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Printed High-Gain Yagi Antenna for 5G Applications

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***Abstract*— A Yagi printed antenna is designed in this work to achieve a high gain for using in mobile communication. The proposed antenna operates at 3.59 GHz between [3.4-3.8] GHz. The use of four directors exhibits a good return loss of -34.56 at 3.59 GHz wi th a bandwidth of 149.1 MHz between 3.5229 GHz and 3.672 GHz, directional energy patterns and linearly increasing gain ranging of 10.35 dB over the entire bandwidth. The results are very satisfactory and the Yagi antenna can be integrated for 5 G applications enabling its usability for point-to-point and point-to-mul tipoint communication links.**

***Keywords*— Microstrip antenna, yagi-uda antenna, mobile communications, 5G applications, directional radiation pattern.**

I. Introduction

Over the past ten decades, wireless communications have developed exceptionally. Today's communications systems are evolving at breakneck speed. Antennas play an essential role as the e yes and ears of our world, establishing our links with the space around us. These antennas are indispensable to wireless communications, and they also ensure OEM transmission and reception in space. Despite this, their integration into systems requires sma ll sizes and high performance. Microstrip antennas are widely used compared with other types of antennas, due to their lightweight, low cost and ability to be integrated into mobile devices. However, they have drawbacks such as low gain and narrow bandwidth. These limitations can be overcome by using the Yagi-Uda antenna, which was invented in 1926 by Dr. H. Yagi and Shintaro Uda. Its configuration normally consists of a number of directors and reflectors that enhance radiation in one direction when properly arranged on a supporting structure [1] that offers both. high bandwidth and efficient radiation performance. Micros trip YAGI Antenna is an antenna consisting of driven elements and some parasitic elements, including a reflector and director [2]. YAGI antenna, one of the most common antennas to achieve high gain, has been used successfully over decades due to its easy design structure and low cost with a single feed. However, the YAGI antenna needs a sizable volume/area. The parasitic elements called the reflector and the directors, are usually spaced approximately 0.25λ away from the driver. Additionally, each element, including the driver and parasitic elements, has a length of close to λ/2 [1].

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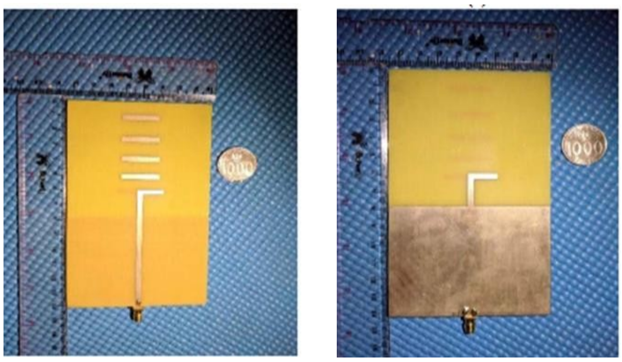

(a) (b)

