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Designing a Yagi-Uda Antenna using Genetic Algorithm Technique

Arkadeep Joardar
Department of Electronics & Communication Engineering
Sikkim Manipal Institute of Technology
Majhitar, Sikkim
Email: arkadeepjoardar@gmail.com

Abhinav Abhishek
Department of Electronics & Communication Engineering
Sikkim Manipal Institute of Technology
Majhitar, Sikkim
Email: abhinav.abhishek.1992@gmail.com

Tanushree Bose Roy
Department of Electronics & Communication Engineering
Sikkim Manipal Institute of Technology
Majhitar, Sikkim
Email: contact_tanushree@rediffmail.com

Abstract **– In this project we have proposed a technique to design and optimize a Yagi-Uda antenna with the help of "Genetic Algorithm" (GA) technique. A genetic algorithm code is developed using MATLAB software. All the results of the antenna are tested on software platform. The software used is IE3D software of Mentor Graphics. The aim of this work is to study and observe better directivity, better gain and better efficiency obtained by designing Yagi-Uda antenna with the help of genetic algorithm as compared to other approaches. Fittest solution or optimum solutions of various antenna parameters such as length of active element, length of reflector, length of directors and spacing between these elements are obtained using the genetic algorithm technique and these are utilised to design the Yagi-Uda antenna using the IE3D software. The design involves a Yagi-Uda antenna being developed on a patch. The patch can take many configurations, the most popular being rectangular and circular configurations. Other configurations are much more complex in design and require heavy numerical computations. In this project a rectangular patch is used. The desired Yagi-Uda antenna is simulated by using IE3D simulator. The design is expected to reach high gain, high directivity, high antenna efficiency and to yield a better radiation pattern. Yagi-Uda antennas are physically small in size, low weight and they are highly reliable. Also, such a software controlled antenna presents an interesting option for next generation communication[1].**

Keywords **– Directivity, Efficiency, Gain, Genetic Algorithm, Radiation Pattern, Resonant Frequency.**

I. Introduction

An Antenna is usually a metallic device for radiating and receiving radio waves. Antennas are employed in systems such as radio and television broadcasting, point-to-point radio[5]. A Yagi-Uda Antenna, commonly known simply as a Yagi antenna or Yagi, is a directional antenna system consisting of an array of a dipole and additional closely coupled parasitic elements (usually a reflector and one or more directors). Several critical parameters affecting an antenna's performance are resonant frequency, directivity, gain, radiation pattern and its efficiency[11]. The Yagi-Uda antenna was invented in 1926 by Prof. ShintaroUda of Tokyo Imperial University, Japan and his colleague Prof. H. Yagi explained the operation in English in 1928[7].

The Yagi-Uda antenna is familiar as the commonest kind of terrestrial TV antenna to be found on the roof tops of houses and is a practical radiator in HF (3-30 MHz), VHF (30-300 MHz) and UHF (300-3000 MHz).

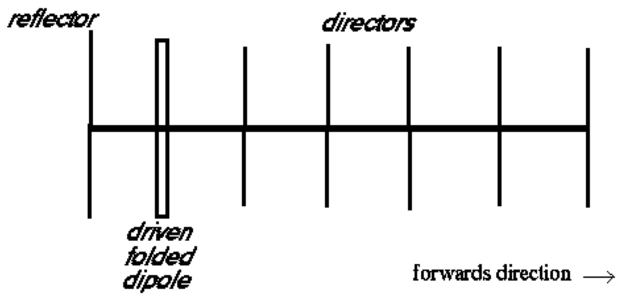

Fig.1. Element Yagi-Uda antenna.

A typical Yagi-Uda antenna consists of three elements – one driven element, a reflector and one or more directors. A detailed description about the antenna elements are as follows –

1) The driven element can be a simple dipole or a folded dipole. The driven element is the only active element in the whole structure of Yagi-Uda antenna. It is directly energized by transmission feed line and it is made up of two aligned conductors of length "λ/4". One conductor is connected to shield of coax cable and other one is connected to the signal. The total length of dipole should be "λ/2" i.e. half of the wavelength. The impedance of the active element is resistive. The folded dipole is used to obtain high impedance for proper matching between transmitter and free space.

2) The reflector is placed at the front side of the Yagi-Uda antenna and the length of reflector is 5% longer than the driven element. The impedance of the reflector is inductive. Reflector resonates at lower frequency than active element. The reflector is used to mitigate the effect of backward wave due to destructive interference.

