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DEVELOPMENT OF A BROADBAND 4x4 BUTLER MATRIX DESIGNED FOR BEAMFORMING NETWORK

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Abstract

Wireless power transmission (WPT) has emerged as a compelling energy alternative set to extend its capabilities, enabling the wireless delivery of electricity to a micro unmanned aerial vehicle (UAV). We propose the utilization of a contemporary circular polarized micro strip antenna (CPMA) configuration for the 5.8 GHz retina system. This paper investigates the low-cost beam forming network approach for antennas array applications at frequency 5.8 GHz. As a result, a reconfigurable planar antenna and a 4×4 Butler matrix are developed. The simulation analysis is performed by CST Microwave Studio and compared with ADS software. The beamforming network has an overall size of 84.74 mm * 76.56 mm. Furthermore, it exhibits a return loss of under -10 db. The Butler matrix demonstrates superior insertion loss characteristics, along with minimized phase shift deviations among its output ports. A prototype of the beamforming network has been successfully developed. Simulation results together with further comparisons will be presented in the paper. The Butler matrix features a lower insertion loss and a lower phase shift deviation. In the interconnection among the output ports. A beamforming network prototype has been implemented. The publication will give the simulation findings as well as other comparisons.

Keywords: Antenna Arrays, Beamforming Network, Butler Matrices, Micro Strip Antenna Arrays, Schottky Diode, 0 Db Crossover, And Retinas Schiff Man Phase Shifter.

I. INTRODUCTION

Unmanned aerial vehicles (UAVs) or drones have garnered enormous appeal among academics due to their low cost and small, compact size on the market. Knowing that these drones have a lot of potential, especially in the sphere of communication, they've been widely used in a variety of domains ranging from military needs to search and rescue and emergency scientific interventions, as well as a variety of other areas that worry society. However, most commercial drones on the market today have a significant constraint in terms of flying time, relying mostly on their battery, which can only provide 20-40 minutes of autonomy [1]. To get over this limitation, we suggest a wireless power transfer (WPT) technology in this work that allows drones to stay in the air for longer periods. In reality, WPT is a technology that allows a supply of energy to deliver electromagnetic flux to an electrical demand across a set distance over an air gap without the need of wires or cables. When contrasted with different WPT technologies, MPT seem to be the best fit for the approach and receiving section [2]. There are three important phases between these parts: A microwave transmitter (RF signals) first converts direct current to microwave current. The electricity is then distributed equally across open space via a transmitting antenna to the receiver. Figure 2 [3] is a schematic illustration of an MPT machine.

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Finally, the emitted RF signal is picked up by a Rectenna system, which transforms it into a usable direct current. This Rectenna can be configured in a variety of topologies, including arbitrary polarization [4], dual polarization [5], linear polarization (LP) [6], circular polarization (CP) [7], and broadband polarization [8].

II. DESIGN AND DEVELOPMENT OF SINGLE BUTLER MATRIX COMPONENTS

2.1 The Frequency Shifter

A 4x4 butler matrix takes two 45-degree phase shifters to be implemented. This work's principal original contribution is based on a new three-array 'T' oriented Defected Electromagnetic Structures (DMS) employed in traditional small strip circuit for creating 450 phases shifter @ 2.4 GHz designs [9]. The operating frequency and phase of this arrangement may be adjusted by varying the length of the slots or the number of arrays. The phase shift of the freshly formed phase shifter could possibly be computed as

$$\text{slow wave factor} = \frac{\lambda_0}{\lambda_g} = \frac{\beta_0}{k_0} \qquad (1.1)$$

2.2 The Cross-Coupler

This component ensures that two lines of communication cross. It is also known as 0 dB coupling. In accordance with references [10] [11], the coupling among the two cables for transmission that comprise the cross-coupling is rather low. Furthermore, it is said that combining two hybrid the couplers allows for cross-coupling Showing in figure 1.

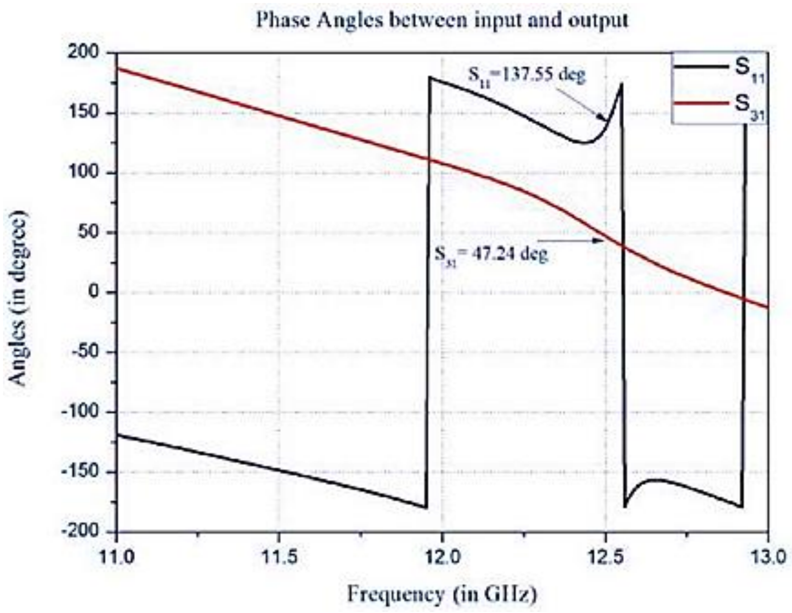

Figure 1: S-parameter Magnitude of a 0 dB Coupler

The rotational position of the both the transmitter and the receiver has no influence on polarized loss, hence circularly polarization transmitters are more immune to fading than linear-polarized antennas.

