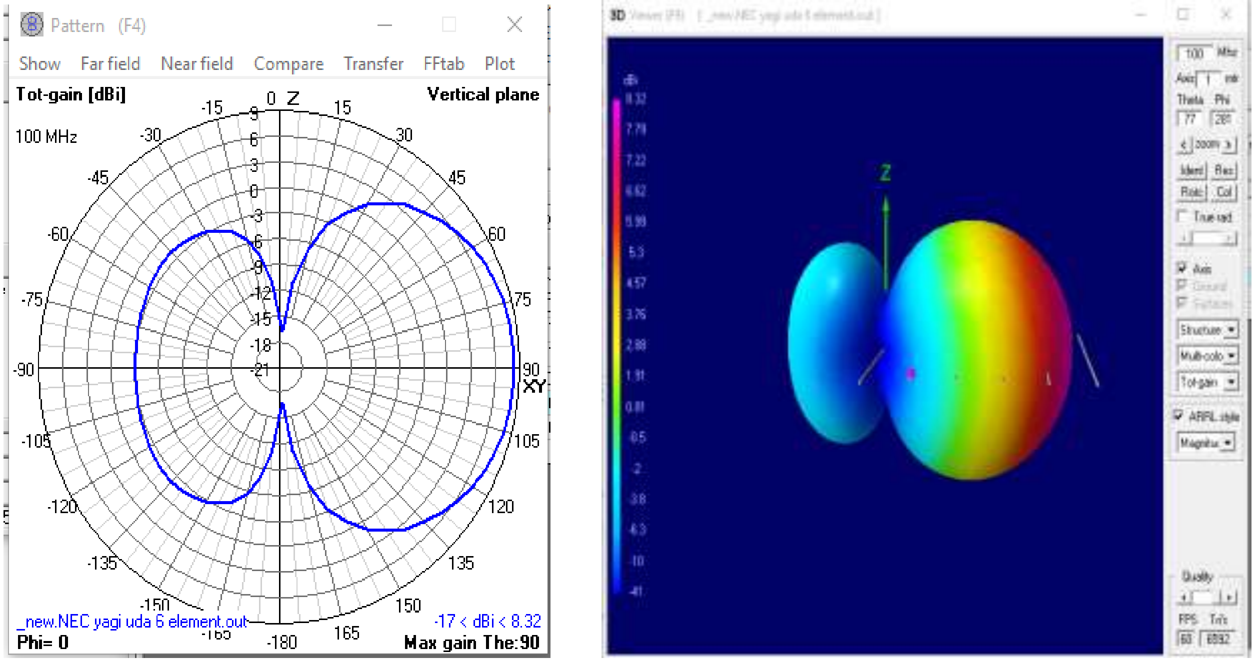


Fig 4.9 2D,3D Radiation pattern for six element Yagi-Uda with fixed element Spacing

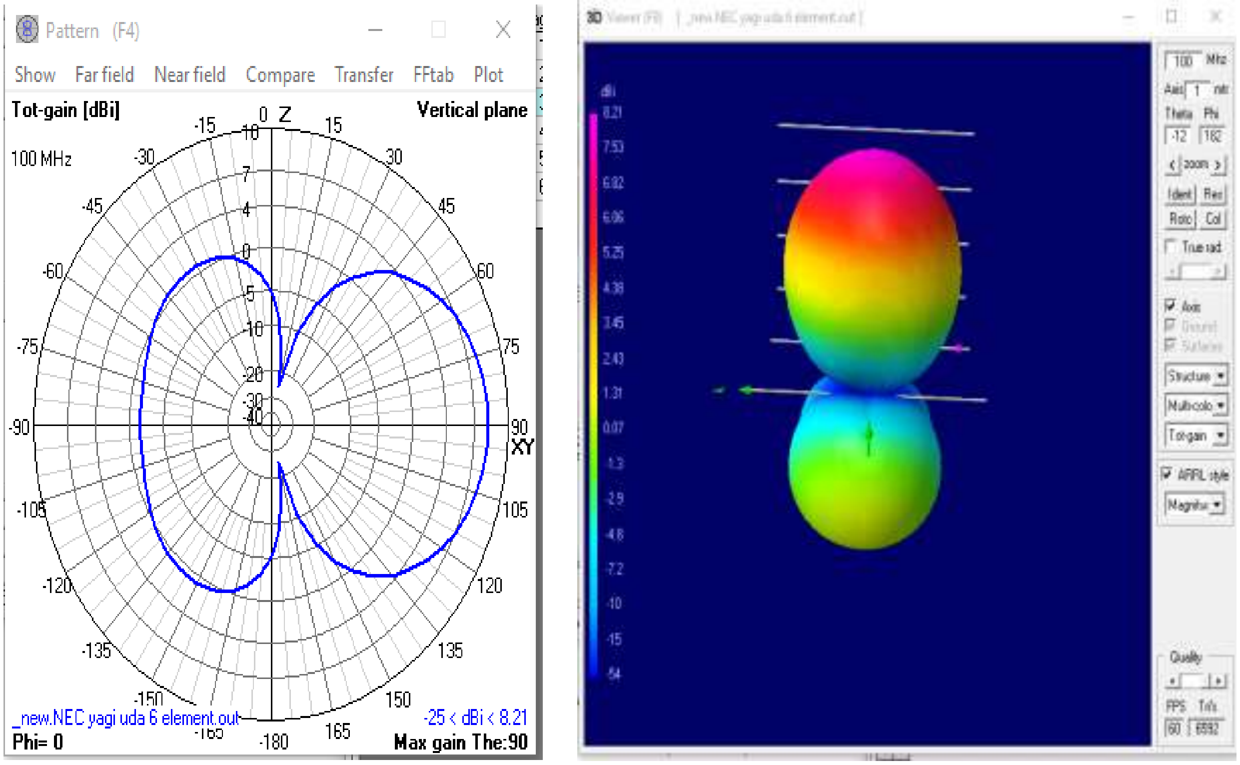


Fig 4.10 2D,3D Radiation pattern for six element Yagi-Uda with fixed element length

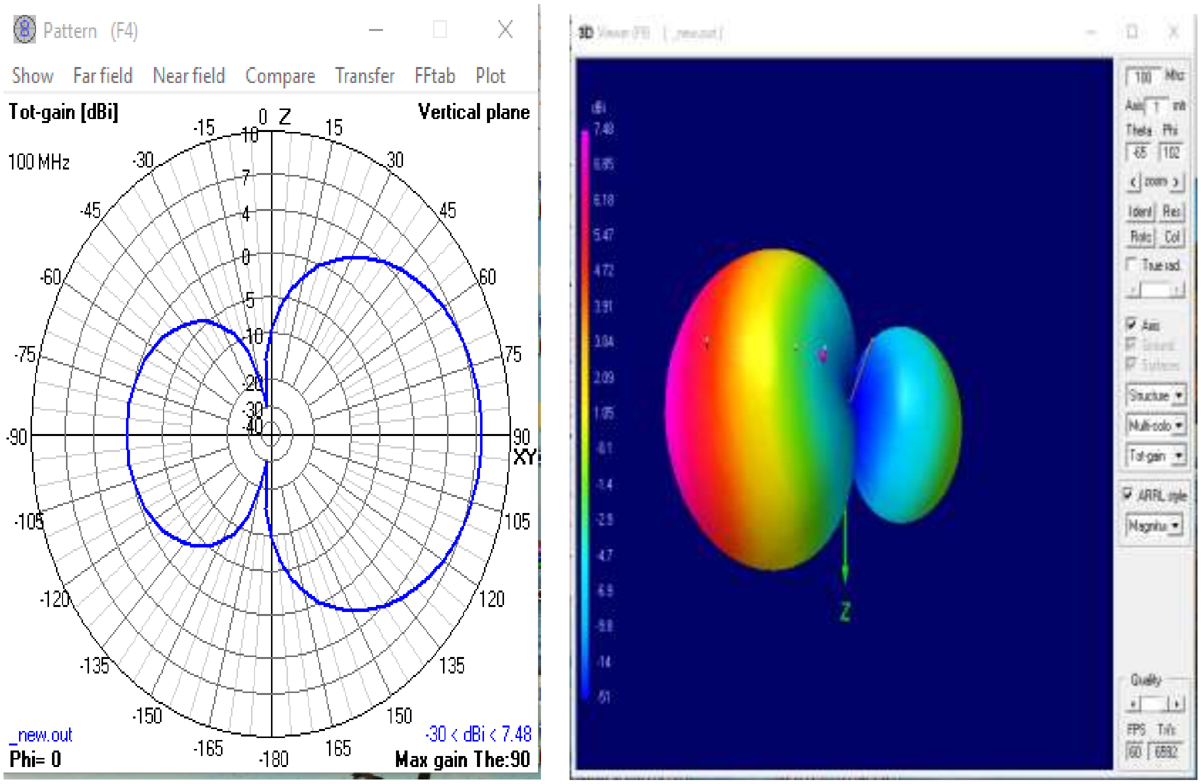


Fig 4.11 2D,3D Radiation pattern for six element Yagi-Uda by varying spacing and length

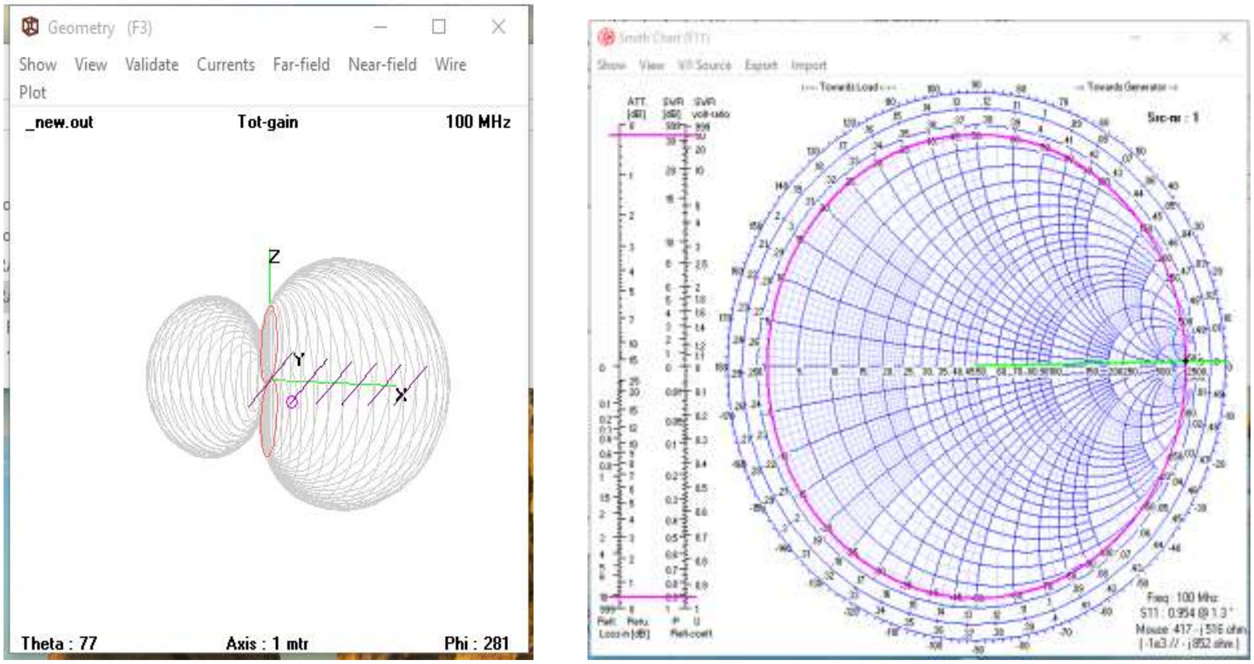


Fig4.12 Optimized gain of six element Yagi-Uda and input impedance using genetic Algorithms