3) The directors are used to shape the antenna beam. They are parasitic elements and are placed infront of active element. The number of directors in the antenna depends on gain requirements. The impedance of the directors is capacitive. The spacing between directors can affect bandwidth as well as gain of antenna. For achieving better gain, equal spacing between the directors should be done. More directors can be used to increase the gain but adding too many directors will change the impedance. The director resonates at higher frequency compared to active element. Some salient features of Yagi-Uda antenna are-

i) Yagi-Uda antenna is usually used at frequencies between 30 MHz and 3 GHz or wavelength range between 10 m to 10 cm. ii) Only the active element is connected to the feeder. The active element is often a folded dipole

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having impedance 300 ohms to the feeder. iii) Its radiation pattern is almost unidirectional and gives a gain of about 7 dB. However if a patch antenna is used, the radiation pattern will be bi-directional giving a gain of about 5-6 dB. iv) It is used as a transmitting antenna at HF and used for TV reception at VHF. v) Back lobe can be reduced by bringing elements closer but this will reduce input impedance of the antenna and hence there will be mismatch. vi) Yagi-Uda antenna is relatively broadband because of the use of folded dipole[5].

This design involves designing a Yagi-Uda antenna on a patch. A patch antenna is also known as a rectangular microstrip antenna. It is a type of radio antenna with a low profile, which can be mounted on a flat surface. It consists of a flat rectangular sheet or "patch" of metal, mounted over a larger sheet of metal called a ground plane.They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonant frequency. A single patch antenna provides a maximum directive gain of around 6-9 dB. The ability to create high gain arrays in a low-profile antenna is one reason that patch arrays are common on airplanes and in other military applications.

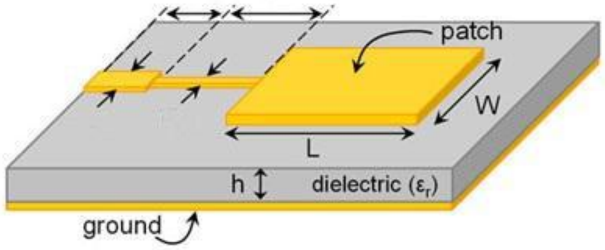

Fig.2. Structure of a patch antenna.

Genetic algorithm (GA) can be defined as a search heuristic and it mimics the process of natural selection[8]. It is a global optimization algorithm derived from evolution and natural selection. This heuristic or a meta-heuristic is used to generate useful solutions to optimization and search problems. Genetic algorithms belongs to the larger class of evolutionary algorithms, which generate solutions to optimization problems using techniques such as inheritance, mutation, selection, and crossover i.e. the techniques inspired by natural evolution[12]. Genetic algorithm finds application inbioinformatics,computational science, engineering, economics, chemistry, manufacturing, mathematics, physics, and several other fields[9]. Genetic algorithms are inspired by Darwin's theory about evolution. Solution to any problem solved by genetic algorithm process is evolved. Although genetic algorithm cannot always provide optimal solution, it has its own advantages and is a powerful tool for solving complex problems[2].

In this antenna design, genetic algorithm is used to find out the various Yagi-Uda antenna parameters such as length of active element, length of reflector, length of the directors, spacing between active element & reflector, and spacing between active element & various directors. Genetic algorithm technique is utilized to find out the fittest or the optimum solution of each of these parameters[8].

II. Modelling

A genetic algorithm code is developed using MATLAB software for finding out values of various antenna parameters.

A. Equations

Yagi-Uda antenna parameters can be found out by the use of following simple formulas –

- Length of active element, La=λ/2=0.5λ
- Length of reflector, Lr=0.515λ
- Length of 1st director, Ld1=0.48λ
- Length of 2nd director, Ld2=0.46λ
- Spacing between active element and reflector, S1=0.29λ
- Spacing between active element and 1st director, S2=0.35λ
- Spacing between active element and 2nd director, S3=0.32λ

B. Flowchart for Genetic Algorithm

The basic thought of Genetic algorithm is:

- Randomly producing a original population whose number of individuals is a constant N.
- Producing next generation by crossing over and mutation among individuals.
- Forming the new population of N individuals from the generation of step 2).
- Producing the next population by repeating the step2) and 3) until obtaining the individual which satisfies conditions.

A typical genetic algorithm requires:

- A genetic representation of the solution domain.
- A fitness function to evaluate the solution domain.

The flowchart can be given by:

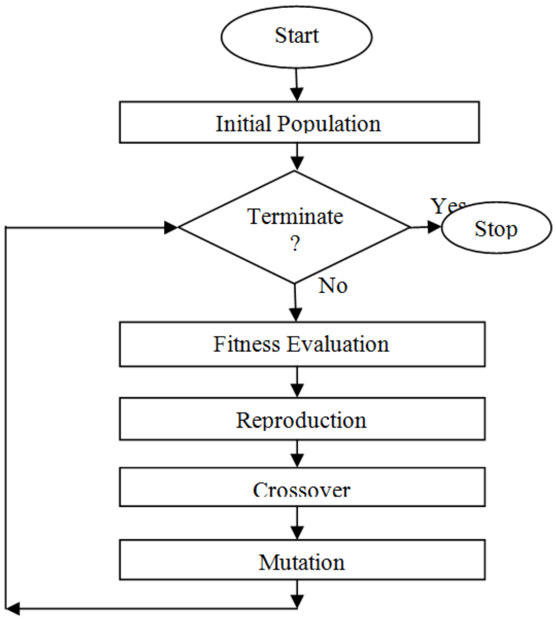

Fig. 3.Flowchart for Genetic Algorithm.