Fig. 1 Fabricated Yagi antenna by [3] (a) top view and (b) bottom view

YAGI microstrip antennas have been the subject of several research papers. In a study by [4], the first YAGI microstrip antenna was presented. It comprises driven elements and parasitic patches (reflector and director elements) located on the same plane, used for the mobile satellite system (MSAT). YAGI-Uda dipole antenna operating at [3.4-3.8] GHz was designed and built for 5G applications [3]. A presentation was given on the design and results obtained with single-beam and dual- beam dipole antennas. First, the authors designed a printed dipole antenna with a single director. A printed dipole antenna with four directors was then studied to increase antenna gain. Finally, they developed a special dual-beam antenna for the node in a linear configuration. This antenna was designed as part of the ANR project called CAPNET, dedicated to site security (autonomous sensor network). In conclusion, they simulated, realized, and characterized all the antennas , measuring their return loss, radiation patterns, and gain. They noted very favorable results in terms of gain and obtained an accurate comparison between simulations and measurements [5]. Further work was presented by [6] ; They have developed a Yagi-Uda 5G linear array antenna specifically for vehicular applications. This array consists of two radiating elements with eight parasitic elements each, and its overall dimensions are 110×60×1.6mm3. Their[7] presented a modified broadband Quasi-Yagi microstrip antenna. This antenna consists of an insulated microstrip acting as director, a microstrip dipole acting as driver, and a truncated ground plane at the rear of the substrate serving as a reflector. The two arms of the driver dipole are positioned on opposite sides of the substrate. One arm is fed by the tapered strip of the 50-Ω microstrip feedline, while the other is fed by the tapered strip of the truncated ground plane. There have been several generations since the advent of mobile technology. Among them, the first was 1G, followed by 2G, 3G, 4G, and finally 5G. Throughout history, communication systems have evolved significantly with each new iteration [8]. The Fifth-generation (5G) technology[8], which is developing rapidly to meet the growing demand for mobile communications [9], has been designed to overcome the limitations of fourth-generation (4G) technology [8]. The key aspect of 5G is the ability to achieve and maintain data rates around 10 Gbps, delivering a superior customer experience by speeding up downloads and uploads[10].5G frequencies are grouped into three categories: low frequencies, medium frequencies, and high frequencies [11]. 5G mobile networks are extending their reach to enable higher data rates. In 2015, the World Radio Communication Conference (WRC) allocated frequency bands below 6 GHz, sparked debate. Several frequency bands were proposed, including 470-694 MHz, 1427-1518 MHz, 3300-3800 MHz, and 4500-4990 MHz Of these, the 3.5 GHz frequency band was preferred, as it is recognized by most countries [12]. Printing antennas for 5G technology is the subject of a number of research projects. In a paper by [13], a microstrip antenna for 5G, operating at 3.5 GHz with a gain of 3.661 dB, was designed and implemented. In another work [14], the aim was to design and simulate an antenna based on metamaterials in order to miniaturize the dimensions of planar antennas. Firstly, they modelled and designed a rectangular patch antenna with notches. This was used to better adapt the antenna to the resonant frequency of 3.5 GHz, with a gain of 6.2 dB. This study preceded the design of a four-element antenna. This research demonstrates commitment to the development ofof printed antennas optimized for 5G technology in a variety of geometric configurations.

In this work, we simulate a printed Yagi antenna between [3.4-3.8] GHz printed on an FR-4 substrate, having permittivity $\varepsilon r = 4.3$, thickness $h = 1.5$ mm, and dielectric loss tangent of 0.025. We used four directors to achieve a high gain for using in 5G applications enabling its usability for point-to-point and point-to-multipoint communication links.

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II. ANTENNA DESIGN

In figure 2, a printed Yagi dipole antenna with a permittivity of 4, 35 and a thickness of 1.5 mm was simulated on FR4 substrates. We calculated the antenna dimensions using [1] to operate between [3.4 - 3.8] GHz for 5G applications.

$$Lde = 0.47\lambda \quad (1)$$

$$Ldi = 0.406\lambda \quad (2)$$

$$Lr = 0.76\lambda \quad (3)$$

$$Sr = 0.25\lambda \quad (4)$$

$$Sdi = 0.34\lambda \quad (5)$$

The width of the feed line from the following equation (6) [3]:

$$W = \frac{2h}{\pi}\left\{B-1-\ln(2B-1)+\frac{\varepsilon r-1}{2\varepsilon r}\left[\ln(B-1)+0.39-\frac{0.61}{\varepsilon r}\right]\right\} \quad (6)$$