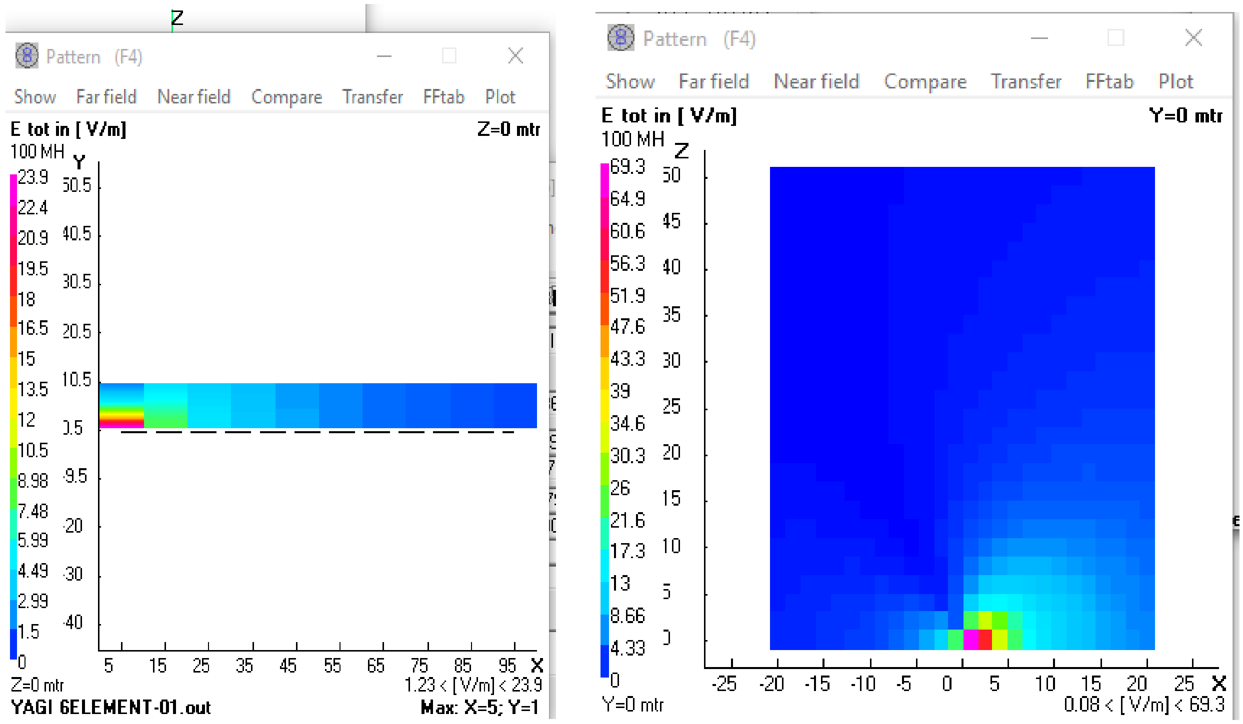


Fig 4.13 a) E total near field of six elements Yagi-Uda b) E total near field of dipole antenna

