Special Issue - 2019

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
CONFCALL - 2019 Conference Proceedings

Design Optimization of Yagi - Uda Antenna using Antenna Toolbox

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Abstract:- **The Yagi-Uda antenna is a widely used radiating structure for a variety of applications in commercial and military sectors. This antenna has been popular for reception of TV signals in the VHF-UHF range of frequencies [1]. The Yagi is a directional traveling-wave antenna with a single driven element, usually a folded dipole or a standard dipole, which is surrounded by several passive dipoles. The passive elements form the reflector and director. This paper optimizes a 6-element Yagi-Uda antenna for both directivity and 300 ohms input match using a global optimization technique. The radiation patterns and input impedance of antennas are sensitive to the parameters that define their shapes.**

I.INTRODUCTION

1.1 YAGI UDA ANTENNA

The driven element for the Yagi-Uda antenna is a folded dipole. This is a standard exciter for such an antenna. Adjust the length and width parameters of the folded dipole. Since we model cylindrical structures as equivalent metal strips, the width is calculated using a utility function available in the Antenna Toolbox™. The length is chosen to be $\lambda/2$ at the design frequency.

The multidimensional surface over which such optimizations must be performed have multiple local optima. This makes the task of finding the right set of parameters satisfying the optimization goals particularly challenging and requires the use of global optimization techniques. One such technique is pattern search, a direct search based optimization technique that has yielded impressive results for antenna design optimization.

1.2 MATLAB ANTENNA TOOLBOX

- Antenna Toolbox provides functions and apps for the design, analysis, and visualization of antenna elements and arrays. We can design standalone antennas and build arrays of antennas using either predefined elements with parameterized geometry or arbitrary planar elements.
- Antenna Toolbox uses the method of moments (MOM) to compute port properties such as impedance, surface properties such as current and charge distribution, and field properties such as the near-field and far-field
- Radiation pattern. we can visualize antenna geometry and analysis results in 2D and 3D.

- We can integrate antennas and arrays into wireless systems, and use impedance analysis to design matching networks. Antenna Toolbox provides radiation patterns for simulating beam forming and beam steering algorithms. we can generate Gerber files from your design for manufacturing printed circuit board (PCB) antennas.

II. DESIGN ASPECTS

2.1 DESIGN:

STEP: 1 CREATE YAGI-UDA ANTENNA

Create a Yagi-Uda antenna with the exciter as the folded dipole. Choose the reflector and director length to be $\lambda/2$. Set the number of directors to four. Choose the reflector and director spacing to be 0.3λ, 0.25λ respectively. These choices are an initial guess and will serve as a start point for the optimization procedure. It shown the initial design in Fig 1.

Prior to executing the optimization process, plot the radiation pattern for the initial guess in 3D shown in Fig 2.

This initial Yagi- Uda antenna does not have a higher directivity in the preferred direction, meaning at zenith (elevation = 90 deg) and is therefore a poorly designed radiator
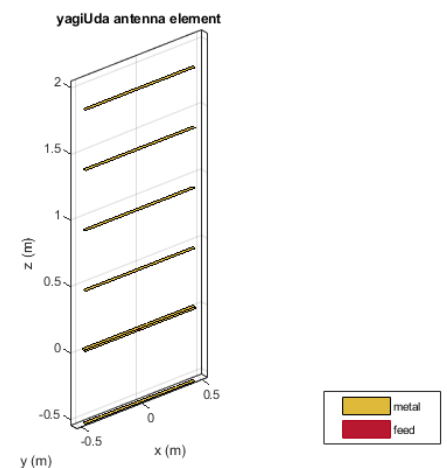

FIG : 1 DESIGN OF 6 ELEMENT YAGI-UDA

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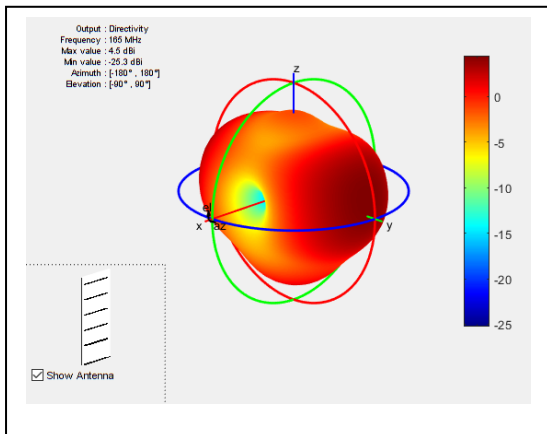## STEP: 2 PLOT RADIATION PATTERN AT DESIGN FREQUENCY