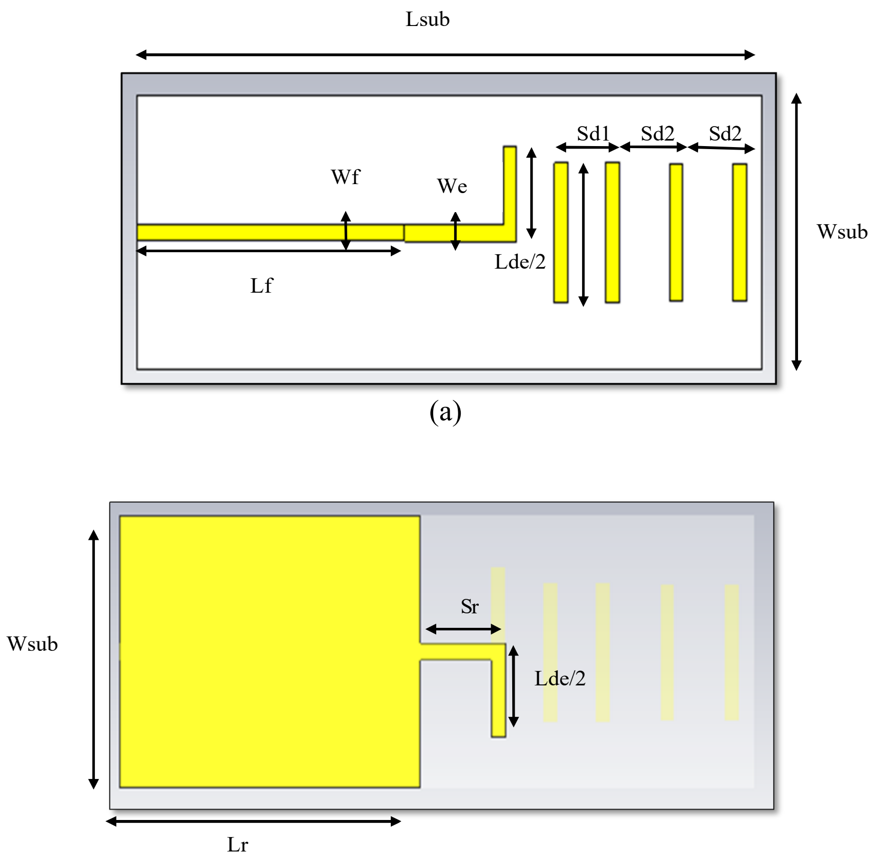

Fig. 2 Yagi dipole printed antenna, (a) top view, (b) bottom view

All numerical dimensions can be detailed on table I as below:

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TABLE .I

DIMENSIONS OF THE PROPOSED YAGI ANTENNA

Parametres	Value
λ0	85.71mm
Wsub	λ0+5mm
Lsub	Lr+Sr+5*Sd+5mm
h	1.5
εr	4.35
Sr	λ0*0.25
Lr	λ0*0.76
mth	λ0*0.001
We	λ0*0.003
Lde	λ0*0.478
Sdi	λ0*0.34
Ldi	λ0*0.406
C0	C Light*1E-06
Wf	2.89mm
Lf	Lr-1mm
frequency minimum	0.8*frequency
frequency maximum	1.2*frequency
frequency center	3.5