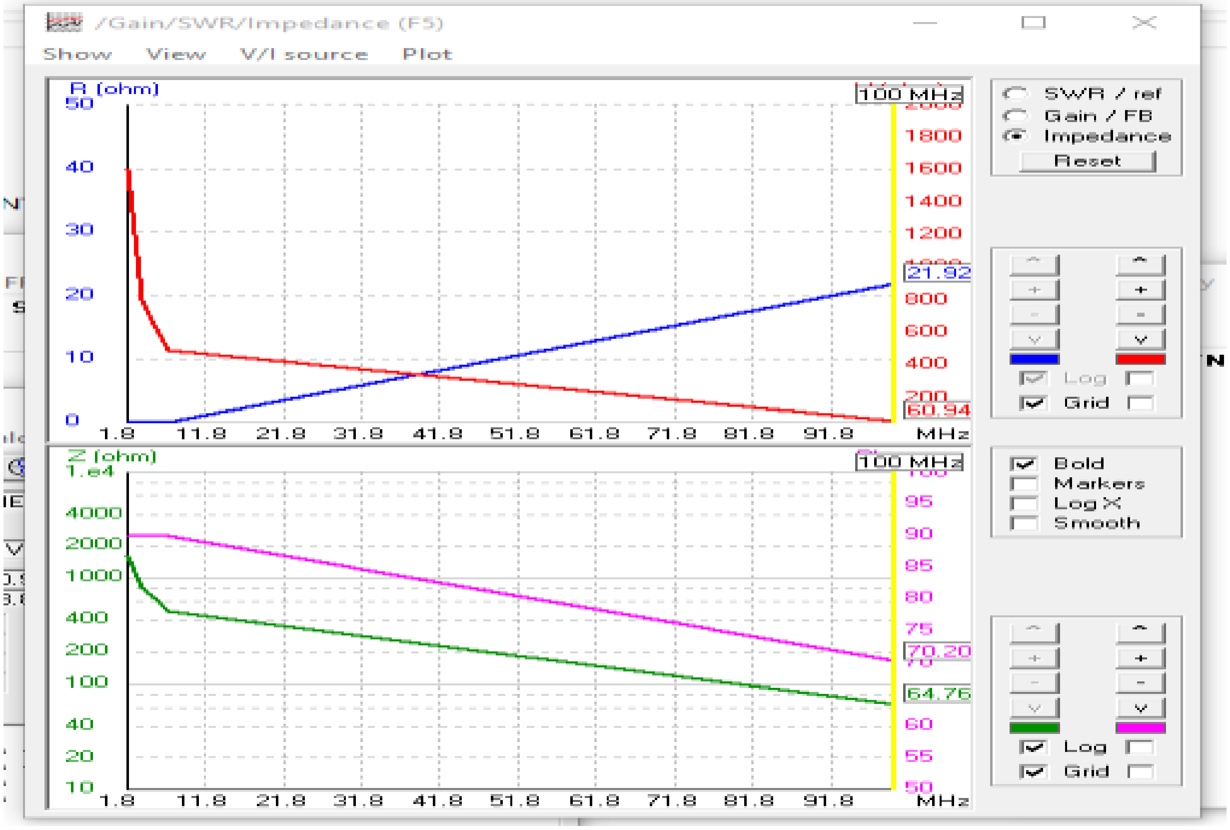


Fig 4.14 Impedance graph of six element Yagi-Uda antenna vs frequency

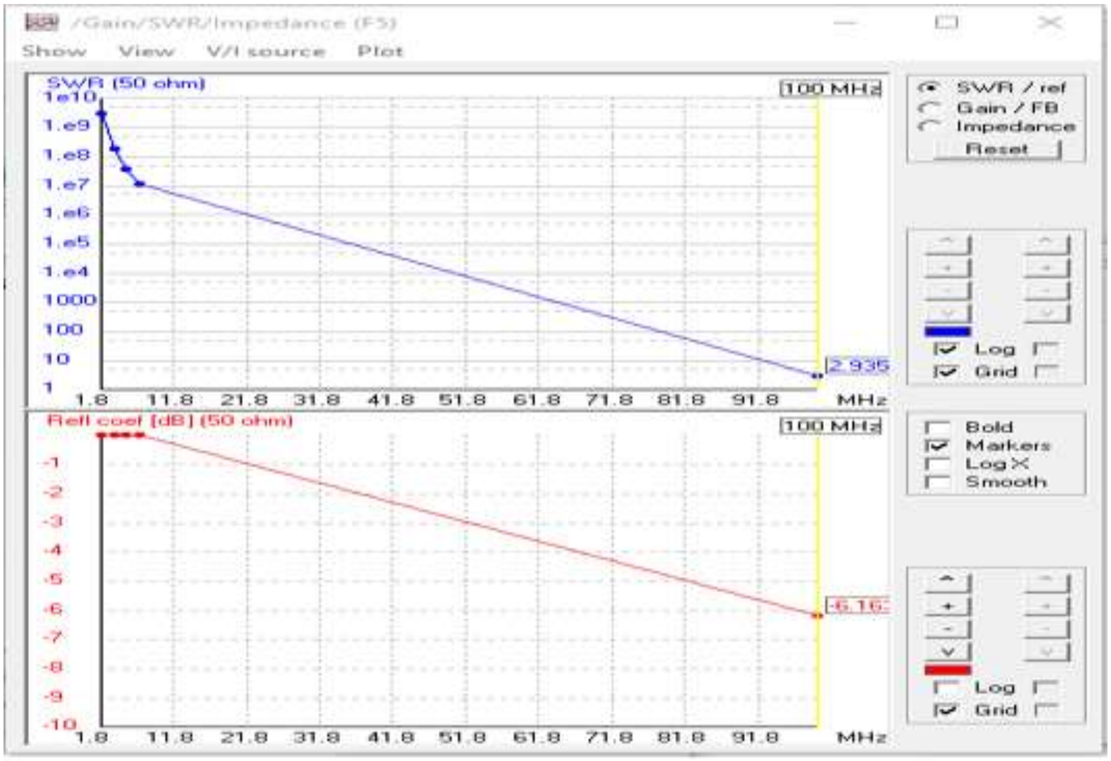


Fig 4.15 Standing wave ratio and reflection coefficient vs frequency

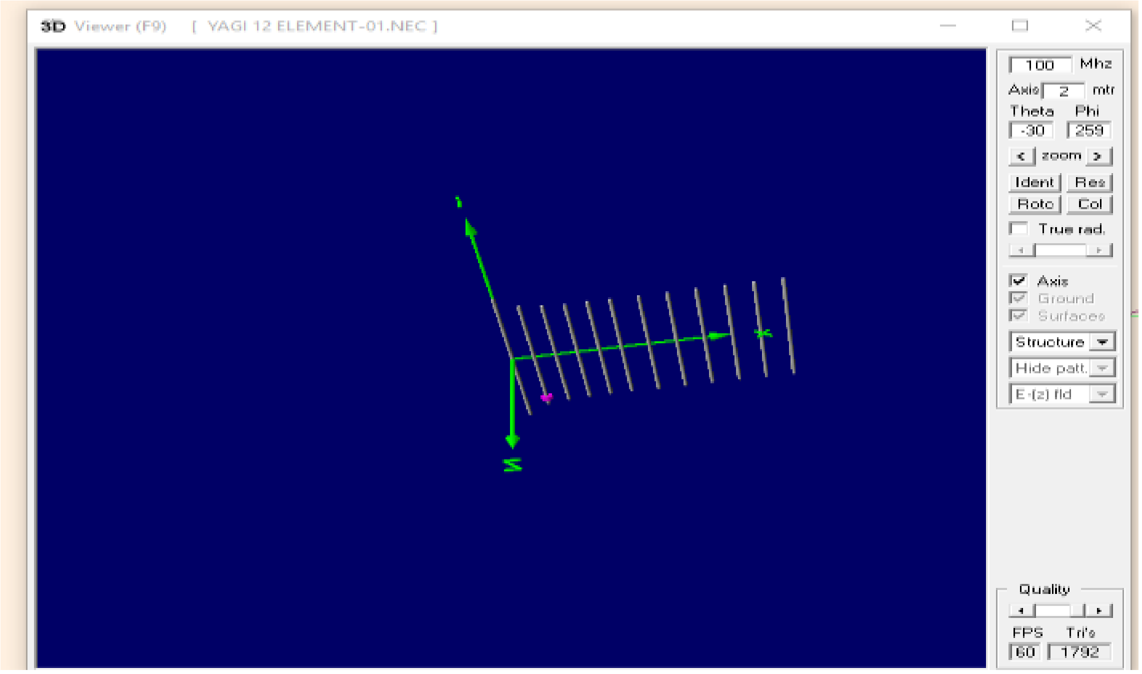


Fig 4.16 3D Geometry of twelve element Yagi-Uda antenna

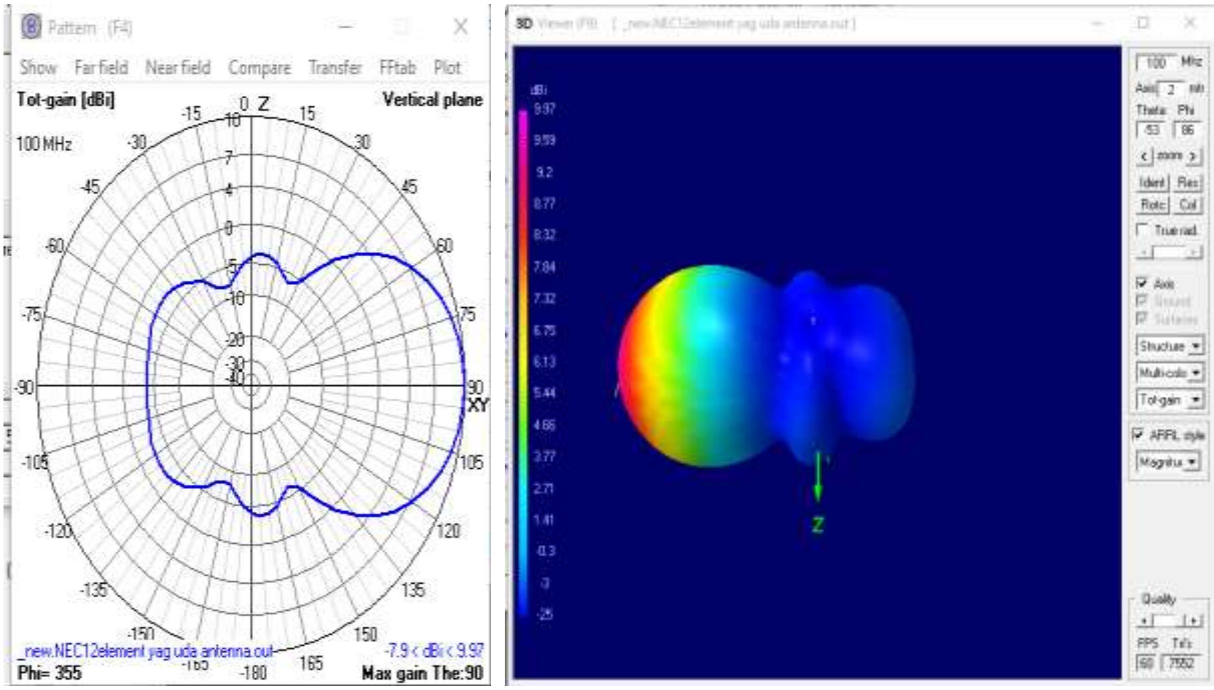


Fig 4.17 2D,3D Radiation pattern for twelve element Yagi-Uda with fixed Element spacing

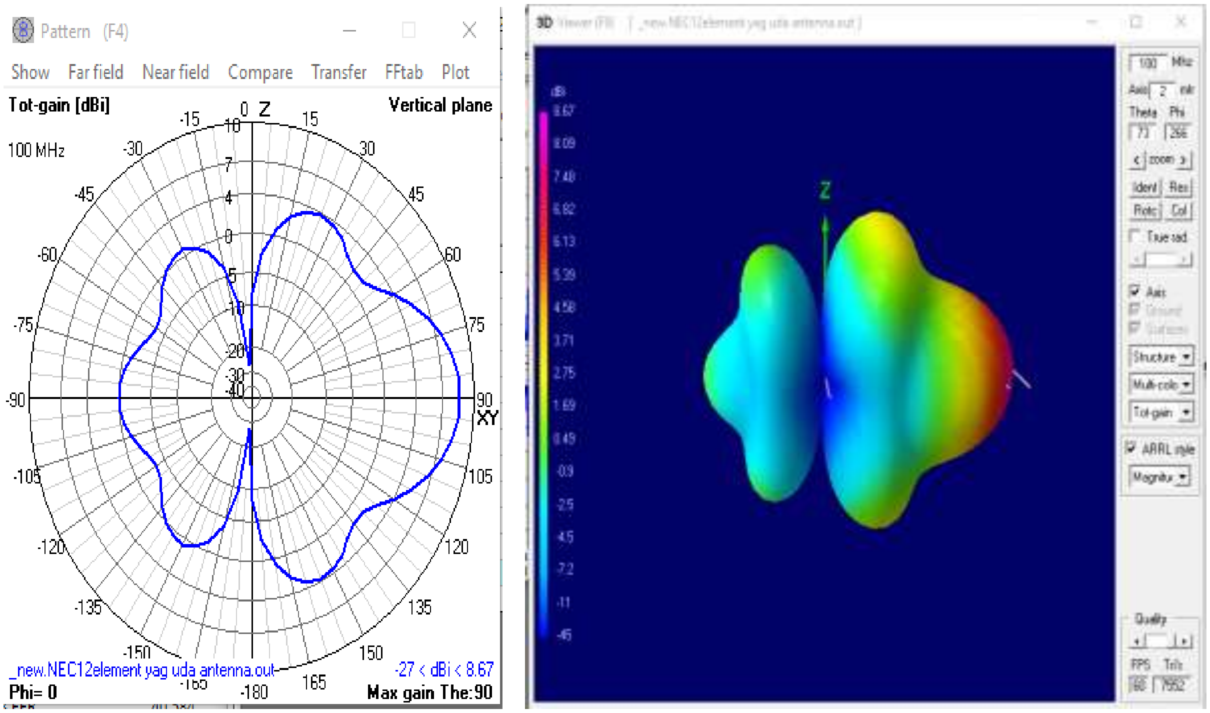


Fig4.18 2D,3D Radiation pattern for twelve element Yagi-Uda with fixed element length

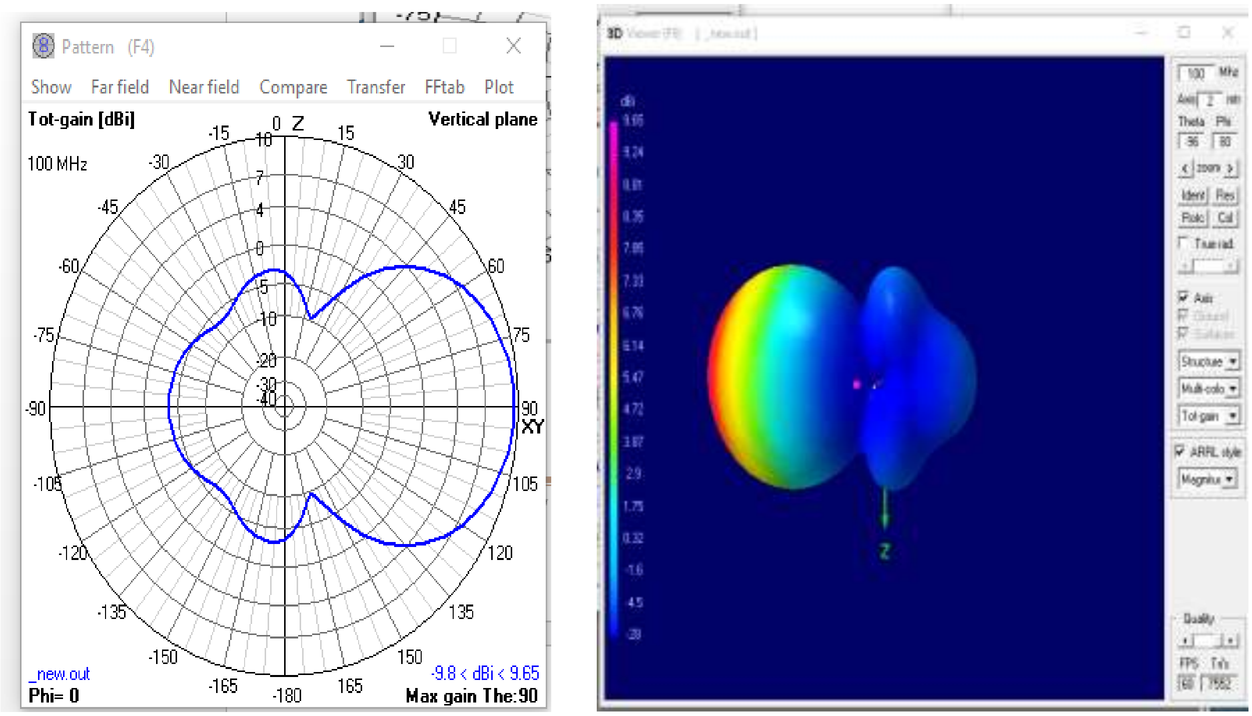


Fig 4.19 2D,3D Radiation pattern for twelve element Yagi-Uda by varying spacing and lengths