FIG : 2 RADIATION PATTERN

STEP : 3 SET UP OPTIMIZATION

Use the following variables as control variables for the optimization:

- Reflector length (1 variable)
- Director lengths (4 variables)
- Reflector spacing (1 variable)
- Director spacing (4 variables)
- Exciter length (1 variable)
- Exciter spacing (1 variable)

In terms of control Vals, set an objective function that aims to have a large directivity value in the 90 degree direction, a small value in the -90 degree direction, and a large value of maximum power between the elevation beam width angle bounds. In addition to the directivity goal an impedance match condition is also included as a constraint. Any constraint violations will penalize the objective

III IMPLEMENTATION
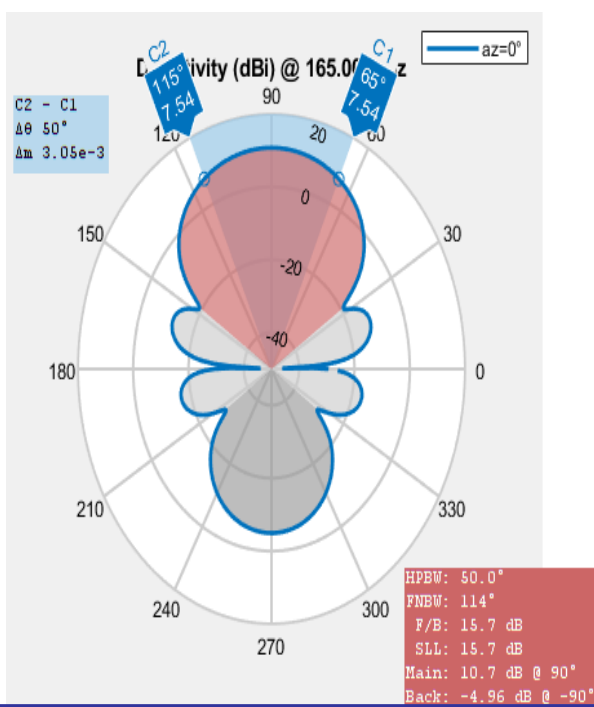
DIRECT SEARCH BASED OPTIMIZATION

The Global Optimization Toolbox™ provides a direct search based optimization function called pattern search. We use this function with options specified with the psoptimset function. At every iteration, plot the best value of the objective function and limit the total number of
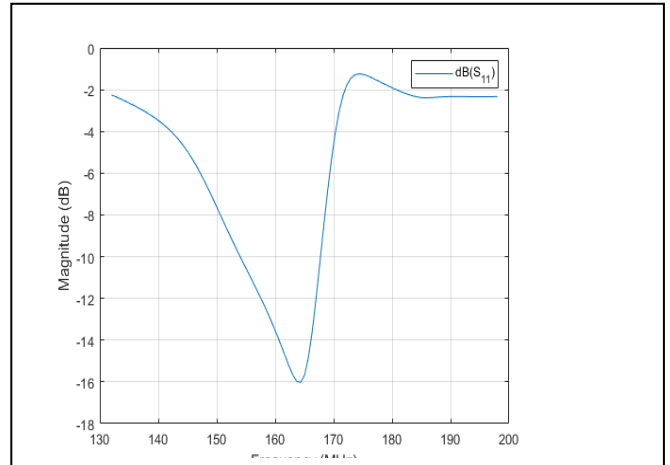
iterations to 300. Pass the objective function to the pattern search function by using an anonymous function together with the bounds and the options structure. The objective function used during the optimization process by pattern search is available in the file yagi -objective_function.

The evaluation of the directivity in different directions corresponding to the angular region defined for maximum radiation as well as maximum side lobe/ and the back lobe level is given in the calculate_objectives available within yagi_objective function. The result is shown in Fig 3.

