10-Element Yagi Antenna For 38 GHz Frequency

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***Abstract*—In this paper, our primary emphasis is on investigating the Yagi antenna at a working frequency of 38 GHz, and evaluate antenna characteristics such as return loss, gain, directivity and radiation pattern. The material for making the antenna consists of PEC pipes as reflector element, driven element and director elements with a diameter of 0.2 mm. The design of the Yagi antenna uses CST studio suite 2021 software. The proposed antenna has return loss values of -16.29 dB, and attains a peak gain of 10.88 dBi for 38 GHz millimeter wave-band. The proposed antenna's performance in terms of radiation efficiency, directivity, gain, and radiation pattern positions it as a viable option for 5G millimeter-wave communication.**

Keywords—Yagi antenna; reflector; driven; director; millimeter-band.

I. INTRODUCTION

The millimeter-wave band emerges as a highly promising solution for fifth-generation mobile communication, primarily due to the availability of a broad spectrum [1][2]. However, the signal attenuation and propagation loss of millimeter-waves will be to choose high gain antennas [3]. High-gain arrays incorporating electrically small antenna (ESA) elements are often pursued to ensure robust received signals or to minimize input power to transmitters, particularly in electronic systems requiring compact dimensions [4]. Recently, there has been a growing interest in the millimeter-wave (mm-Wave) endfire antenna. The Yagi antenna, initially proposed in 1926 [5], serves as a fundamental reference point in this development. The Yagi antenna is highly compatible with mm-Wave endfire radiation owing to its structural benefits, low-profile design, and ease of fabrication [5]. Yagi antennas arrays have been employed in industrial, scientific, and medical (ISM) contexts operating at 2.4 GHz, where directional radiation is imperative, for facilating long distance and point-to-point wireless communications [6] due to their advantages, such as high gains, high bandwidths, endfire radiation patterns, and ease integration with other microwave circuits. The Yagi antenna comprises a reflector element, a driven, and one or more directors [7][8]. The Yagi antenna, incorporating integrated filtering capability, merges filtering functionality with endfire radiation. This integration not only diminishes system size and loss but also elevates the overall integration level [9]. In addition, the Yagi antenna has typically been used to enhance directivity [10].

This paper introduces a novel Yagi array antenna design, capable of attaining substantial gain while minimizing backside radiation across a range of applications, including those extending into the millimeter-wave frequency spectrum. Simulation results for the suggested antenna show that S11 is -16.29 dB, attains an elevated gain of 10.88 dBi at the resonant frequency of 38 GHz, and the results show good agreement which covers the 38 GHz band.

II. ANTENNA DESIGN

During the antenna design phase, the process involves specifying key parameters such as working frequency, Return Loss, and Bandwidth. After obtaining the specifications for the antenna design process the next step involves simulating the calculation of the antenna element length and the distance between elements. The process of designing the antenna can be outlined as follows:

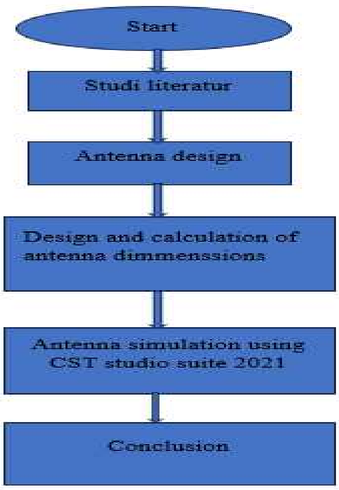

Fig. 1. System block diagram.

Whithin the scope of this study, a Yagi antenna with 10 elements will be designed. Prior to starting the antenna design process, we must first determine the specifications of the antenna to be designed and then proceed to perform dimensional calculations for the Yagi antenna.

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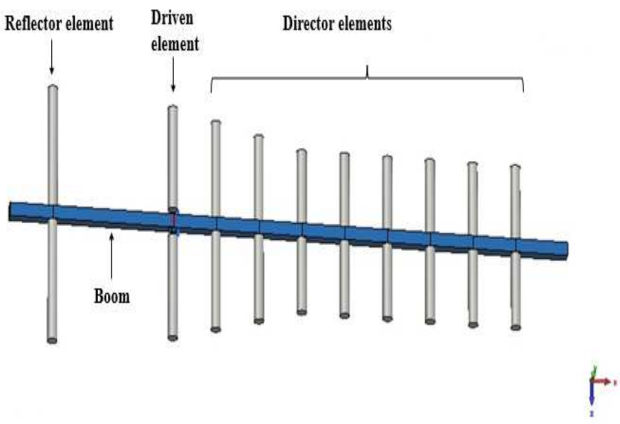

Fig. 2. Design of 10-element Yagi antenna.