Figure 2 depicts the efficiency of an electromagnetic firestorm torched (also called MPT discharges atom emission spectroscopy (AES) system that is directly associated with hydroxide generating (HG) for the detection of as and Sb. The nitrogen MPT system can maintain a stable plasma across an extensive range of transporter and gas flow rates, with its highest efficiency at 250 and 1440 ml min1, respectively.

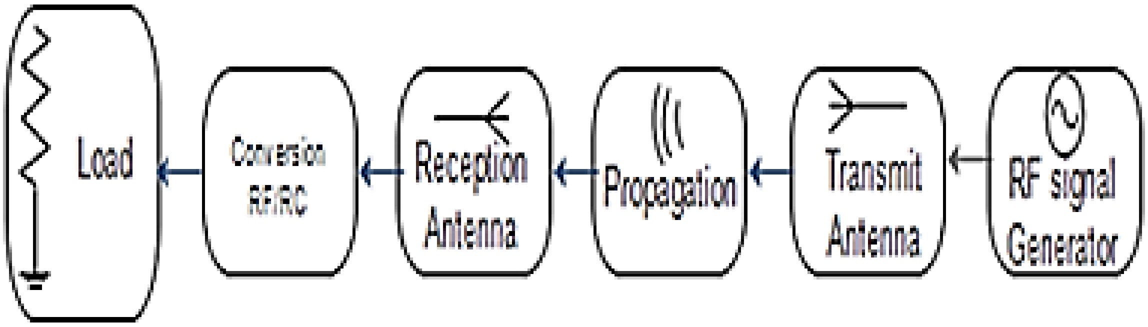

Figure 2: An MPT System's Schematic Depiction

The retina is the primary aspect of RF capture of energy. It has a detecting antenna and an adjustment circuit. The antenna picks up on the radiated RF waves. The rectifier circuit subsequently changes the alternating current energy to direct current power. Figure 3 depicts the fundamental parts of a retina chain. The filter can guarantee that the antenna's connector is properly connected to the circuit of the rectifier and that the transmitter is unable to transmit again the higher harmonics of the rectifier, which operates hence maximizing power transfer [9]. A diode is a microwave transformer that addresses opposing electricity and transforms it to direct current.

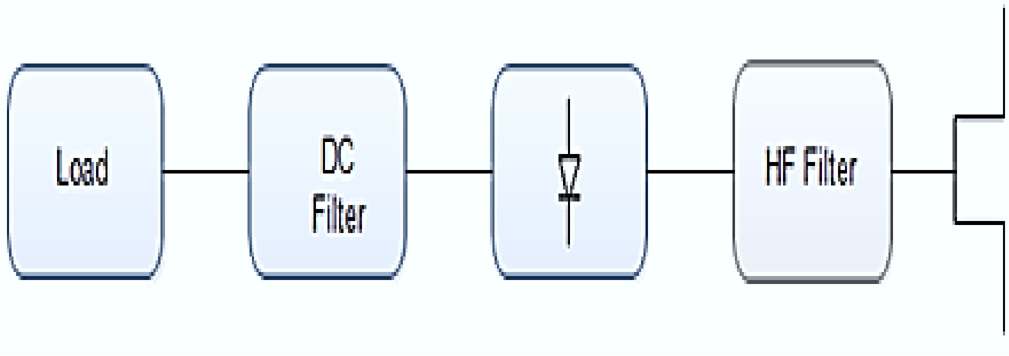

Figure 3: Essentials Elements of a Rectenna Circuit

The primary goal of a Rectenna device is to increase efficiency and minimize translation damages, which is only possible by using antenna arrays.

As a result, the MPT's efficiency is improved and its dimensions are reduced by using a smart antenna in the transmission system (Butler Matrix and patch antenna array). The radiation

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pattern or energy is focused only in the desired direction via smart antennas (UAV position). Micro strip patch antennas were chosen because they are lightweight, conformable to planar structures, and compatible with modern circuit technology.

The created antenna may be utilized as and either a transmitting or a receiving antenna device based on its antenna action mechanism. The four variations on antennas include frequency configurable antennas [10-12], directed figure configurable antennas [13, 14], multiple-methods hybrid reconfiguration antennas, which are and stabilize changeable antennas.

In our scenario, polarization reconfigurable antennas are of importance because they allow us to change the polarization properties of the radiators between various linear and circular polarizations. When RF energy is radiated, the antenna is called a transmitter; however, when RF energy is captured in the built overall system, it is considered a receiver.