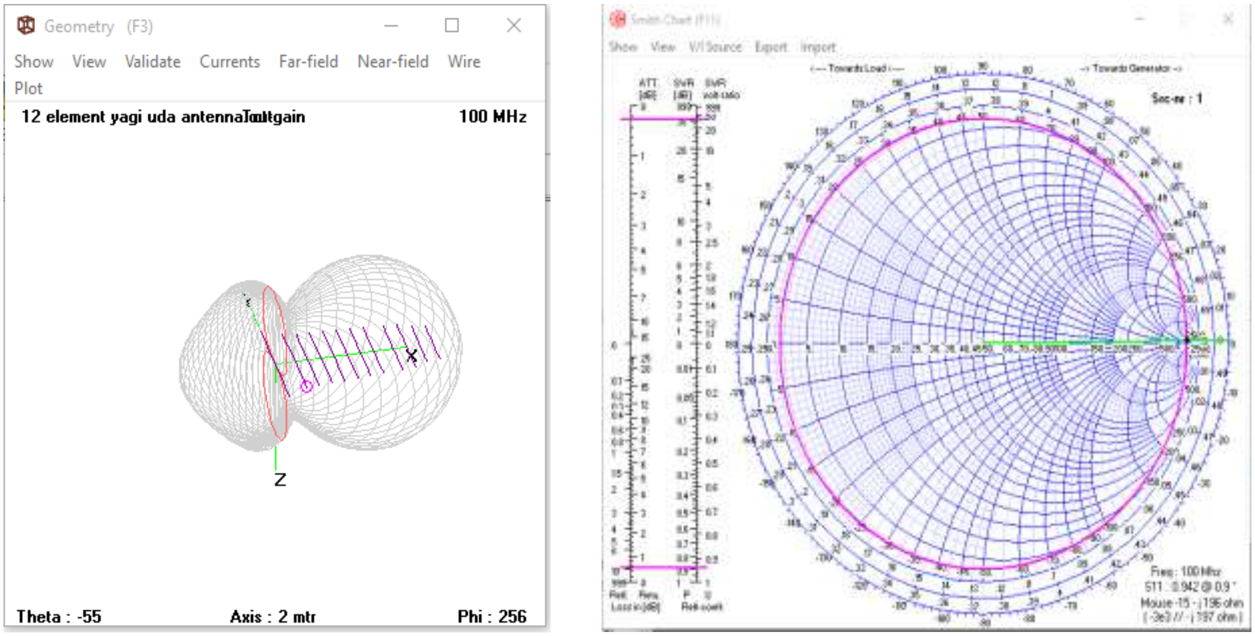


Fig 4.20 Optimized gain of twelve element Yagi-Uda by using Genetic Algorithms

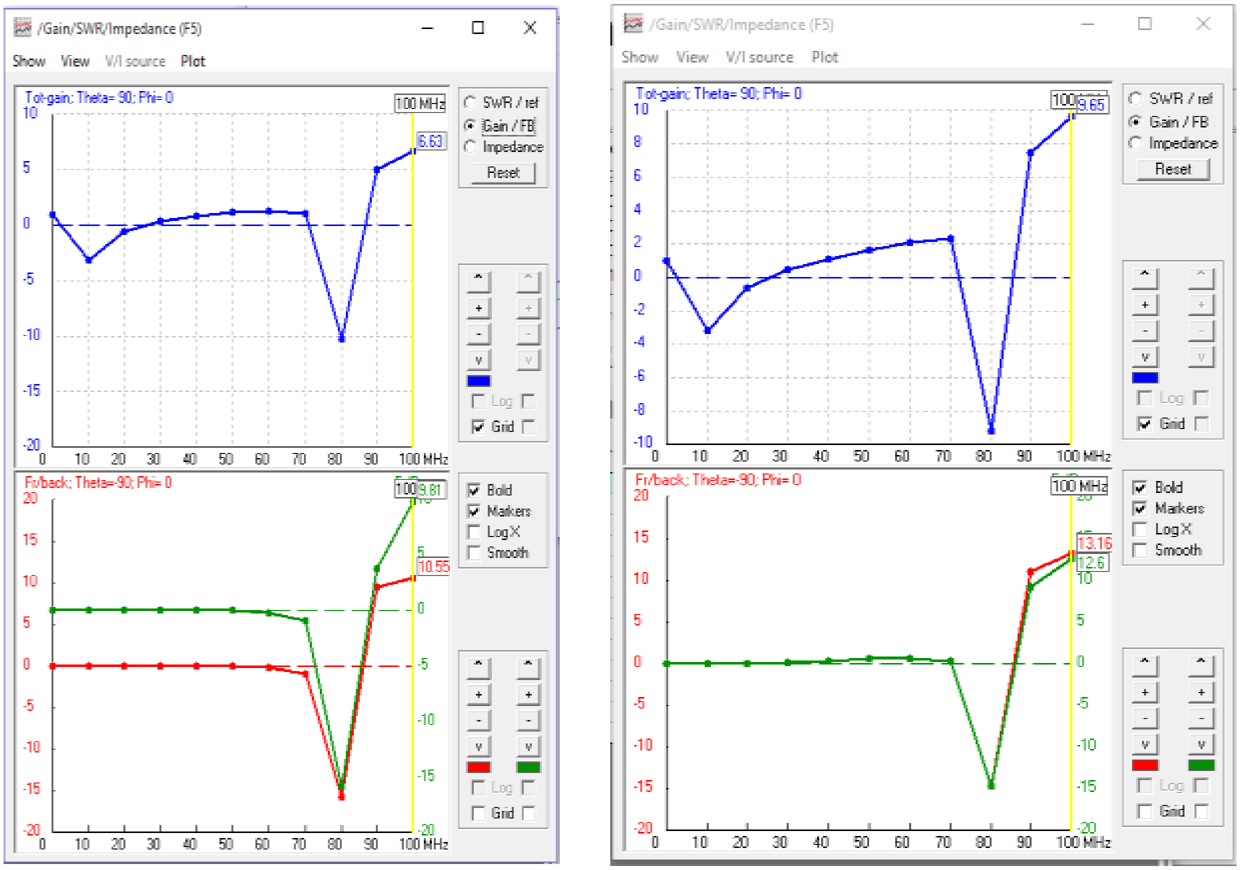


Fig 4.21 Twelve element Yagi-Uda gain and front to back ratio vs frequency

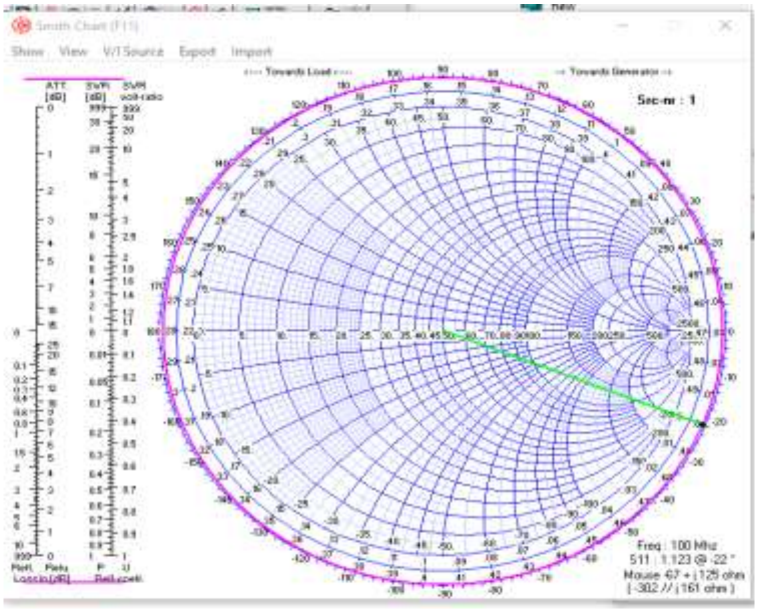


Fig 4.22 Input impedance for twelve element at100Mhz

CHAPTER FIVE

GENETIC ALGORITHM OPTIMIZATION OF YAG-UDA ANTENNA

5.1 Introduction

During the latter half of the nineteenth century. The biological sciences underwent a revolution when Charles Darwin discovered the processes by which nature selects and optimizes organisms fit for life. Gregor Mendel learned the basic laws of genetic inheritance which elucidate by what means evolution takes place [18]. In all its diverse and complex forms, evolved by natural selection and adaptation processes controlled by the survive ability of species, with this acceptance has come the temptation to pursue computer implementations of nature's selection and adaptation engine that can be applied to the solution of engineering optimization problems. Genetic algorithms (GAs) are a class of search techniques that use the mechanics of natural selection and genetics to conduct a global search of a solution space. Nowadays the advent of computers and powerful computational techniques enables us to apply nature’s optimization processes in the form of genetic algorithms.

GAs begin a search with a large population of randomly generated individuals that are solutions to a problem this randomness produces a diverse population of possible solutions. Representing a broad cross section of the entire solution space each individual in the population represents an antenna design. The characteristics of each design is evaluated and then assigned a fitness based on how closely the design meets the desired performance properties by using a survival of the fittest paradigm, members of the population are selected to breed and have offspring. More fit individuals are assigned a larger probability of breeding by exchanging information between two good solutions, the better solution may be produced. There is also a small chance that an individual may mutate which random altering of a small percentage of the population helps maintain the global nature of search. A new populations are produced and evaluated for many generations until the population converges to the same solution. Before starting the algorithms the variables that to be optimized must be selected, together with their minimum and maximum allowable values limits these user-selectable upper and lower limits define the boundaries for the search-space. Mostly these limits are set according physical limits, like available space, maximum length or spacing, however setting a too wide range may slow down.

The GA and might cause it to miss a good solution, because it searched not long enough. Setting a too narrow range might exclude useful and interesting solutions. The most important factor and insight in what may affect antenna performance is also very useful each variable to optimize gene. The genes together form the chromosome when the GA is started an initial random population is created by uniform random selection of the gene value on the interval between the lower and upper variable can be limited.

5.2 ADVANTAGE OF GENETIC ALGORITHMS

GA is an interactive optimization process that imitates the adaptation and evolution of a single species of organism using a chromosomal mapping system. The GA starts with a large number of potential design configurations with range possible configurations is determined by the constraints of the problem and the method of encoding all configuration information into the chromosome. GA's are fundamentally different from other optimization techniques analytical optimizers usually compute derivatives to locate maximum or minimum points for the function being optimized GA's however firstly create random populations of individuals or chromosomes which are then evolved to converge to an optimum solution. Gradient methods produce one best answer but they are often trapped in local extremes which prevent the global optimum from being found GA's can produce groups of solutions. The large number of variables is involved with mutual influences among each other performance of the genetic algorithms is expected to better than that of than other optimizer antenna design. Genetic algorithms(GAs) was dealt with in different research papers and strange problems that used to be hard to go over were treated various antenna types. Nowadays optimized using genetic algorithms ranging from simple geometries to the very complicated forms. Wire antennas were among the first type of antennas to take advantage of this tool Yagi-Uda array is one of the complicated, optimizing for one characteristic leads to very complex calculations. The things get worse if we are to optimize for two or more characteristics such as gain,standing wave ratio (SWR),the front-to back ratio (FBR) and the Side lobe level (SLL) are added to improve antenna performance, however genetic algorithms is the best method.