The Yagi antenna comprises multiple elements, including a reflector, driven element, directors, boom, feed line, as shown in Fig. 2. The reflector reflects radio waves forward, increasing anntena directivity and gain, the driven element is connected to the feed line and receives or transmits radio waves, directors aid in concentrating and guiding radio waves towards specific directions, the boom serves to stabilize the antenna and facilitates mounting and alignment, while the feed lines establish connections between the antenna and transmitters or receivers [11]. Our structure is feeding by a 50-ohm discrete face port.

During the antenna design process, determining the size of each antenna element is crucial. Before starting this calculation for the Yagi antenna, all antenna parameters are computed and optimized presented in TABLE. I, and the resonant frequency of the intended antenna must be determined by:

$$\lambda = \frac{c}{f} = \frac{3 \times 10^{8} m/s}{38 \times 10^{9} GHz}$$

The relationship between the wavelength (λ) and the overall size of a Yagi antenna is crucial in determining its design and performance. The lengths of the elements (reflector, driven element, and directors) in a Yagi antenna are typically fractions of the wavelength. The reflector length is determined by 0.55λ, and the driven element is typically about 0.5λ. The directors are shorter than the driven element, with lengths as follows: L_Director_1 = 0.45λ, L_Director_2 = 0.40λ, and L_Director_3 = 0.35 λ. The spacing (S) between the driven element and the first director is typically between 0.1λ and 0.15λ, for additional directors, the spacing can be up to 0.25λ. In this work, there the spacing between driven element and the first director (S_Driven_Director) is given as 0.125, and S_Reflector = 0.35. In addition, S_Reflector_Driven = S_Reflector × λ.

TABLE I. OPTIMIZED PARAMETERS OF YAGI ANTENNA.

No	Element type	Element length(mm)
1	L_Reflector	4.34
2	L_Driven element	3.94
3	L_Director_1	3.55
4	L_Director_2	3.15
5	L_Director_3	2.76
6	S_Reflector	0.35
7	S_Dipole_Director	0.125

III. RESULTS AND DISCUSSION

The simulation results for the Yagi antenna reveal promising performance metrics. Fig. 3 shows the reflection coefficient as a function of frequency, we can see that the Yagi antenna performance is at the limit of what is acceptable with a -16.29 dB at 38 GHz. From Fig. 4 The surface current distribution on a Yagi antenna typically follows a pattern where the driven element, directly connected to the transmission line, exhibits the highest current (elements positioned in front of the driven element). This current gradually diminishes towards the director elements and increases towards the reflector element (element positioned behind the driven element).

In Figs. 5 and 6: show the antenna radiation patterns in 2D in E plane (Phi=0º), H plane (Phi=90º), and in 3D with a maximum directivity value of 10.9 dBi towards the director elements, and an efficiency of 99%, and norrow beamwith of 51.7º as illustrated in Fig. 6. (e). Regarding to the simulated gain shown in Fig. 7 we notice that the gain value is excellent at a value of 10.88 dBi at resonant frequency 38 GHz and the antenna gain is largely positive over the entire frequency range from 26 GHz to 45 GHz.

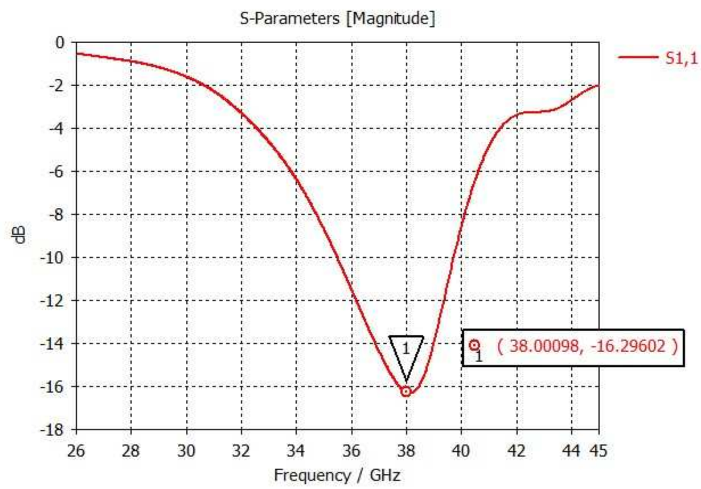

Fig. 3. The Yagi antenna return loss.