The proposed antenna and broadband 4x4 Butler Matrix geometry are described in this study, which then evaluates the findings before concluding.

III. RELATED WORK

The MPT method for an MAV was explored as part of the Foundation for Superior "Innovative Aerial Robo Program" of the modern era [14-16] at the National University of the Tokyo's Faculty of Aeronautics & Astronautics. In the writing, various MPT parts have been distinguished proposed. The segments that follow offer a fast outline of every part.

3.1 Transmitter Subsystem

In [15], [16], a receiving wire game plan of 4*4 composites radio wire fix boards working at 5.8 GHz was made. At 5.7 GHz, the fix receiving wire exhibited a general return cost (S11) of -22.5 db. The total game plan of 16 receivers offers a powerful increase of 16-.8 dB and a S11, which is of - 18.19 dB at 5.8GHz. By [15], the creators proposed a microwave staging cluster with 8 progressively turning radio wires working at 5.8 GHz.

The periods of the receiving wires are changed utilizing 6-bit staging shifters. Every part delivers 0.7 watts of power, for an all-out correspondence force of encompassing 5.6 megawatts. A stunned outfit of five horn-working transmitters was worked at 5.8GHz [16], [17].

The horn-formed radio wire sends 0.7 W and has a most extreme force of 3.5 W. Remote six-bit stage switchers connected to a PC directed each period of the microwave. Conversely, [18] made a staged cluster comprised of 5 horn receiving wires, however this time utilizing both circularized and energized shape. For this situation, it had a global remaining of 5 W.

3.2 Subsystem's Functionality Receiver

For the rectenna framework, the journalists introduced a solitary around and around polarization square recieving wire as a fix with a S 11 of - 13 a dB and a directional proportion that was 0.35dB in [18], [19]. Likewise, a solitary RF-DC intersection converter was worked to invigorate 70% return for twenty decibels of source. In [20], a progression of eighth equal associated, CP fix radio wires is utilized to make a getting radio wires for a 5.8GHz rectenna

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circuit.

[21] Is a reference. To make a cheap, conservative rectenna, I used a crowd of people felt cushion as the radio wire's foundation and copper wrapping to frame a Miniature board radio wire with just a single round enraptured fix radio wire. Place a rectenna made out of a three-sided spellbound fix on the left half of the cushion's substrates at [20].

3.3 Synthetic

In our research, we will focus on constructing the receiver subsystem. Based on the results of the preceded section's study, we will offer our system. 5.8GHz was chosen as the frequency to obtain a small-sized antenna. The antenna itself is compact, planar structure compatible, easy to copy, made with a low profile, and compatible with cutting-edge printed semiconductors.

We are keen on utilizing a CP round square fix radio wire inside the meeting subsystem to deliver the proposed framework in [21], which contains a solitary CP squarer fixing radio wire cluster. We could utilize the recieving wire itself. To expand gain and dependability, as well as to bring down the disappointment pace of the rectenna transmission framework. In any case, as a result of its viability, size, and coordinating significance, the square radio wire structure was picked for gathering [20]. As the wheel of the MAV is featured, the yaw point moves persistently [21]. A CP is then decided to use this radio wire to empower consistent and continuous power conveyance unmistakable of the yaw bearing of the MAV. For this recieving wire, a CP is picked. As the spatial direction of the both getting and sending terminals changes, CP accommodates an almost steady DC signal for a rectenna. There are a few techniques accessible in the writing for making a CPMA recurrent energized Nano strip fix radio wires.

Single-feed and dual-feed techniques are often used [22]. When compared to a single-feed, the dual-feed approach provides a greater bandwidth to CPMA. However, a more extensive feeding infrastructure is necessary [23].

IV. DESIGN, SIMULATION, AND OUTCOMES

4.1 Displayed Antenna

The proposed antenna has a frequency range of 5.8 GHz. This is where the architectural parameter for a particular patch is determined. The patch antenna recommended for use on a FR-4 substrate is intended for use in a Broadband application. The dielectric constant of the FR-4 substrate is 4.4, and it has a height of 1.6mm. The first step is to determine the patch antenna's length and width [23].

CST developed, optimized, and simulated the antenna's performance. It should be noted that the antenna parameters are investigated by changing one of them and adjusting the others. Several antenna patch 5, 8 GHz microruban optimizations have been made for the energy transmission network without a wire to MAV.

CST methodology were used until the recurrence that was great for the best radio wires productivity was found. Table 1 shows the different arranged settings. Figure 4 and 5 portray the planned radio wire design and a displayed loss of gathering S eleven.

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Table 1 displays the suggested design's many optimal parameters.