Genetic algorithms are classified as global optimizers while more familiar traditional techniques, such as conjugate gradient and the quasi-Newtonian methods, are classified as local optimizer. The major classification of global optimization methods are categorized as following.

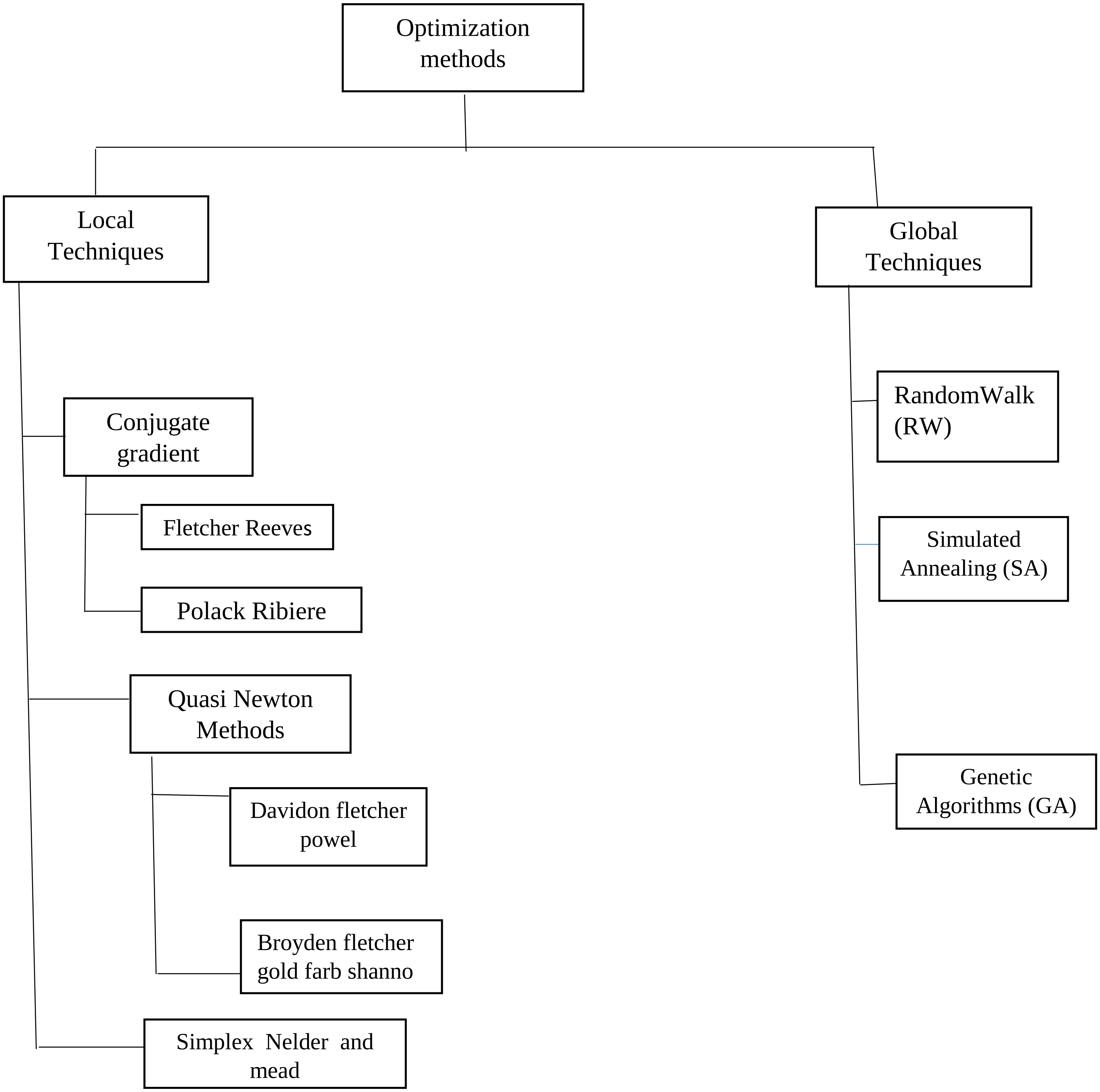


Fig 5.1 Classification of the major optimization methods

Genetic algorithm is one of the stochastic optimization techniques that use the concepts of natural selection and genetics to conduct a global search of a solution space [19].

The distinction between local and global search of optimization techniques is that the local techniques produce results that are highly dependent on the starting point or initial guess, while the global methods are highly independent of the initial conditions. They possess the characteristic of being fast in convergence. Yagi-Uda optimization Simulation time is a key factor in using any optimization algorithms. Optimization of Yagi-Uda antenna either gradient-based or stochastic methods can be used. In this work stochastic methods is used to optimize Yagi-Uda antenna gain by varying element spacing and length. The evaluation of each of the antenna designs generated by the genetic algorithms during the optimization is done using stochastic methods. In this method only the first mode for element currents in is considered which makes antenna evaluation faster than typical MoM based analysis. The results of this method are accurate enough for radiation pattern optimization, specially Yagi-Uda antennas with large number of elements can be optimized rapidly. The length and spacing of elements are optimized mainly for gain maximization. In genetic algorithms a set or population of potential solutions is caused to evolve toward a global optimal solution. Evolution toward a global optimum occurs as a result of pressure exerted by a fitness-weighted selection process and exploration of the solution space is accomplished through combination and mutation of existing characteristics present in the current population.

The genetic algorithm (GA) used in 4nec2 is a real-value based algorithm. This GA includes a number of selection, crossover and mutation-techniques like Roulette-Wheel SUS tournament selection,N-point Blend simulated binary crossover and random Gaussian or none-uniform mutation mostly takes more time to optimize before starting the algorithm. The variables to optimize must be selected, together with their minimum and maximum allowable values limits these user-selectable upper and lower limits define the boundaries for the search-space. Mostly these limits are set according physical limits, like available space, maximum length or spacing however, setting a too wide range may slow down. The GA and might cause it to miss a good solution. The most important factor and insight in what may affect antenna performance is also very use full each variable to optimize is called a gene. The genes together form the chromosome when the GA is started an initial random population is created by uniform random selection of the gene value on the interval between the lower and upper variable limits.

A population is a group of N chromosomes or individuals. Each individual representing a different 4nec2antenna design. The genetic algorithms evolves the initial random population by creating successive generations of individuals. The population size N is constant from generation to generation, the individuals comprising the population are genetically altered from one generation to the other one of the most important features of a genetic algorithm is its ability to optimize a population using any desired measure of goodness unlike gradient methods. GA's easily handle discontinuous functions with this acceptance to the computer implementations of nature's selection and adaptation engine that can be applied to the solution of engineering optimization problems.

Genetics to conduct a global search of a solution space [20]. Nowadays, the advent of computers and powerful computational techniques enables us to apply Nature's optimization processes in the form of genetic algorithms (GAs) [21]. As an optimizer, GAs are powerful and effective at solving complex problems.

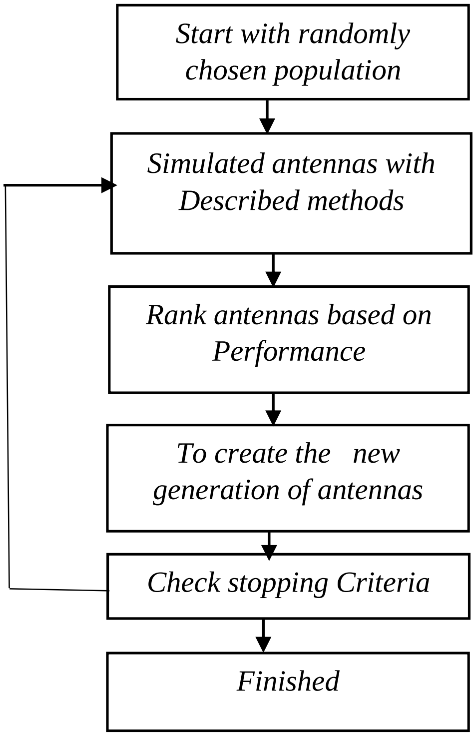


Fig 5.2 flow chart of genetic algorithms

5.3 Objective function and fitness scaling

The goal of antenna designer is to develop an antenna that meets or exceeds some desired performance. The few of the characteristics that define the antenna performance are side-lobe level, front-to-back ratio, voltage standing wave ratio reflection coefficient gain and input impedance is the parameters which quality of a design is expressed mathematically by an objective function. The following objective function, for rewards an antenna design ***x*** for having a high gain *G* if the real part of the input impedance does not equal 50**Ω** or if the imaginary part of the input impedance *Z* does not equal zero [22]. The objective function determined as follows.

Objective to maximize gain *F(x)*

With constrained function

$$f_1(x) = 10-|Re\ (z)-50|>0$$

$$f_2(x) = 10-|im\ (z)-0|>0$$

$$f_3(x) = 3-vswr>0$$

Objective function

$$F(x) = a\ G(\boldsymbol{x})-b|50 - Re\big(z(\boldsymbol{x})\big)| - c|I_m(z(x))|-vswr \ldots\ldots\ldots\ldots\ldots (4.1)$$

The constants *a, b* and *c* are weights that control the contribution from each term to the overall objective function. The fitness value used to rank the individual designs for the selection process is scaled version of the objective function. Scaling the objective function serves two main purposes First, the selection phase requires that the fitness of an individual is a non-negative value,while the objective function for many problems can become negative for some design parameters.

The second scaling is useful way of controlling the competition between individuals [23]. In early generations there is often a large discrepancy between the quality of the best and worst individuals. In the population this can lead to a situation where a single extremely fit individual begins to dominate the populations,stifling the search for other good solutions and resulting in premature convergence.

By using a scaling function to reduce the difference in the fitness of individuals in the population diversity maintained. The exact opposite problem occurs in later generations when the population has begun to converge to similar solutions. The search is more localized because the population is full of similar,highly fit individuals. In this case,it is desirable to reduce the differences between individuals so that the search is concentrated around the most promising solutions [24]. One of the standard methods is linear scaling. Linear scaling translates objective functions to fitness values in the following manner.

$$F(x) = a*o(x) + b \ldots\ldots\ldots\ldots\ldots\ldots (4.2)$$

The constants *a* and *b* are chosen so that an individual with the average objective value will have an average fitness value and so that fitness of the best individual is some desired multiple of the average fitness.

$$F_{max} = C_{mult} * f_{avg} \ldots\ldots\ldots\ldots\ldots\ldots (4.3)$$

C mult is usually between 1.2 and 2 for small populations of 50 to 100 individuals. The presence of negative objective scores complicates linear scaling. The negative values are present,it is not always possible to choose *a* and *b* [25]. Another approach is to scaling objective functions, known as sigma truncation,which is more appropriate in situations where negative objective scores are possible in sigma truncation scaling, the objective function is scaled according to the following formulas.

$$f(x) = O(x) - (O_{avg} - d_{\sigma}) \ldots\ldots\ldots\ldots\ldots\ldots (4.4)$$

Here *o avg* and *σ* are the average and the standard deviation of the objective function for the population. Extremely poor individuals with an objective value *d* standard deviations below the average end up with negative fitness values. These individuals are assigned a fitness of zero the values for ***d*** are between one and three in many research.