STEP: 4 PLOT OPTIMIZED PATTERN

Plot the optimized antenna pattern at the design frequency This is shown in Fig :4
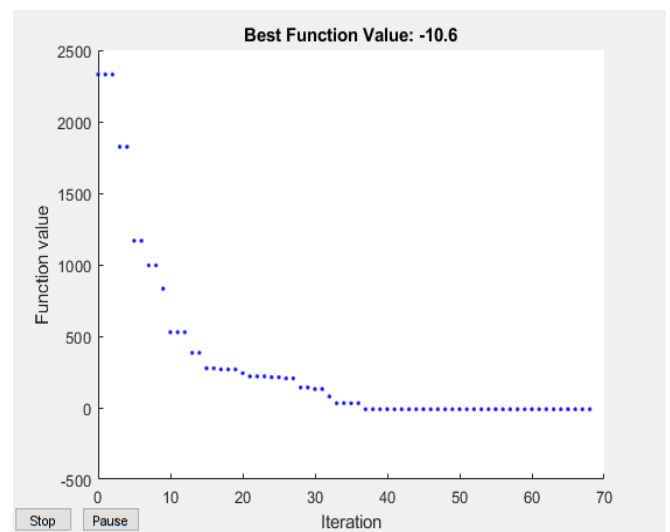

FIG 5: OPTIMIZED PATTERN

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STEP: 5 E AND H-PLANE CUTS OF PATTERN

To obtain a better insight into the behaviour in the two orthogonal planes, plot the normalized magnitude of the electric field in the E and H-planes, i.e. azimuth = 0 and 90 deg respectively. Enable the antenna metrics on the polar pattern plots to establish the directivity at zenith, Front-to-Back ratio, and the beam width in E and H-planes. This is shown in **FIG: 5**

FIG: 5 E AND H-PLANE CUTS OF PATTERN

The optimized design shows a significant improvement in the radiation pattern. There is higher directivity achieved in the desired direction toward zenith. The back lobe is small resulting in a good front to back ratio for this antenna.

STEP: 6 INPUT REFLECTION COEFFICIENT OF OPTIMIZED ANTENNA

The input reflection coefficient for the optimized Yagi-Uda antenna is computed and plotted relative to the reference impedance of 50Ω. A value of -10 dB or lower is considered as a good impedance match. This is shown in Fig:6
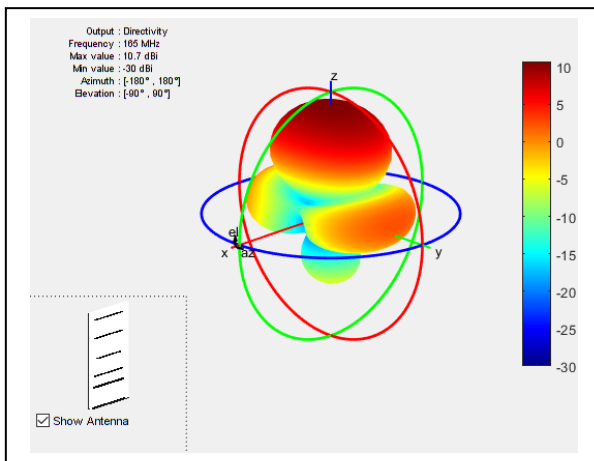

FIG:6 INPUT REFLECTION COEFFICIENT OF OPTIMIZED ANTENNA

IV. RESULT AND DISCUSSION

Comparison with Manufacturer Data Sheet

The optimized Yagi-Uda antenna achieves a forward directivity greater than 10 dBi, which translates to a value greater than 8 dBd (relative to a dipole). This is close to the gain value reported by the datasheet (8.5 dBd). The F/B ratio is greater than 15 dB. The optimized Yagi-Uda antenna has a E-plane and H-plane beamwidth that compare favorably to the datasheet listed values of 54 degrees and 63 degrees respectively. The design achieves a good impedance match to 300Ω, and has a -10 dB bandwidth of approximately 8%.

TABULATING INITIAL AND OPTIMIZED DESIGN TABULATE THE INITIAL DESIGN GUESSES AND THE FINAL OPTIMIZED DESIGN VALUES.

TABLE :1 COMPARISON OF DATA SHEET VALUE AND OPT. VALUE

S.NO	PARAMETER	DATA SHEET VALUE	OPT. SIGNAL VALUE
1.	GAIN (DBI)	10.5	10.6
2.	F/B	16	15.7
3.	E-PLANE BEAMWIDTH (DEG.)	54	50
4.	H-PLANE BEAMWIDTH (DEG.)	63	60
5.	IMPEDANCE BANDWIDTH (%)	10	9

IV CONCLUSION

In this paper the author discussed about the procedure for designing the yagi-Uda antenna with 6 element and optimized by direct search method . The Matlab antenna toolbox is an efficient tool for effective designing and analysing the yagi Uda antenna . In the future work the author introduces the optimization with increasing the number of element ..

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