Table 1: An Indicated Antenna's Specifications Are Optimized

Parameters	Size (mm)	Parameters	Size (mm)
W	28.4	L	30
Wg	13.45	Lg	14.642
Wr	11	Lr	3
Wt	5.2	Lm	7.3
G	0.358	R1	1.5
G1	0.25	R2	2.5
F	1	M	5.3

L= the length of the patch antenna

W = the width of the patch antenna

Δl = fringing field of the antenna

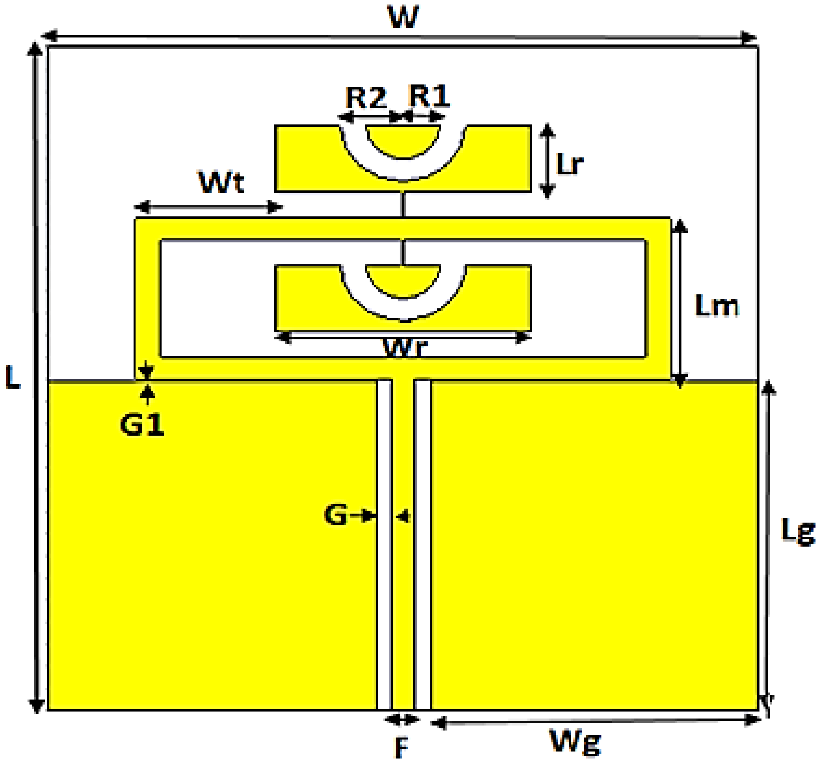

Figure 4: The Proposed Antenna's Geometry

The CST Microwave Studios was implemented to run many optimization procedures on the CP antenna until the optimal performance at the functional frequency of 5 GHz was attained.

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The first math of the proposed recieving wire was developed utilizing standard conditions [25].

$$W = c/(2f0\sqrt{\frac{(\varepsilon r+1)}{2}}) \tag{3.1}$$

$$L = \frac{c}{2f0\sqrt{\varepsilon eff}} - 2\Delta l \tag{3.2}$$

The following formula is used to calculate the effective dielectric strength of the material ff:

$$\varepsilon e = \frac{1}{2(\varepsilon r+1)} + 1/2(\varepsilon r - 1)(1 + \frac{12h}{w})\text{^}(\frac{-1}{2}) \tag{3.3}$$

$$\Delta l = \frac{0.412h\left((\varepsilon r+0.3)\left(\frac{w}{h}+0.264\right)\right)}{(\varepsilon r-0.258)\left(\frac{w}{h}+0.8\right)} \tag{3.4}$$