5.4 Selection

After the population has been evaluated, individuals are selected from the population to contribute to the next generation. Some of the selected individuals are simply copied into the new population others are chosen to mate with another individual and their offspring become part of the new population during selection. Individual is assigned a probability of selection based on the ratio of the individual's fitness to the total fitness of the member in the populations.

The selection probability determined mathematically

$$Pi = \sum_{k=1}^{N} \frac{fi}{fk} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (4.5)$$

5.5 Representing Antennas as Chromosomes

Individuals are combined through breeding to form new offspring, it is first necessary to see how an individuals represented. In genetic algorithms GA work with chromosomes which are abstract representations of the solution to the problem for each individual in the population is represented by a chromosome.

In this work, N-element Yagi-Uda array antenna is described by specifying the length *L* of each element and the spacing *S* between adjacent elements one approach to represent the antenna as a chromosome. The parameters are discretized and encoded as binary values so that consists of a single driven element, one reflector element, and N-2 director elements.

$$L_{encoded} = l_1 l_2 \ldots\ldots l_{BL} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (4.6)$$

Here *BL* is the number of bits used to represent *L*. *BL* is found by

$$BL = [\ \ log_2 (\frac{Lmax-Lmin}{Lres}) + 1] \ldots\ldots\ldots\ldots\ldots\ldots \ (4.7)$$

Where L_{min} and L_{max} define the range over which *L* can vary and L_{res} is the resolution of the discretization If *BL* is not an integer, it is rounded up to the next integer value binary representation of *L* is decoded by

$$L = l_{min} + \sum_{k=1}^{N} \ Lres * kI \ 2^{k-1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (4.8)$$

The chromosome is formed by concatenating all the encoded parameters together into a single binary string. The size of the search space is defined by the length of the chromosome. GAs converge to a solution faster for smaller search spaces because of this, there is a tradeoff between the range and resolution allowed for the floating point parameters and the speed of convergence. In all the optimizations N bits has been used to code each of the Yagi-Uda parameters. Although having a smaller resolution for parameters can lead to better solutions but choosing a very small resolution does not help in practice as there is always a limit for the accuracy. The best choice would probably be to take the resolution equal to the minimum accuracy in the process information can be transfer from one generation to other generation through the following ways.

- Reproduction
- Crossover
- Mutation

Reproduction is the simplest of the operators,directlycopies an individual from the old generation into the new generation. The breeding of two chromosomes, accomplished using the crossover operator is only slightly more complicated than reproduction.

Crossover the information between two chromosomes is exchanged by cutting the chromosomes at a randomly chosen location and swapping the ends of the chromosomes to create two new chromosomes. The process that provides a simple way for chromosomes to exchange information in a search for better chromosomes the percentage of individuals chosen to participate in crossover during each generation is specified by the parameter p crossover in the simulations. After several generations,the population will contain multiple identical copies of the most fit individual. This is desirable because the offspring from this individual are also likely to be fit,however the offspring are also likely to be very similar to their parent which can lead to a localized search of the solution space.

Mutation is the value of the bit is simply changed from zero to one or from one to zero by applying mutation to a small percentage of the population. The global nature of the search is preserved the value of *Mutation* =0.005 has been used in most of the optimizations and the effect of *Mutation* is studied on the convergence of optimization the problem is simple enough for the GA to find the optimal solution. The GA also tends to find a niche solution and optimize it a fitness function for an antenna and another to force the impedance toward 50**Ω**. If the best antennas from several different methods are inspected chances are that some of them will have good gain values with somewhat less desirable input impedance values, while others will have smaller gain values but better impedance values.

Fitness The objective function defining the optimization goal is called the fitness function. It assigns goodness or badness to the different members.

Elitism It ensures the propagation of the fittest member through the different generations and provides a greater probability that the algorithm will locate the global optimum.

In general, genetic algorithm must be able to perform the following basic tasks.

- Encode the solution parameters as genes.
- Create a string of genes to form a chromosome.
- Initialize a starting population by creating a set of specific chromosomes, usually in a randomized manner.
- Evaluate and assign fitness values to individuals in the population.
- Perform reproduction through the fitness-weighted selection of individuals from the population.
- Perform recombination and mutation to produce individuals of the next generation.

5.6 Validation of the optimization method

The radiation characteristics of the Yagi-Uda antenna can be adjusted by controlling geometrical parameters of array. For the optimization of one or more characteristics of the antenna, different methods have been used [23]. The first is to keep the lengths fixed and vary the spacings between the directors with the reflector-pilot distance fixed. The second approach would be by varying element length with fixed element spacing. The third is both element lengths and inter element spacings to vary. In all methods stated the wire diameter is fixed constant these procedures have been implemented to optimize.

Yagi-Uda antenna gain and to minimize standing wave ratio with minimum reflection coefficients. All the geometrical parameters, elements lengths, inter element spacings and wire diameter are considered as optimization variables. Moreover, the use of genetic algorithms gives the freedom to play with all the geometrical dimensions of the antenna, including the wire diameter. The dimensions obtained using genetic algorithms do not show the great respect to the conventional simplified rule.

Design specifications

- The elements length varied from 0.6*λ to 0.3*λ
- The element spacing are confined between 0.1* λ to 0.3* λ
- Wire diameter is constant 0.00033* λ in meter (0.1mm)
- Resonant frequency 100 MHz

