Yagi Antenna with Minimal Side-Lobe Levels for UHF

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Abstract – **In this paper a 9-element Yagi antenna is presented. The antenna is designed and optimized for 70-cm UHF band. Optimization is done for minimizing side and back-lobe levels in exchange of lower antenna gain. The proposed antenna incorporates a folded half-wave dipole as driven element.**

Keywords – **Yagi antenna, UHF, side-lobe.**

I. INTRODUCTION

Yagi antennas are a subset of the traveling wave antenna type. Since their introduction, they have found many use cases over the past century. Their popularity has grown due to the ease of construction and achieving high directivity. Generally, higher directivity is achieved by increasing the antenna length, however, this usually results in higher side-lobe levels as well. Although, Yagi antennas have received exhaustive analytical investigations shaping the radiation pattern still requires some experimental work [1, 2]. This paper proposes a Yagi antenna design which minimizes the side and back-lobe radiation. Simulation and optimization is done using 4nec2 software which is based on the Method of Moments (MoM) [3].

II. ANTENNA GEOMETRY

The proposed Yagi antenna geometry consist of a total of 9 elements, 8 of which are parasitic. The elements are as follow: reflector element, a driven element and 7 directors. The reflector is positioned behind the driven element in respect to the axis of propagation. The driven element is chosen to be a half-wave resonant folded dipole. The lengths and spacing between the 7 directors are optimally chosen to achieve the best compromise between achieved gain, input impedance and a single lobe radiation pattern. The diameter of the elements is chosen at 6 mm. The geometry is shown in Fig. 1. The physical dimensions as labeled in Fig. 1 are given in Table 1, where b1 is the length of the folded dipole and b2 is the distance between the two halves. All measurements are in cm. All physical dimensions are rounded to 0,5 centimeters for ease of construction which has been taken into account while optimizing and simulating.

A second antenna based on data from [2] for achieving maximum gain was modeled as a base for comparison. Its physical dimensions are given in Table 2. Labels remain the same as in Fig. 1. Diameter of rods has been changed to 0,63 cm (0,25 inches) to match the conditions in [2].

TABLE I
OPTIMIZED MINIMAL SIDE-LOBE LEVELS ANTENNA DIMENSIONS

a	**b1**	**b2**	**c1**	**c2**	**c3**
33	29,5	5	30	28	22
c4	**c5**	**c6**	**c7**	**d0**	**d1**
21	21	21	17	13	7,5
d2	**d3**	**d4**	**d5**	**d6**	**d7**
6,5	7	7	7	8	6

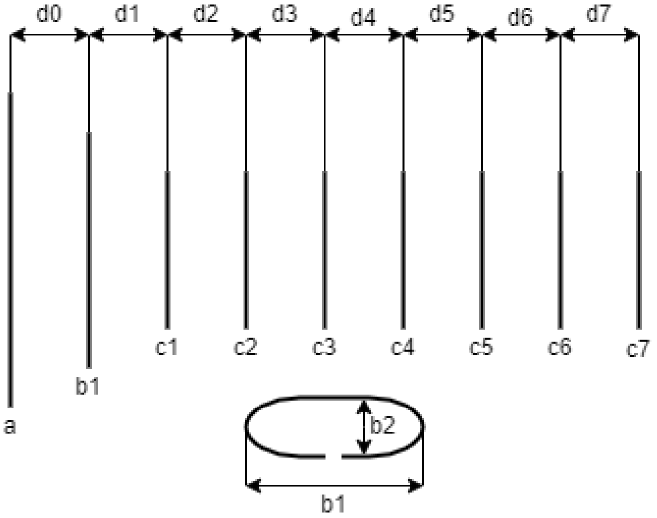

Fig. 1. Antenna geometry

TABLE II
MAXIMUM GAIN ANTENNA DIMENSIONS

a	**b1**	**b2**	**c1**	**c2**	**c3**
33,59	29,8	4,1	30,11	28,92	28,37
c4	**c5**	**c6**	**c7**	**d0**	**d1**
27,74	27,18	27,18	27,18	13,94	13,94
d2	**d3**	**d4**	**d5**	**d6**	**d7**
13,94	13,94	13,94	13,94	13,94	13,94

III. SIMULATION RESULTS

The MoM-based 4nec2 software is used to simulate the antenna parameters and optimize its characteristics Optimization is done by adjusting the length and spacing of the directors using a local search hill climb algorithm Center frequency is set to 430 MHz and sweeps are calculated from 400 MHz to 460 MHz. The simulated radiation patterns for the center frequency in vertical plane (Theta = -180÷180°) in Phi=0° and Phi=90° cuts are given in Fig. 2 and Fig.3 respectively. The minimal side-lobe level MSL pattern is given in blue while the optimized for maximum gain MG pattern in

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orange. Beamwidth at half power for the MG antenna is 45° in the Phi=0° cut and 40° in the Phi=90° cut. The MSL pattern has increased beamwidth of 80° and 60° respectively for the Phi=0° and Phi=90° cuts. Comparing the MSL and MG patterns makes it clear that a significant reduction of side-lobe levels is achieved in expense of broadening the main beam and loss of directivity.