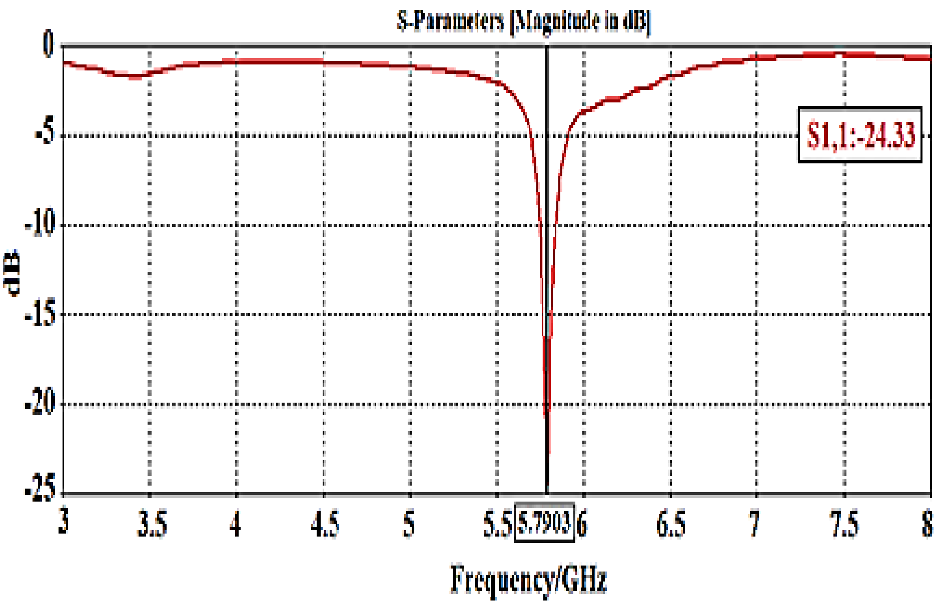
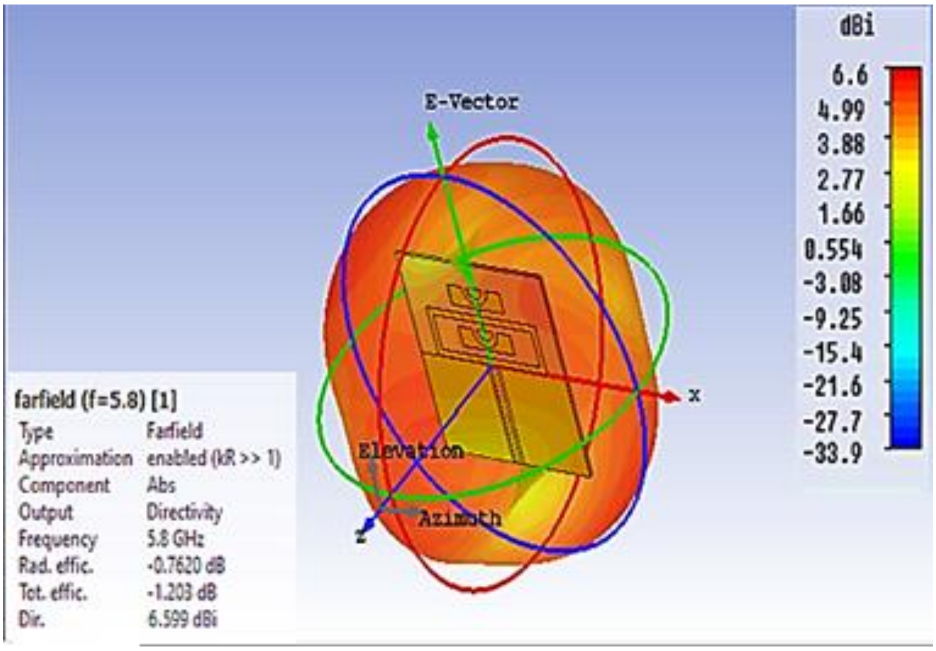


Figure 5: S11 vs Frequency Simulation for the Recommended Antenna

The antenna's resonance frequency is 5.8 GHz. At 5.8GHz, the coefficient S11 equal -24.30 a dB (-10dB), suggesting high impedance of the balancing (the antenna has a good fit to an admittance of 50). The simulated bandwidth at -10dB is 160 MHz, corresponding to a frequency that spans 5.72 to 5.88GHz.

Figure 6 displays our antenna's 3D radiation patterns at 5.8 GHz. As can be observed, this antenna has an emission direct pattern of 6.6 db.



farfield (f=5.8) [1]

Type	Farfield
Approximation	enabled (kR >> 1)
Component	Abs
Output	Directivity
Frequency	5.8 GHz
Rad. effic.	-0.7620 dB
Tot. effic.	-1.203 dB
Dir.	6.599 dBi