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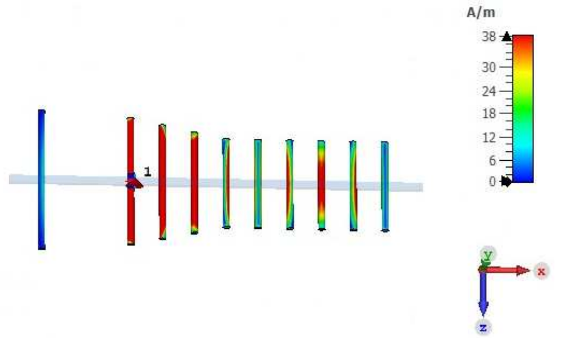
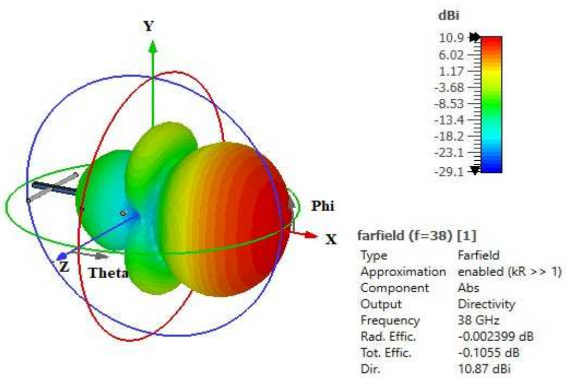
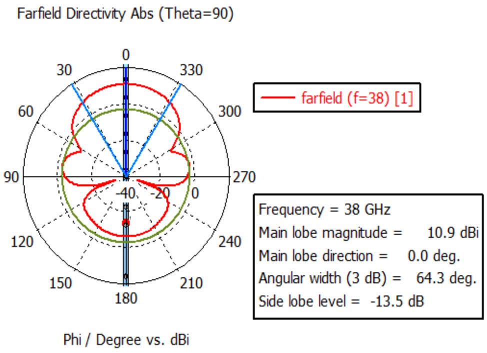


Fig. 4. Surface current distribution for a Yagi antenna aperating at 38 GHz.



(a)



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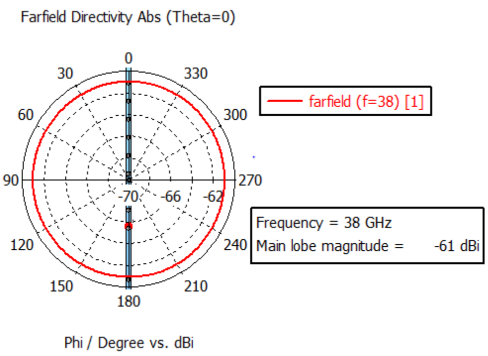

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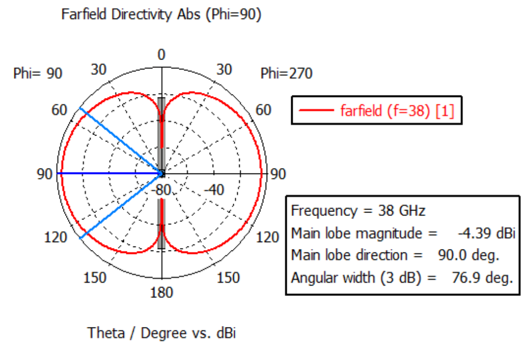

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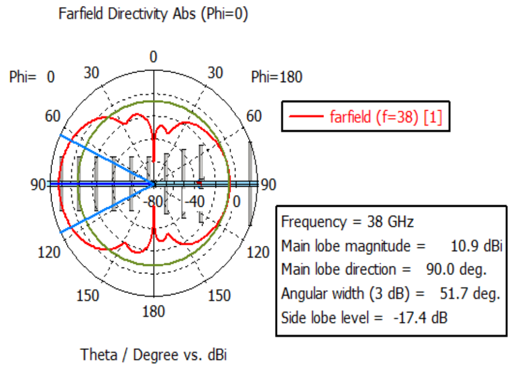
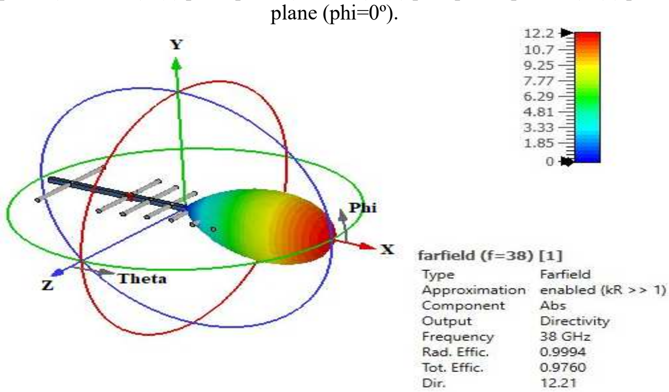
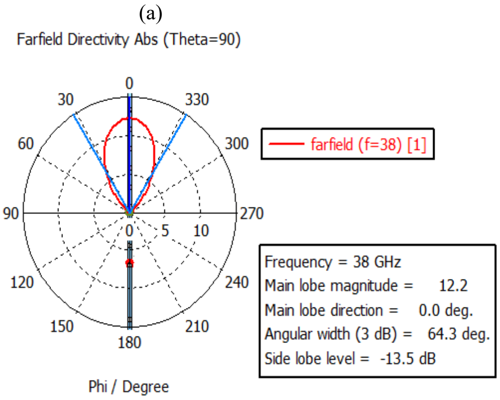