III. Simulation Results

A. *Return Loss | S11|*

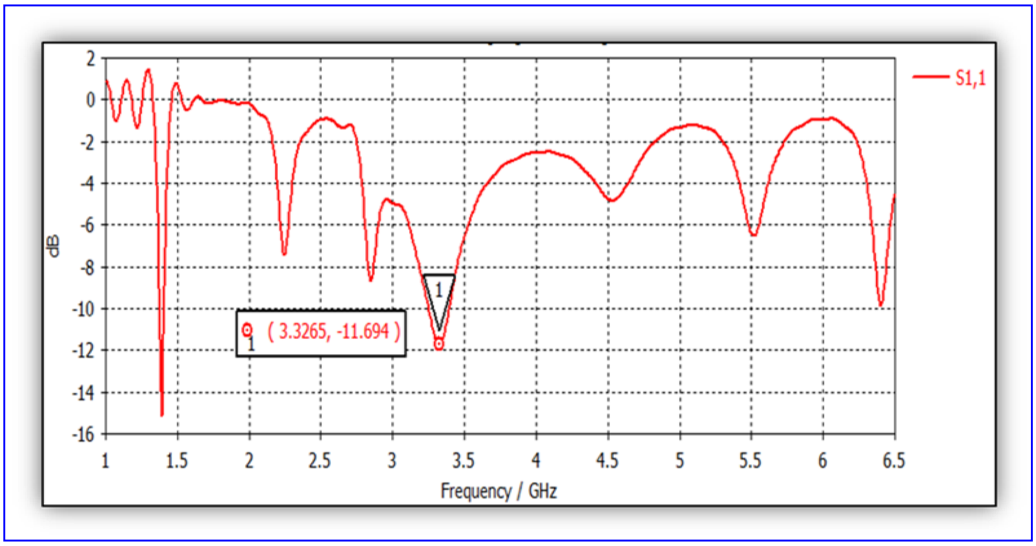
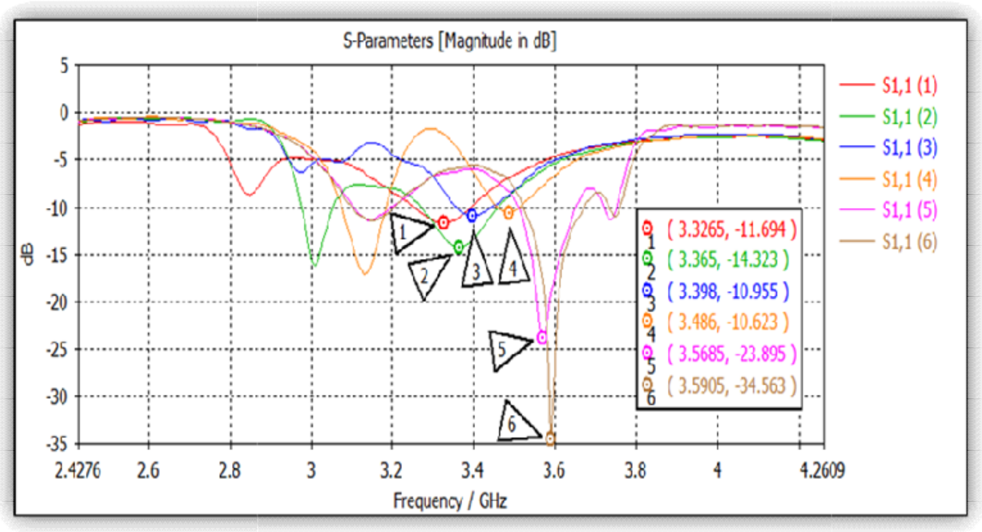


Fig. 3 Return loss of proposed Yagi printed antenna

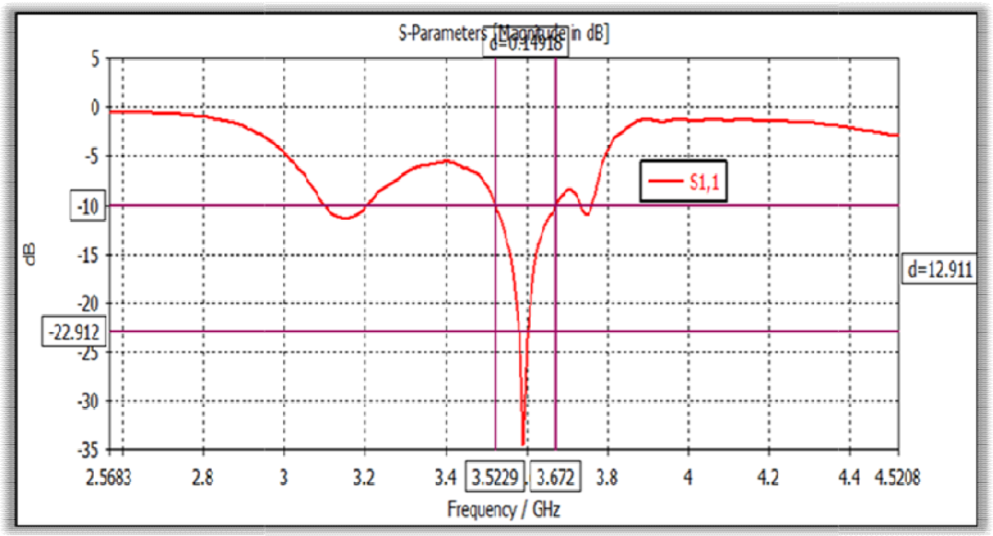
Figure 3 shows the 1st simulation with the initial Yagi antenna parameter values proposed from Table 1, the reflection coefficient obtained is equal to -11.694dB with a frequency of 3.3265 GHz wish is not satisfactory for 5G applications.