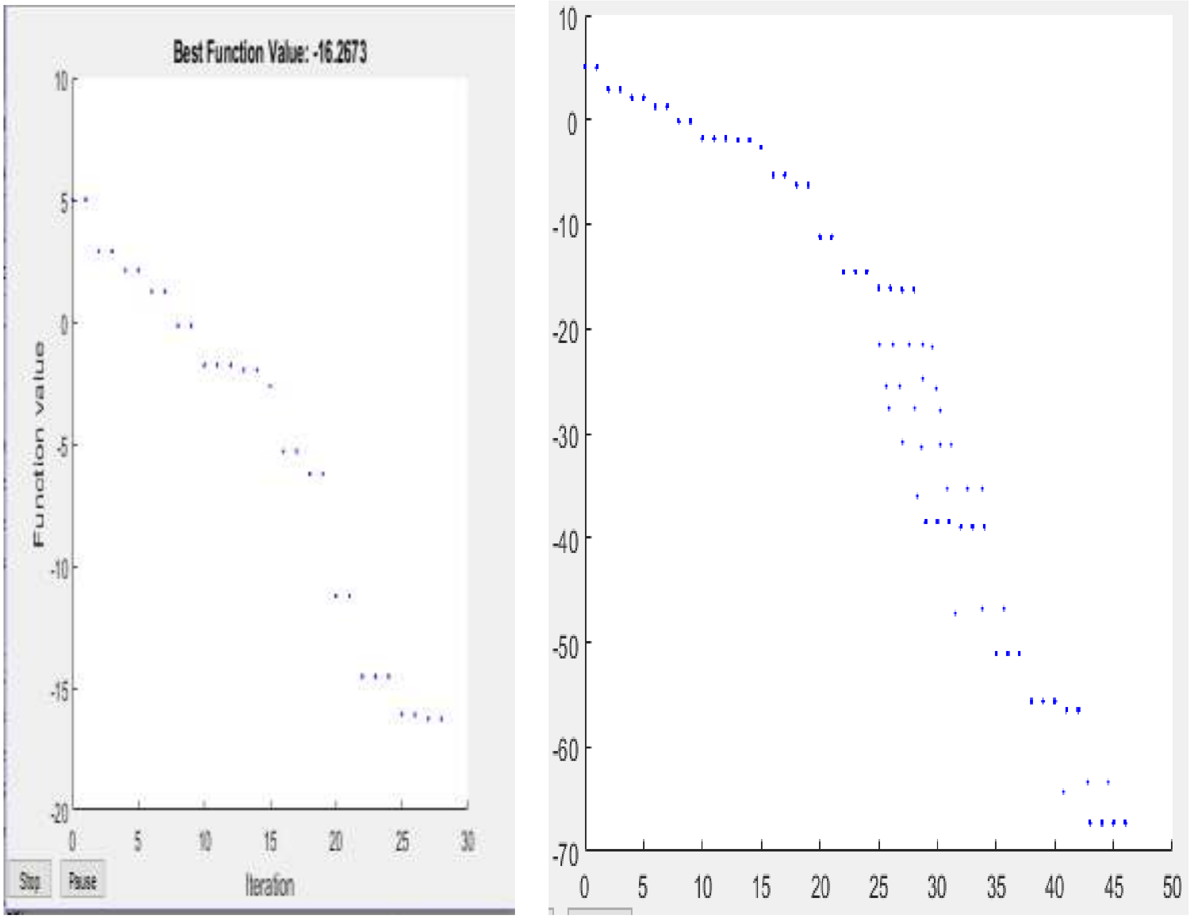


Fig 5.3 a) function value vs iteration b) Pareto front of f_1 and f_2

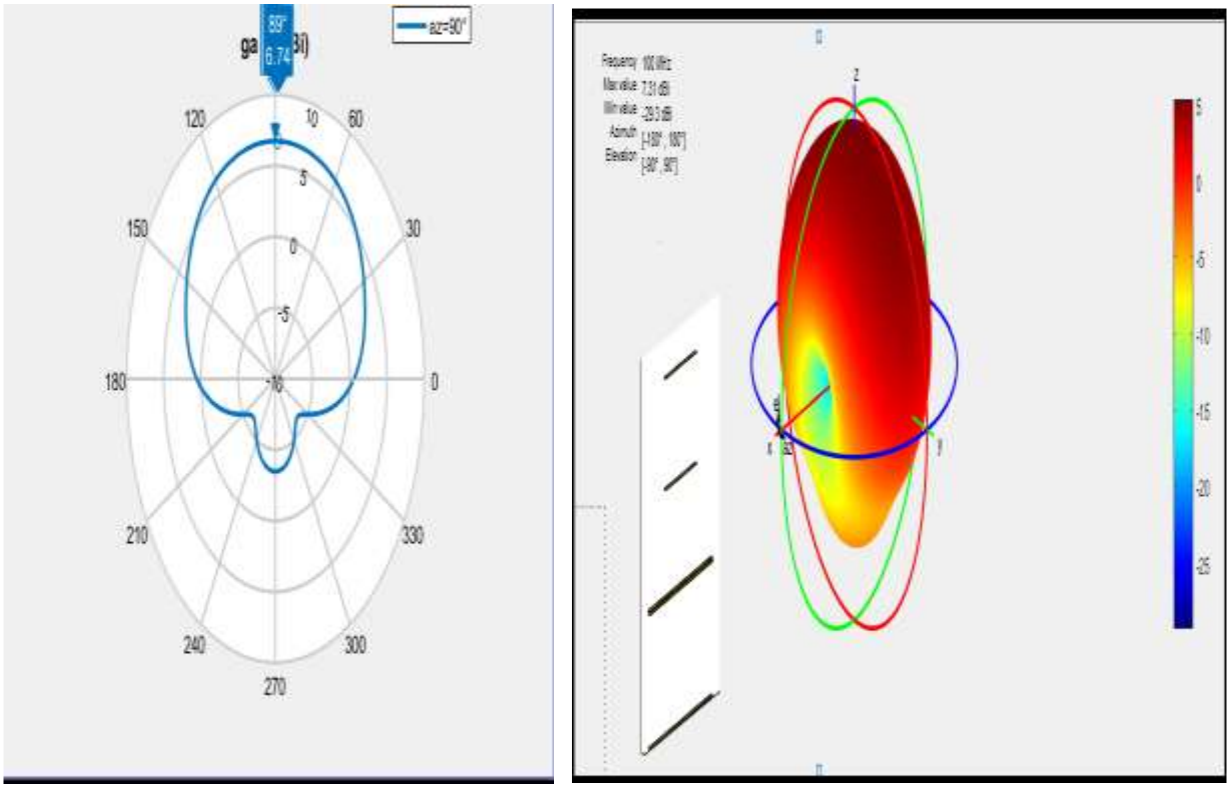


Fig 5.4 2D,3D Radiation pattern of optimized Yagi-Uda antenna at N=4

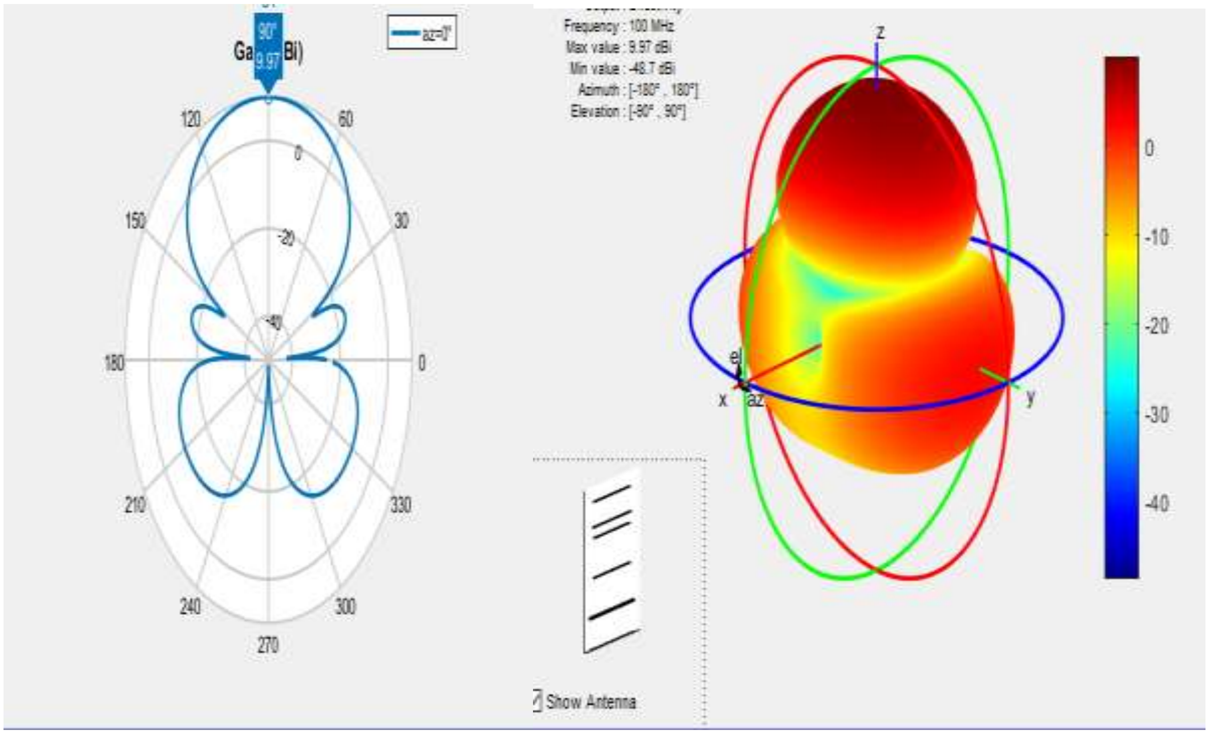


Fig 5.5 2D, 3D Radiation pattern of optimized yagi-uda antenna at N=6

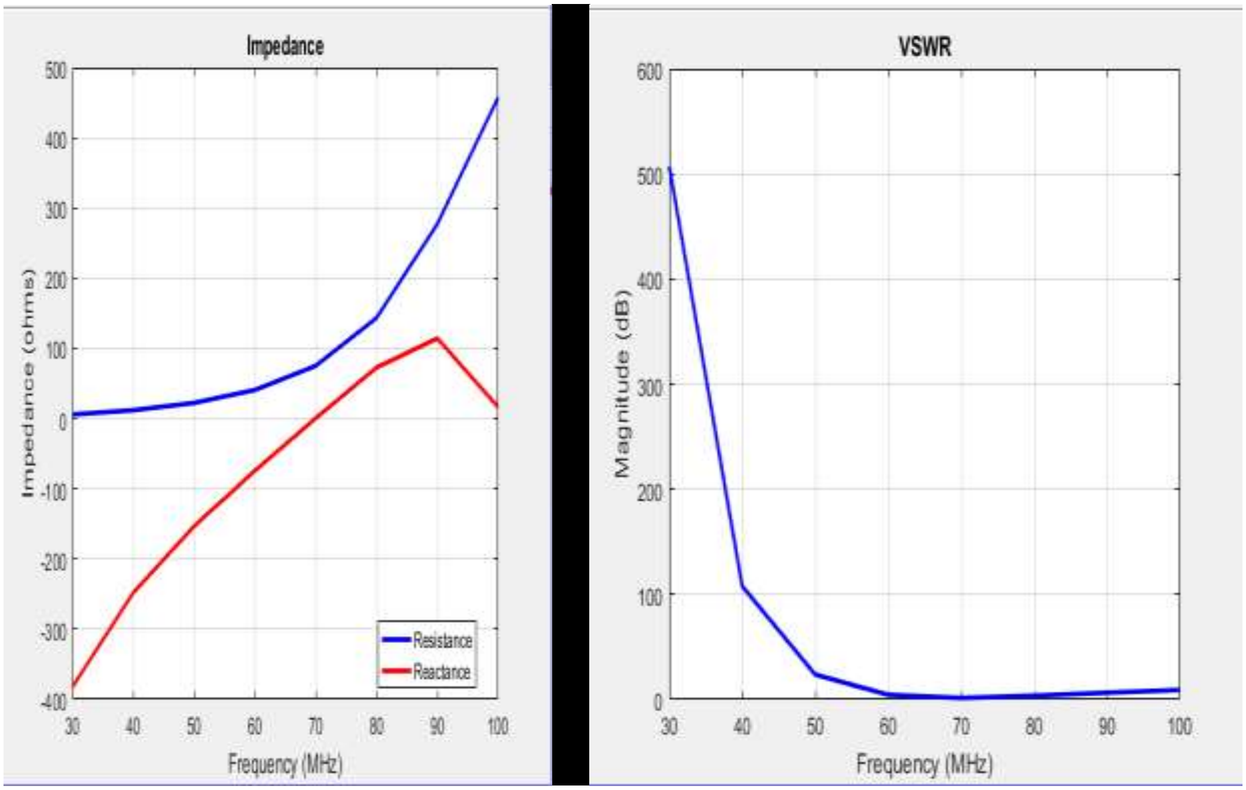


Fig 5.6 a) input impedance and vswr vs frequency for driven element

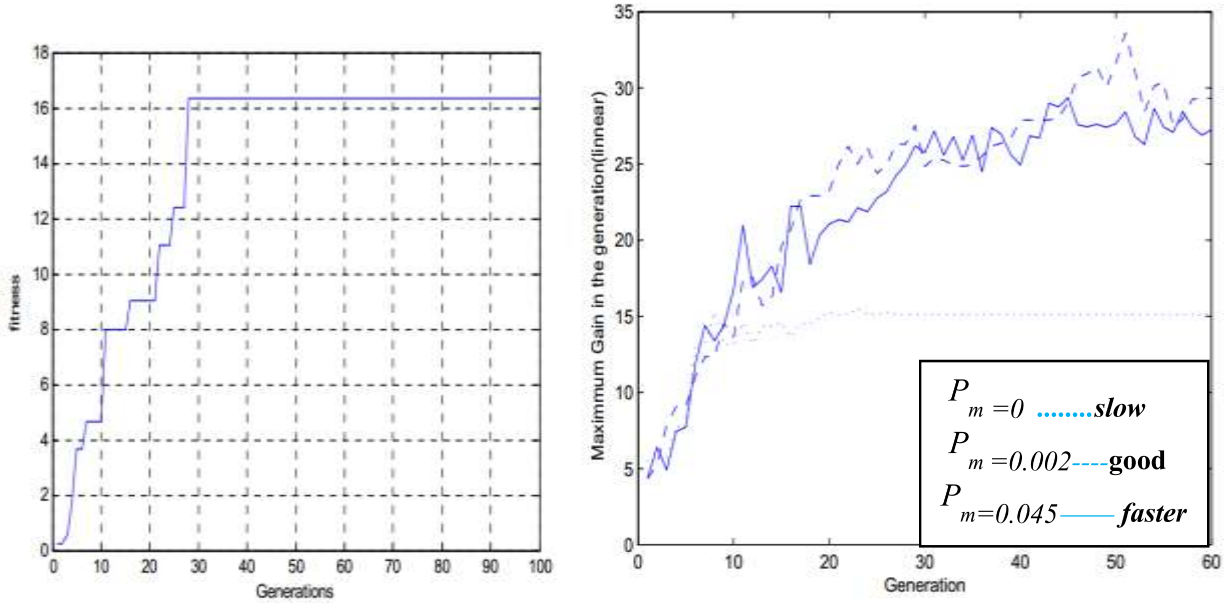


Fig 5.7 a) b) fitness value of 12 element Yagi-Uda   b) GA convergences at different P_m value

5.7 Result Summary

Table 5.1 Four element Yagi-Uda antenna elements spacing and length with optimized gain.