Frequency over which the various antenna parameters operate is considered as the fitness function[6].

C. Antenna Design

After obtaining the optimized values for various Yagi-Uda antenna parameters using the genetic algorithm technique, the antenna is designed using the IE3D software of MentorGraphics.

For comparison between antenna design using genetic algorithm technique and antenna design using conventional technique, another antenna is designed using the same software. In this, simple formulas are used to find out the values of the parameters. These values are not optimum, unlike the values obtained using genetic algorithm technique.

Table 1 shows the values of the input parameters for design of both the antennas:-

Table 1: Comparison between the conventional technique and genetic algorithm technique on the basis of input parameters.

S.No.	Input Parameters	Values using conventional method	Values using genetic algorithm method
1	Length of active element	43.4 mm	43.35260115606936 mm
2	Length of reflector	44.7 mm	44.653179190751444 mm
3	Length of 1st director	41.6 mm	41.61849710982659 mm
4	Length of 2nd director	39.9 mm	39.884393063583816 mm
5	Spacing between active element and reflector	25.1 mm	25.144508670520226 mm
6	Spacing between active element and 1st director	30.3 mm	30.34682080924855 mm
7	Spacing between active element & 2nd director	42.3 mm	42.34682080924855 mm

III. Results and Discussion

After the design of antenna using both the techniques, the output parameters were compared. The output parameters which were taken into consideration were – resonant frequency, directivity, gain and antenna efficiency. The table (2) gives the comparison between the two antenna designs.

From the table (2), it can be clearly seen that using a global optimization algorithm i.e. the genetic algorithm technique to design a Yagi-Uda antenna gives much better values of the different antenna performance characteristics as compared to conventional techniques to design the same antenna. It is also observed the gain obtained using genetic algorithm technique is 4.75, which can be considered to be a good gain when the Yagi-Uda antenna is developed over a patch[10]. It can be clearly seen that the antenna efficiency is much better when we design the antenna using genetic algorithm technique. The efficiency obtained is 92.59%, which is more as compared to the efficiency obtained when we design the antenna using the conventional technique (87.39%). The radiation pattern obtained is bi-directional as patch is being used to design the Yagi-Udaantenna[1]. A uni-directional radiation pattern can be obtained if a monopole is used to design the antenna. Back lobes can be reduced by bringing the elements closer but this will reduce the input impedance of the antenna and hence there will be mismatch. Thus, it can be clearly observed that using a global optimization technique for designing the Yagi-Uda antenna gives much better directivity, gain and antenna efficiency[3].

Table 2 : Comparison between the conventional technique and genetic algorithm technique on the basis of output parameters.

S.No.	Output Parameters	Antenna designed using conventional technique	Antenna designed using genetic algorithm technique
1	Resonant Frequency (GHz)	3.58	3.50
2	Directivity	4.92	5.13
3	Gain	4.3	4.75
4	Antenna Efficiency	87.39%	92.59%

IV. Conclusion

In general, Yagi-Uda antenna is quite difficult to design and optimize due to its sensitivity at high gain and good front-to-back ratio[4]. However, using genetic algorithm technique, Yagi-Uda antennas gives good directivity, gain and antenna efficiency as evident from this discussion. Use of genetic algorithm decreases the complexity of typical mathematical formulas. It gives the optimized values of the required parameters as chosen[12].

As we know Yagi-Uda antenna provides a directional beam in a particular direction, this antenna design can be very helpful in the communication system for many applications in fields such as radar, medical and industrial communication [11]. Yagi-Uda antennas have some limitations such as large size and narrowband character. By making a microstrip Yagi-Uda antenna or patch Yagi-Uda antenna, these difficulties are overcome. As the demand for communication has increased, the use of band has gone from narrowband to wideband and broadband within a very short time. To meet with these increasing demands, more efficient antennas such as patch Yagi-Uda antennas are required.

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AUTHOR’S PROFILE

Arkadeep Joardar
was born in Alipurduar, West Bengal on 18th March, 1994. He is currently in his final year, pursuing Bachelor of Technology (B.Tech.) degree in Electronics and Communication Engineering (ECE) at Sikkim Manipal Institute of Technology (SMIT), Majhitar, Sikkim, India

Abhinav Abhishek
was born in Ranchi, Jharkhand on 24th October, 1992. He is currently in his final year, pursuing Bachelor of Technology (B.Tech.) degree in Electronics and Communication Engineering (ECE) at Sikkim Manipal Institute of Technology (SMIT), Majhitar, Sikkim, India.

Tanushree Bose Roy
was born in Ranchi, Jharkhand on 4th September 1979. She completed her Ph.D. in Design of Printed Antennas using Neural Network in the Department Electronics and Communication Engineering, B.I.T., Mesra, in the year 2011. Presently she is working as an Associate Professor in Sikkim Manipal Institute of Technology, Majitar, Sikkim.