Figure 6: At 5.8 GHz, the Suggested Design's 3D Radiation Pattern

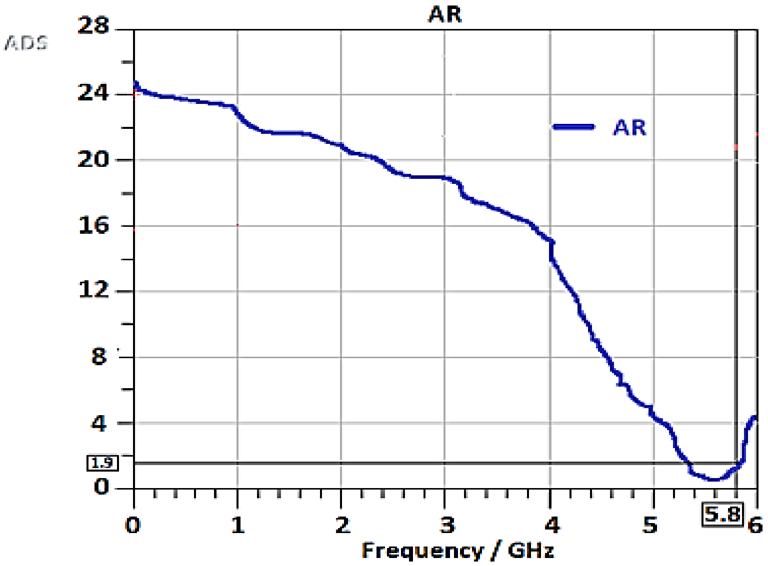


Figure 7: Axial Ratio of the Antenna Suggested Vs Frequency

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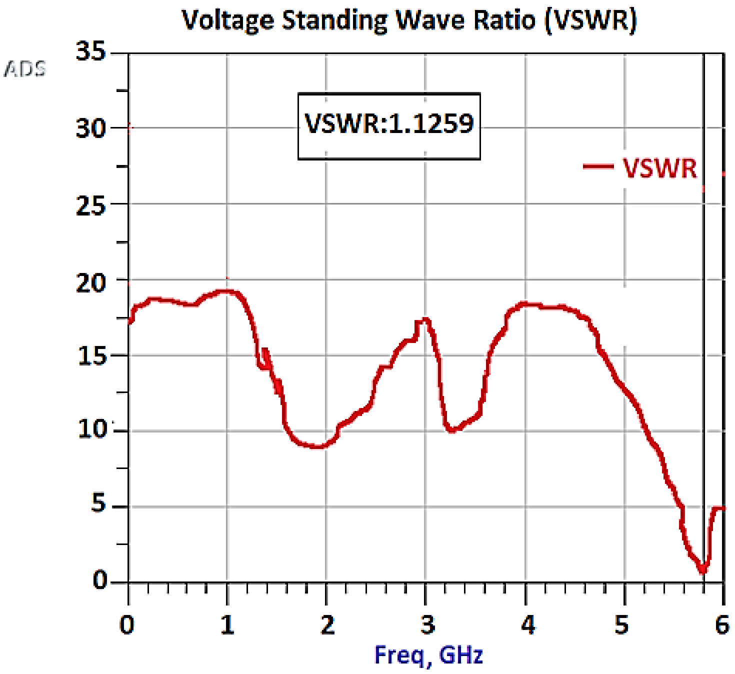


Figure 8: VSWR Simulation of the Planned CP Antenna

Figures 7 and 8 show how our proposed plan's upward proportion and a VSWR (Voltage Stand Wave Rate) develop with frequencies. As displayed in the charts, the constructed recieving wire has a decent hub proportions with a negligible increase of 1.9 decibel (3 dB) and a successful VSWR of 1.5 (2) at the recurrence of 5.8 GHz.

Table 2 differences the productivity of a CP radio wires cluster presented in the current writing for Rectenna at 5 GHz with that of our proposed one.

Table 2: At 5.8GH, a Comparison of the Old Antenna and the Planned Antenna is made

Ref	S11 (dB)	Bandwidth (MHz)
[20][21]	-21	130
Our work	-24.30	160

As demonstrated in Table 1, the suggested antenna produces greater accuracy and has generally more advantageous characteristics than other MPT transmission antennae proposed in previous study. Furthermore, the suggestion for an antenna is circularly separated, which is required for MAV activities.

4.2 4x4 Butler Matrix

The performance of the Butler Matrix was examined using system CST (Computer Simulated Techniques), Electromagnetic the Studios, and ADS (Advanced Designing System). To construct a 4*4 BM [25]. Figure 9 shows the signal route and attachment.

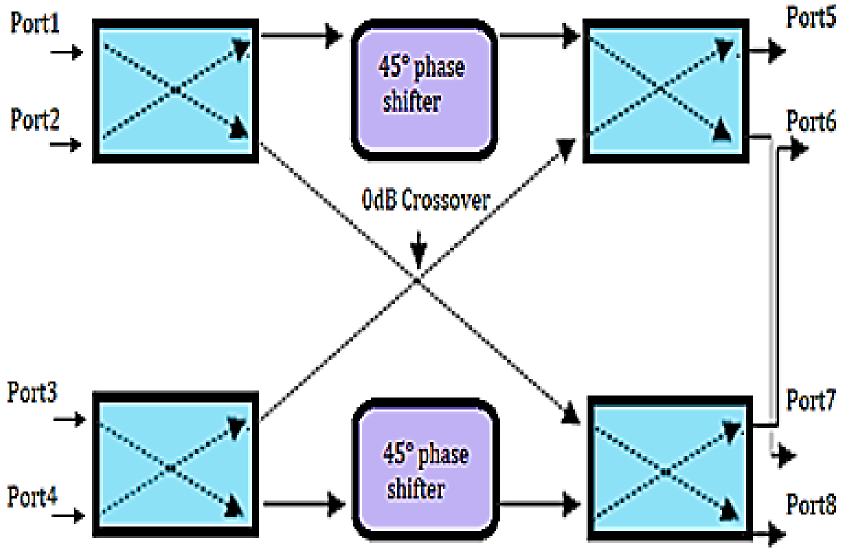


Figure 9: 4*4 BM Connection Architecture and Signals Routing

Figure 9 depicts the geometry of the BM. There are two small shifters, as well four connectors, and a 0 a dB crossing included. Figure 10 depicts the computerized outcomes of the suggested BM's loss of returns obtained via the use of both simulation tools.