No of Element N=4		Fixed length varying Spacing	Fixed spacing Varying length	Both spacing length varying	GA optimization By using 4Nec2	GA optimization by using matlab
Element length	Ref	0.6λ	0.6λ	0.6λ	0.55λ	0.55λ
	Dri	0.5λ	0.5λ	0.5λ	0.45λ	0.45λ
	Dir1	0.45λ	0.45λ	0.38λ	0.44λ	0.44λ
	Dir2	0.45λ	0.4λ	0.378λ	0.43λ	0.43λ
Element spacing	S1-2	0.11λ	0.1λ	0.1λ	0.1λ	0 .1λ
	S2-3	0.12λ	0.1λ	0.116λ	0.11λ	0.11λ
	S3-4	0.15λ	0.1λ	0.12λ	0.12λ	0.12λ
Gain (dBi)		***6.43***	***6.88***	***6.71***	***6.92***	***6.74***
Input imped		***21.04+j9.56***	***27.5+j29.48***	***14.8+j13.5***	***14.8+j13.5***	
VSWR		***25.4***	***4.5***	***2.7***	***3.5***	***1.32***

Table 5.2 Six element Yagi-Uda antenna elements spacing and length with optimized gain.

No of element N=6		Fixed length varying Spacing	Fixed spacing Varying length	Both spacing length varying	GA Optimization by using (4Nec2)	GA Optimization by using matlab
Element Length	Ref	0.6λ	0.6λ	0.6λ	0.55λ	0.55λ
	Driv	0.5λ	0.5λ	0.5λ	0.45λ	0.45λ
	Dir1	0.45λ	0.45λ	0.45λ	0.44λ	0.44λ
	Dir2	0.45λ	0.43λ	0.42λ	0.43λ	0.43λ
	Dir3	0.45λ	0.41λ	0.41λ	0.42λ	0.42λ
Element spacing	Dir4	0.45λ	0.4λ	0.40λ	0.40λ	0.40λ
	S1-2	0.1λ	0.1λ	0.1λ	0.1λ	0.1λ
	S2-3	0.11λ	0.1λ	0.11λ	0.12λ	0.11λ
	S3-4	0.12λ	0.1λ	0.12λ	0.13λ	0.12λ
	S4-5	0.13λ	0.1λ	0.13λ	0.2λ	0.13λ
	S5-6	0.14λ	0.1λ	0.14λ	0.25λ	0.14λ
Gain (dBi)		***8.21***	***8.32***	***7.84***	***9.2***	***9.97***
Input impedance		***47.9+j12.6***	***32.6+j8.8***	***33.6+j4.94***	***30.5+j5.2***	
VSWR		***3.63***	***3.6***	***3.65***	***2.95***	***1.54***

Table 5.3 Twelve element Yagi-Uda antenna elements spacing and length with optimized gain.

No of element N=12		Fixed length varying Spacing	Fixed spacing Varying length	Both spacing and length varying	GA optimization by using 4Nec2	GA optimization by using matlab
Element lengths	Ref	0.60λ	0.60λ	0.60λ	0.55λ	0.55λ
	Driv el	0.50λ	0.50λ	0.50λ	0.46λ	0.46λ
	Dir1	0.45λ	0.45λ	0.45λ	0.44λ	0.44λ
	Dir2	0.45λ	0.43λ	0.43λ	0.42λ	0.42λ
	Dir3	0.45λ	0.42λ	0.42λ	0.40λ	0.40λ
	Dir4	0.45λ	0.41λ	0.41λ	0.37λ	0.37λ
	Dir5	0.45λ	0.40λ	0.40λ	0.34λ	0.34λ
	Dir6	0.45λ	0.38λ	0.38λ	0.35λ	0.35λ
	Dir7	0.45λ	0.36λ	0.36λ	0.34λ	0.34λ
	Dir8	0.45λ	0.34λ	0.34λ	0.32λ	0.32λ
	Dir9	0.45λ	0.32λ	0.32λ	0.31λ	0.31λ
	Dir10	0.45λ	0.30λ	0.30λ	0.30λ	0.30λ
Element spacing	S1-2	0.10λ	0.1λ	0.10λ	0.10λ	0.10λ
	S2-3	0.11λ	0.1λ	0.11λ	0.11λ	0.11λ
	S3-4	0.12λ	0.1λ	0.12λ	0.12λ	0.12λ
	S4-5	0.13λ	0.1λ	0.13λ	0.13λ	0.13λ
	S5-6	0.15λ	0.1λ	0.25λ	0.15λ	0.15λ
	S6-7	0.26λ	0.1λ	0.26λ	0.20λ	0.20λ
	S7-8	0.27λ	0.1λ	0.27λ	0.22λ	0.22λ
	S8-9	0.13λ	0.1λ	0.13λ	0.23λ	0.23λ
	S9-10	0.15λ	0.1λ	0.15λ	0.25λ	0.25λ
	S10-11	0.18λ	0.1λ	0.18λ	0.30λ	0.30λ
	S11-12	0.20λ	0.1λ	0.20λ	0.35λ	0.35λ
Gain (dBi)		***9.43***	***9.94***	***9.65***	***9.97***	***10.98***
Input impedance		***12.26+j15.78***	***28.38+j11.74***	***29.62+j4.66***	***29.62+j4.66***	
VSWR		***2.26***	***2.78***	***3.77***	***3.35***	***1.65***

CHAPTER SIX

Conclusion and Recommendations for future work

6.1 Conclusion

Yagi-Uda has been designed for home television receiver. In this work Yagi-Uda with single reflector and single folded dipole was designed at 100MHz. The result was simulated and analyzed by using comsol multi-physics, numerical electromagnetic code and matlab software. The reflector numbers, length and reflectors spacing has a little effect on the forward gain, however directors length, spacing and number of directors has high effects on forward gain,standing wave ratio input impedance and front to back ratio as summarized below

- The same director length and director spacing result in less forward gain and poor radiation pattern and high in voltage standing wave ratio.
- Varying director length result in high forward gain than when varying director spacing, while reducing voltage standing wave ratio and reflection coefficient.
- By varying both director spacing and director length the forward gain becomes high for large number of elements than for few number of elements and result in reduced input impedance.
- As number of director increase the forward gain also increased but after some number of elements the effects of number of director becomes insignificant.

Finally by using genetic algorithms with multiobjective optimization methods. The antenna gain was optimized and the result was compared as per the cases mentioned above. The unconventional (optimized) result was 6.74 dBi,9.97 dBi,10.98dBifor N=4,6and12 respectively. On the other the conventional result was 6.71dBi,8.32 dBi and 9.94dBi for the same element number. From the result,one concludes that the conventional design is better for few number of elements,while the unconventional design is better for large number of elements.

6.2 Recommendations for future work

In this work few number of Yagi-Uda antenna elements has been optimized. For further studies large number of elements will be optimized by using different latest algorithms. Yagi-Uda antenna has some limitations such as large size and narrowband character,by making micro stripYagi-Uda antenna or patch Yagi-Uda antenna, these difficulties will be over comes. Another interesting issue is to add substrate on the whole surface of parasitic elements which is the extension of Yagi-Uda antenna into two dimensions. These methods can increase the antenna performance than proper optimization of the parameters.

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APPEDIX

4NEC2 Input file for four element Yagi-Uda antenna

```
CM 4element Yagi-Uda antenna in free space
CM See Get started.txt
CE
SY ref length=1.8       'reflector length
SY dipole length=1.5    'symbol: length WL/2
SY director1=1.44       'director length
SY director2=1.4        'director length
GW      1       9       0       0.9     0       0       -0.9    0       0.0001
GW      2       9       0.3     0.75    0       0.3     -0.75   0       0.0001
GW      3       9       0.5     0.72    0       0.5     -0.72   0       0.0001
GW      4       9       0.7     0.7     0       0.7     -0.7    0       0.0001
GE      0
LD      5       2       0       0       58000000        'trans-line
GN      -1
EK
EX      0       2       9       0       1       0       0       0         'voltage source (1+j1)
FR      0       0       0       0       100     0
EN
```

*4*NEC2 Input file for Six element Yagi-Uda antenna

```
CM 6 element Yagi-Uda in free space
CM See GetStarted.txt
CE
SY ref length=1.8          'reflector length
SY dipole length=1.5    'symbol: length WL/2
SY director1 length=1.44         director length
SY director2 length=1.4     director 3 length=1.36
```

```
SY director4 length=1.32
SY fr =100
GW      1       9       0       0.9     0       0       -0.9    0       0.0001
GW      2       9       0.3     0.75    0       0.3     -0.75   0       0.0001
GW      3       9       0.5     0.72    0       0.5     -0.72   0       0.0001
GW      4       9       0.75    0.7     0       0.75    -0.7    0       0.0001
GW      5       9       1       0.68    0       1       -0.68   0       0.0001
GW      6       9       1.3     0.66    0       1.3     -0.66   0       0.0001
GE      0
LD      5       2       0       0       58000000        'trans-line
GN      -1
EK
EX      0       2       9       0       1       2       0       0       'voltage source (1+j1)
FR      0       0       0       0       100     0
```

4NEC2 Input file for Twelve element Yagi-Uda antenna

```
CM 12 element Yagi-Uda in free space
CM See GetStarted.txt
CE
SY ref length=1.8       'reflector length
SY dipole length=1.5    'symbol: length WL/2
SY director1length=1.44         'director length
SY director2length=1.4
SY director3length=1.4
SY director4length=1.36
SY director5length=1.32
SY director6length=1.24
SY director7length=1.22
SY director8length=1.2
```

```
SY director9length=1.16
SY director10length=1.08
GW  1   9   0     0.9   0   0         -0.9   0   0.0001
GW  2   9   0.3   0.75  0   0.3       -0.75  0   0.0001
GW  3   9   0.5   0.72  0   0.5       -0.72  0   0.0001
GW  4   9   0.75  0.7   0   0.75      -0.7   0   0.0001
GW  5   9   1     0.7   0   1         -0.7   0   0.0001
GW  6   9   1.3   0.68  0   1.3       -0.68  0   0.0001
GW  7   9   1.5   0.66  0   1.5       -0.66  0   0.0001
GW  8   9   1.7   0.64  0   1.7       -0.64  0   0.0001
GW  9   9   1.95  0.62  0   1.95      -0.62  0   0.0001
GW  10  9   2.15  0.6   0   2.15      -0.6   0   0.0001
GW  11  9   2.35  0.58  0   2.35      -0.58  0   0.0001
GW  12  9   2.55  0.54  0   2.55      -0.54  0   0.0001
GE  0
LD  5   2   0     0     58000000  'trans-line
GN  -1
EK
EX  0   2   9     0     1   0         0      'voltage source (1+j1)
FR  0   0   0     0     100 0
EN
```