(e)

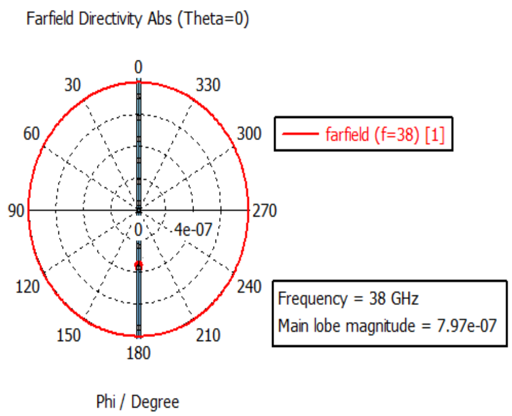
Fig. 5. Radiation pattern at 38 GHz in logarithmic scale, (a) 3D view, (b) polar plane (theta=90º), (c) polar plane (theta=0º), (d) plan polar (phi=90º), (d) polar plane (phi=0º).



(a)



(b)



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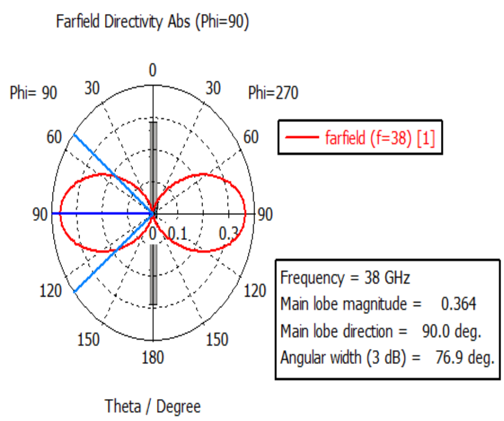
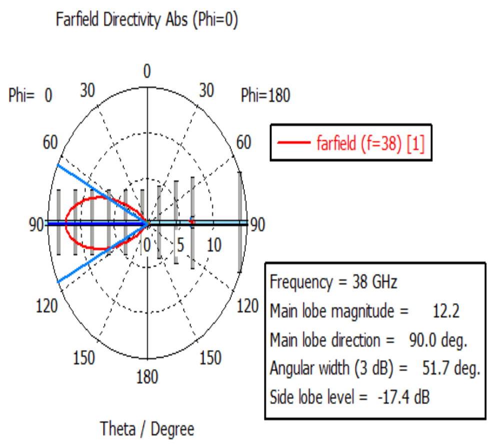


(d)



(e)

Fig. 6. Radiation pattern at 38 GHZ in linear scale, (a) 3D view, (b) polar plane (theta=90º), (c) polar plane (theta=0º), (d) plan polar (phi=90º), (d) polar plane (phi=0º).

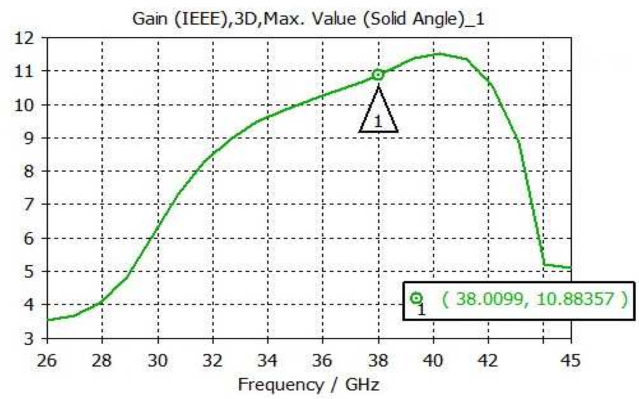


Fig. 7. The Yagi antenna simulated gain.

CONCLUSION

This communication presented a millimeter-wave Yagi antenna for working frequency at 38 GHz, where the return loss value is -16.29 dB, and an average gain about 10.88 dBi, efficiency of 99%, narrow beamwith of 51.7º, and the radiation pattern formed is unidirectional. This antenna can be scaled for automotive radars and high data-rate communication systems.

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