We have carried out a parametric study of the length of the components of the Yagi antenna, which have a profound influence on return loss and the formation of its radiation pattern. To obtained more performances of our proposed antenna, the parameters chosen for the study are: L_de= [40.28: 0.5: 33], L_di2= [33.80 : 0.5: 23.9], L_di=[34.80 : 0.5: 24.5].

Simulation results are given in figure 4 (a):



(a)



(b)

Fig.4 Return loss S11 of YAGI printed antenna

In figure 4, we obtained with four directors a high gain of 10.385 dB, a reflection coefficient |S11| of -34.563 dB at 3.5905 GHz and a bandwidth equivalent to 149.1 MHz between 3.5229 GHz and 3.672 GHz. The results are very satisfactory for 5G applications.

B. The Voltage Standing Wave Ratio| VSWR |

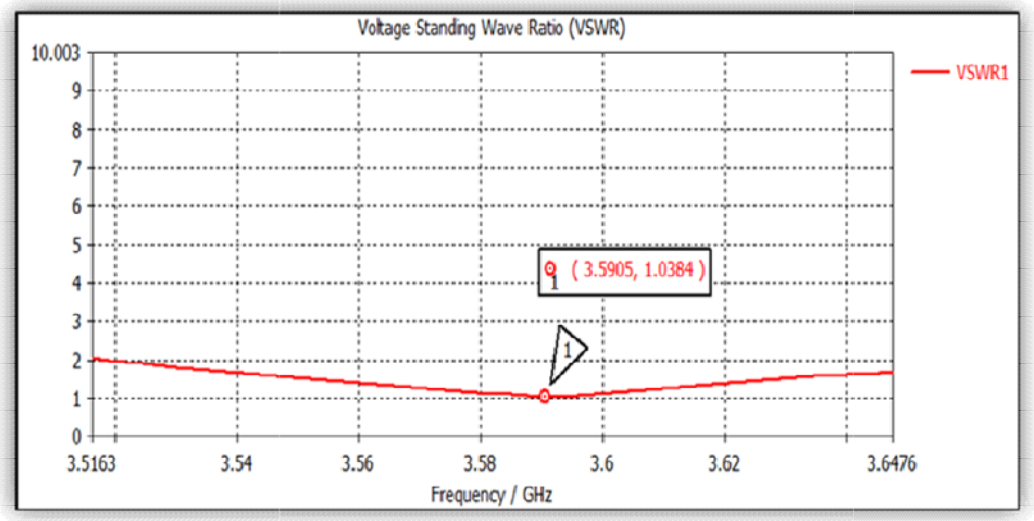
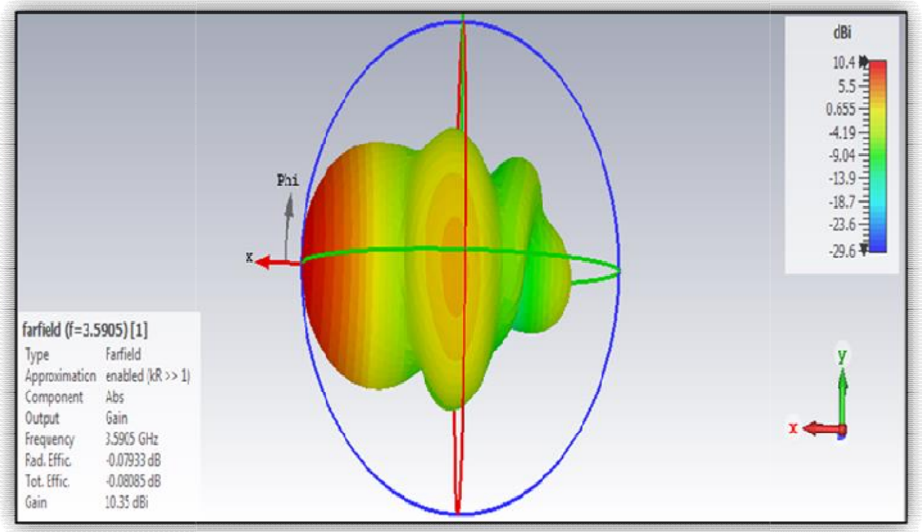