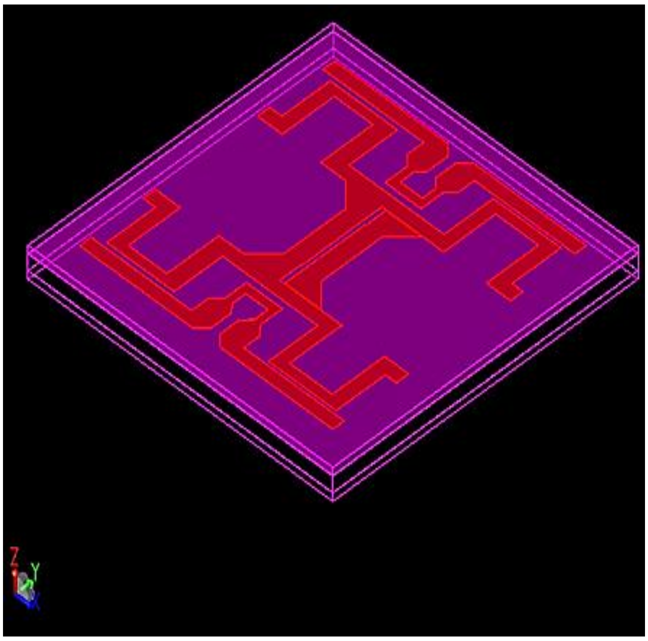


Figure 10: Its Suggested 4*4 BM Structure

An N*N BM is made up of N inputs and N line outputs (when N is a negative number that must be larger than or less than 4). There exists a phase variation between the N unit BM output lines.

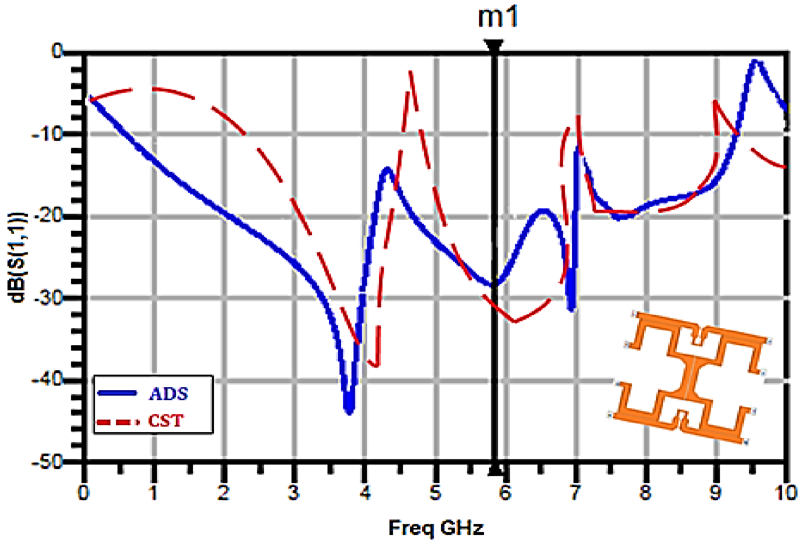
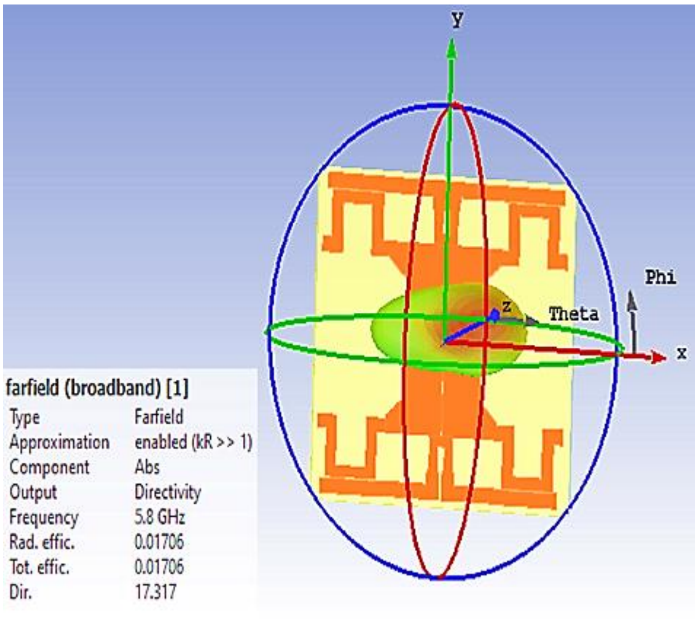


Figure 11: S11 Evaluations of CST and ADS

According to this reflection coefficient curve, the present BM is stimulated at 5.8 GHz having a -27.76 dB return signal loss and an enormous bandwidth.

A Butler Matrix structure of radiation is a graphical depiction of the BM's electromagnetic properties. Figure 11 depicts the planned BM's 3D electromagnetic radiation map. The findings show that the suggested structure has a direction radiation pattern, with a directness of 17.32 dB at 5.8 GHz.



farfield (broadband) [1]

Type	Farfield
Approximation	enabled (kR >> 1)
Component	Abs
Output	Directivity
Frequency	5.8 GHz
Rad. effic.	0.01706
Tot. effic.	0.01706
Dir.	17.317

Figure 12: CST was used to simulate the Designed Smart Antennas System's 3D Gain pattern at 5.8 GHz

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Gain is one of the most vital variables impacting maximum power and ranging performance. Figure 12 displays the proposed Butler Matrix's gain as an estimate of frequency. As can be seen, the BM has an ultimate gain of greater than 17dB over its operative bandwidth.