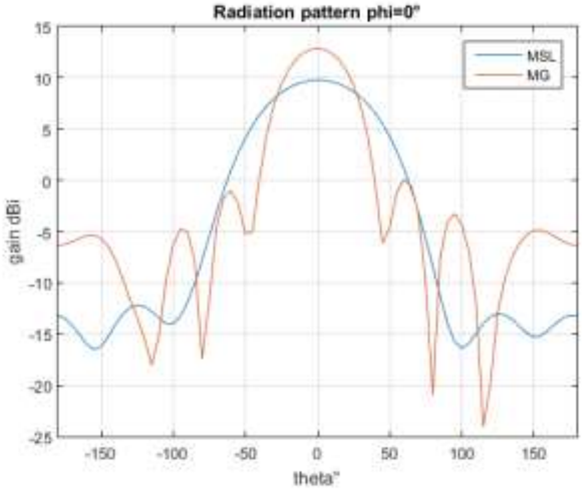

Fig. 2. Simulated radiation patterns for 430 MHz. Phi=0°.cut

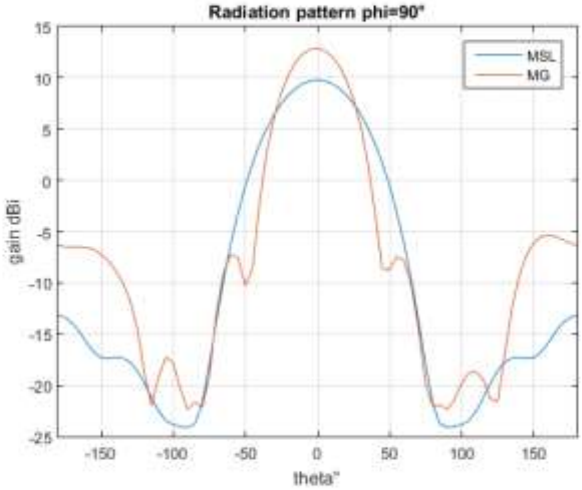

Fig. 3. Simulated radiation patterns for 430 MHz. Phi=90° cut.

Front-to-back or F/B ratio is measured as the difference between the maximum gain and the gain at Theta=180°. MG design has a F/B ratio of 19,2 dB while the MSL antenna increases it to 23 dB.

Fig4 displays the MSL antenna gain as a function of frequency in the Phi=0° cut. The maximum realized gain is 9,8 dBi. This is a 3 dB reduction from 12,8 dBi compared to the MG design (Fig.2 and Fig.3). The MSL antenna's gain increases proportionally with frequency.

Return loss of the MSL antenna is plotted in Fig.5. Calculations for the reflection coefficient are made considering a characteristic impedance of 75 Ω. The fractional bandwidth measured at -10 dB reflection coefficient is 24 MHz (5,58%). A perfect match is achieved at center frequency 430 MHz.

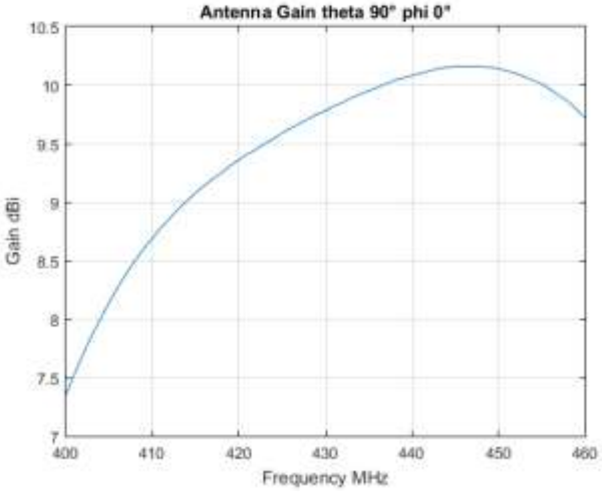

Fig.4. Antenna gain

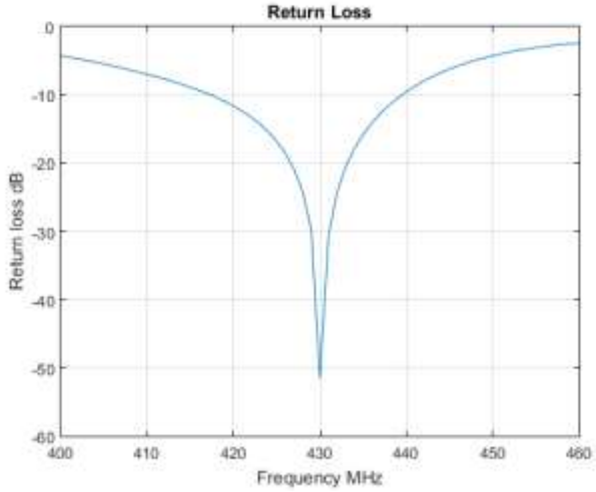

Fig. 5. Return loss

IV. CONCLUSION

A 9-element Yagi antenna with minimal side lobes and backwards radiation is presented in this study. The antenna achieves high gain in a relatively wide bandwidth. Input impedance of 75 Ω allows for easy matching to a wide variety of communication modules. The single lobe radiation pattern allows for simple and precise positioning and higher signal-to-noise ratio can be expected. The proposed design is going to be used in future work as base for narrowing the beamwidth, thus increasing the directivity. This Yagi antenna can find its use in the UHF band for communication with Low Earth Orbit satellites the likes of CubeSats.

REFERENCES

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[3] www.qsl.net/4nec2/