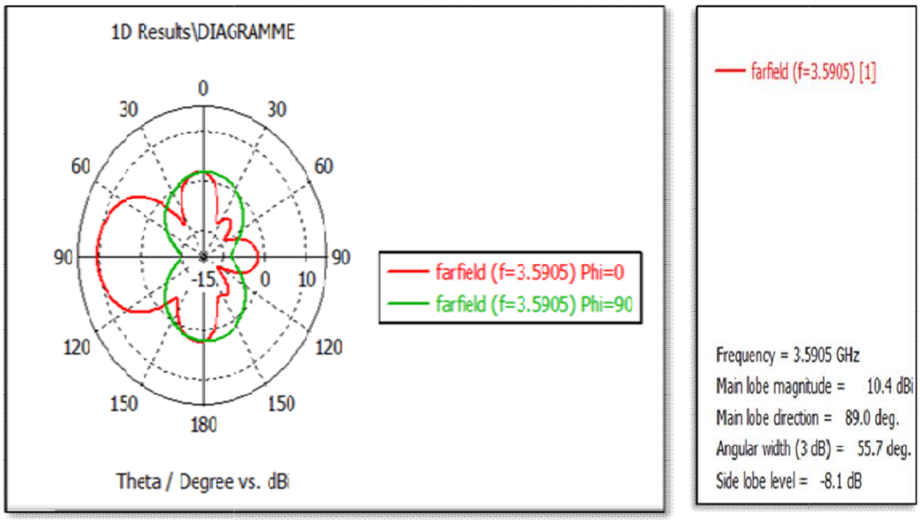
Fig.5 VSWR of Yagi antenna

As shown in figure 5, the Voltage Standing Wave Ratio is 1.0384.

C. Radiation Pattern



(a)



(b)

Fig.6 Simulated radiation pattern of the proposed YAGI antenna (a) 3D, (b) polar

Figure 6 plots both E and H plane radiation patterns of the Yagi printed antenna at 3.59 GHz. The angular width at 3 dB is 55.7 degrees in the H plane (Phi=90°) wish gives a directional and stable radiation pattern.