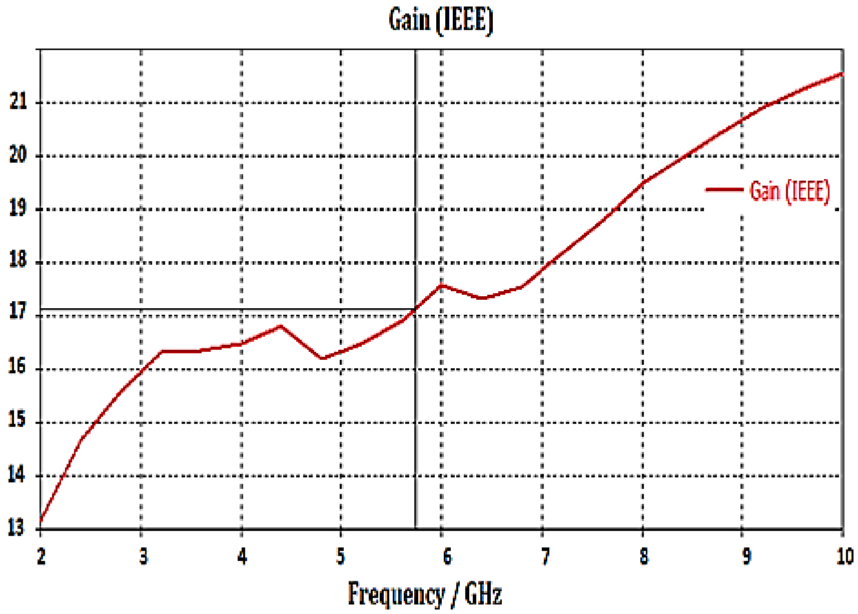

Figure 12: The Suggested BM's gain Versus Frequency Graph

As shown in Figure 13, the VSWR calculated from a simulation performed at 5.8 GHz using the 4X4 antenna is 1.1923, putting it within the acceptable range.

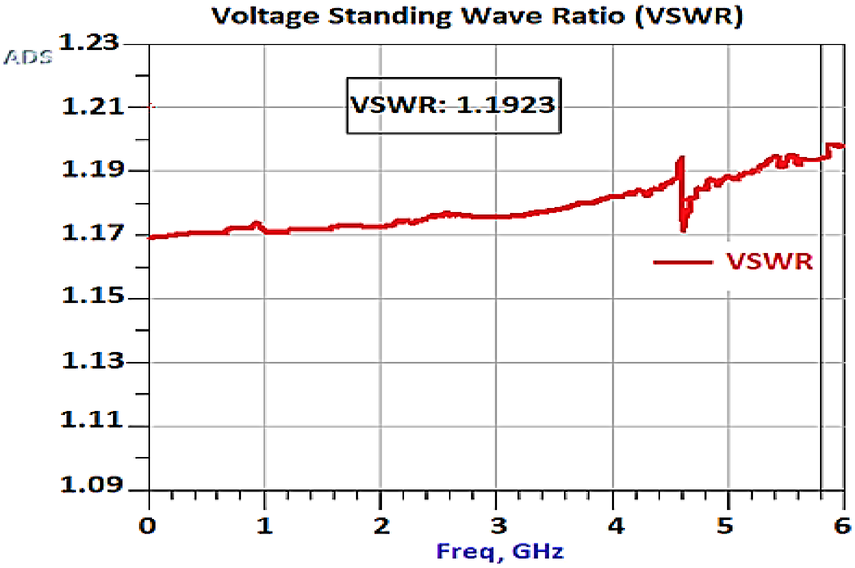

Figure 13: 4*4 VSWR Array Simulation Result

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Table 3: Performance Evaluation of Suggested Work vs Interesting Work

Ref	freq (GHz)	Substrate material	Total size (mm^2)	S11(dB)
[18]	5.8	FR4	90.61×96	-24.69
[19]	2.4	FR4	173.7×173	-35
[20]	5.8	RO4003	90×70	<-11
[21]	2.5	FR4	115.18×64	-20
Our work	5.8	FR4	44.25 ×39.92	-28.26

As per the examination, the BM has superb elements concerning income misfortune and all out extent, delineated in Table 1.

V. CONCLUSION

This research shows the modeling results of the projected patch antenna operated at 5.8GHz, which outperform the references. The designed antenna meets the demands for drones in terms of thereby affecting their volume, strength, and circular polarization. An antenna replica would be created and tested to validate the simulation results.

The recommended antenna size is 30x28.4 mm2. This antenna architecture has reduced the weight of the antenna while simultaneously boosting its performance and simplicity of use.

To excite the antenna, a suitable supply 4x4 patch arrays is needed. The Butler Matrix, as proposed, has proven to be effective. The maximum gain exceeds 17dB, but the resulting loss is less below -10. Because of these features, the proposed structure is appropriate for system integration to enhance the performance of the RF-DC convert that gets electricity at the Retina's input. As a consequence, the research may be broadened to include the fabrication and testing of this prototype.

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