D. Gain

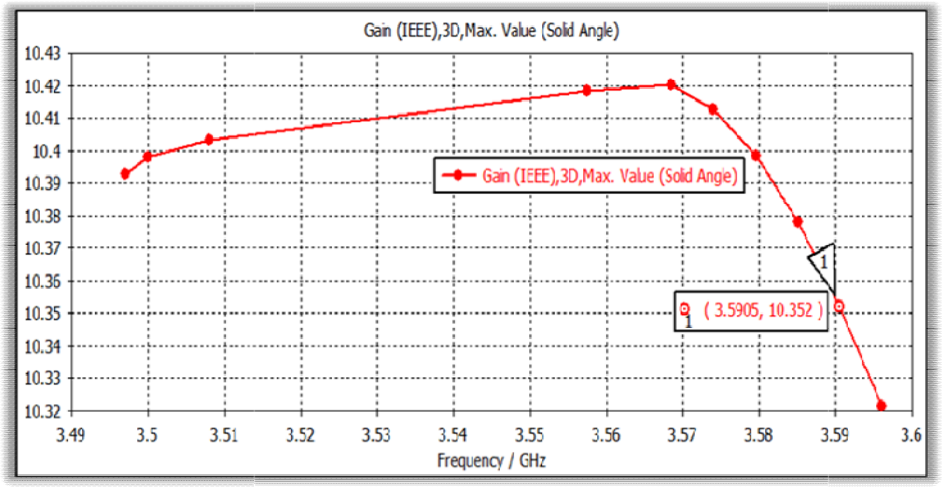


Fig.7 Gain of the proposes YAGI antenna

We obtained a high gain equal to 10.352dB at 3.5905GHz frequency.

E. Current Distribution

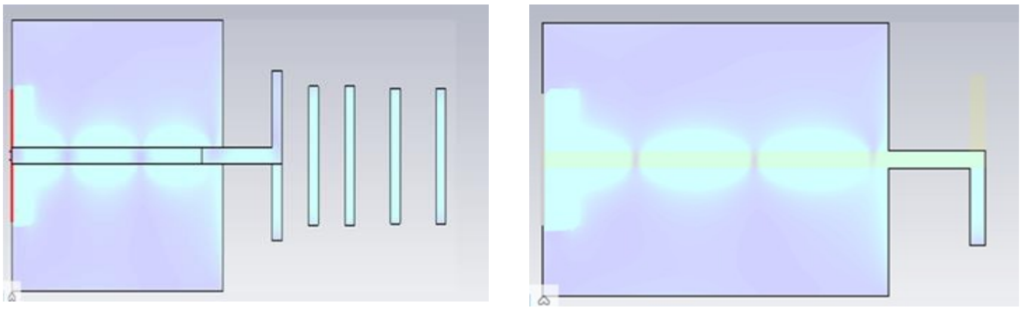


Fig.8 Current distribution of the proposed antenna

Figure 8 shows the current distribution of our YAGI antenna

F. Comparison Results With Other Works

We compared in Table II Our Proposed Yagi antenna with others research's.

TABLE II
COMPARAISON WITH OTHER RESEARCHES RESULTS

Ref	**Freq (GHz)**	**|S11| (dB)**	**Gain (dB)**	**L*W (mm)**	**VSWR**	**Bandwith (Mhz)**
[3]	3.6	-28.65	10.01	140.1* 84.66	/	250
[13]	3.5	-29.77	3.661	45*35	1.0671	233.2
[14]	3.51	-29	6.2	71.76*42	/	/
This work	3.5905	-34.563	10.352	138*48	1.0384	149.1

Table II compares our antenna with various researches studies on printed antennas. The results obtained from our proposed antenna were highly satisfactory in terms of gain. The use of Yagi printed antenna in this paper, especially with 4 directors, we obtained a gain of 10.01dB compared to the other works. The results are very satisfactory for several applications in mobile communications.

IV. CONCLUSIONS

Four directors are used in Yagi-Uda printed antenna to achieve a high gain of 10.35 dB for using in mobile communications especially for 5G applications. This will significantly improve signal strength and range in areas where 5G coverage is weaker. Simulation results give a good return loss of -34.56 at 3.59 GHz with a bandwidth of 149.1 MHz between 3.5229 GHz and 3.672 GHz. The proposed antenna gives a directional radiation pattern with angular wide of 55.7° and linearly increasing gain ranging of 10.35 dB over the entire bandwidth.

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