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# Design and Analysis Multiband Linear and Planer Phased Array Antenna for Unmanned Aerial Vehicle Communications

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# Design and Analysis Multiband Linear and Planer Phased Array Antenna for Unmanned Aerial Vehicle Communications

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***Abstract* --**In this paper, a multiband array antenna design for unmanned aerial vehicle is designed and analyzed. Multiband high directive, microstrip antennas are essential for drone communication networks. This paper presents a detailed investigation and design of 1x4 planar and linear antennas. The proposed single antenna has total dimension of 10x10x1.09 mm3 and it operates at 11GHz, 18 GHz, and 27 GHz, which is in the range of consideration of drone communication in ka- and Ku band communications. This antenna is built with a copper patch and a Rogers RT5880 substrate, it has a tangent losses of 0.0009 and 2.2 permittivity. The results obtained from the designed antenna indicates that it had a high gain, directivity and good bandwidth with beam steering capability at the operation frequencies.

**Keywords—Array, linear, multiband, planner, Unmanned aerial vehicle**

## I. INTRODUCTION

One type of remotely controlled aircraft that can fly without a human pilot is the drone. Drones are becoming more and more popular for a wide range of applications, such as disaster relief, aerial application of agricultural chemicals and fertilizer, environmental sensing and monitoring, operations in dangerous regions, and localized cargo transportation. For these and other purposes, drones are attracting a lot of interest [1]. The antenna radiating in an isotropic pattern presents itself as a promising choice for unmanned aircraft since drone communication required full spatial coverage. For drone applications, the microstrip patch antenna is an excellent choice because of this [2, 3, and 4]. The compact size, low weight, conformability to substrate surfaces, affordability, and ease of integration with other circuits are only a few advantages that the microstrip antenna has over the standard microwave antenna. [1] The literature review indicates that multiband antenna operates in millimeter wave, which is crucial. Based on this, we attempt to build a multiband phased array antenna for drone communications in this paper. The rest of the paper, is organized as section I, introduction, section II, related works, and section III methodology section IV, results and discussion, section V, conclusion.

## II. RELATED WORKES

In [2] a miniaturized high gain flexible antenna for UAV application was proposed. They proposed a coplanar waveguide asymmetric ground feeding and a meander line patch as an antiresonant network, and FR- 4substrate with thickness of 0.8mm is taken as substrate. To simulate and design they used HFSS software. The design antenna was compact size of 196x 15x0.8 mm3. The result shows that Omni directional gain of 4.5dBi in frequency of 902-928MHz.

In [3] a dual mode, thin and wideband MIMO antenna for UAVs was proposed. They proposed a circular microstrip antenna to get two modes, by carefully positioning of the feed point and to enhance the bandwidth they used the technique of parasitic patches. The antenna was designed on thin flexible Rogers's 5880 substrate dielectric permittivity of 2.2 and 0.009 tangent loss. The design antenna have full ground plane with a coaxial feed. The MIMO configuration was 3- element triangular. They achieved bandwidth of 38MHz at 2.4GHz and 155MHz for 5.2GHz on 0.0128 lambda0 and gain of 10 dBi.

In [4] A UAVs mountable flat array antenna system was proposed. They design, the radial power divider monopole shape radiator antenna. The design antenna operates at 2.4 GHz with gain of 4dBi. The authors, [5] proposed directional cloverleaf antenna for UAVs applications. They used FR- 4 substrate to design the antenna, they designed 3 blade and 4 blade cloverleaf antenna in CST software. The proposed antenna have gain of 2.37dBi, while with reflector they achieved 6.38 dBi. The design antenna operates at 2.45 GHz.

In [6], single fed dual mode circular parasitic patch antenna for UAVs application was proposed. To design the antenna they used HFFS software. The shape of the patch is hexagonal slot, with dielectric substrate of

Rogers 5880, er= 2.2 and tangent loss of 0.0009 with thickness of 1.5mm at 2.4 and 5.8 GHz operating antenna.to enhance the bandwidth, they used the technique of parasitic and slot patches. They achieved the impedance bandwidth of 112 MHz and 380 MHz at 2.4 and 5.8 GHz frequency respectively with gain of 4.6 and 4.3 dBi of Gains.

In [7], the authors proposed dual band antenna for drone application. They proposed dual band combo antenna. To design the antenna they used CST software. They used proximity couple feeding and it have five layers, the material used to feed is copper. The design antenna operates at 1.575 GHz frequency with circular polarization and at 2.4 GHz linear polarization. In this proposed antenna they achieved the gain, efficiency and bandwidth was, 5.06 dBi, 6.35dBi, 68.3%, 79.9% and 49.6MHz, 48.4 MHz for 1.575 GHz and 2.4 GHz frequency respectively. Gain enhanced conformal patch antenna with defected ground was proposed for aircraft application [8]. The authors, in this paper design C- band frequency range. To design the antenna they used RT duroid 5880 substrate material with er=2.2, 0.0009 tangent loss with thickness of 0.787 mm. the design antenna structure consists of two patches, quarter wave transformer and, two microstrip lines connecting the patches and defected ground slits on the ground plane. In this proposed antenna the bandwidth achieved was 400MHz for 5.2 GHz with gain of 10 dBi. In [9], low profile conformal antenna for UAVs application was proposed. In this paper, Y bounded shape linearly polarized conformal antenna was design with Rogers Duroid 5800 materials with dimension of 28mmx 39mm in CST software. The proposed antenna operates in 2.9 GHz to 15.9 GHz ranges. In [10], miniature drone antenna was proposed. They authors, design PIFA with a quadrature feed network and reflector plane. The proposed antenna was designed by using FR-4 substrate with thickness of 0.8mm and er=4.4 with tangent loss of 0.021, the overall size of the proposed antenna was 150mmx 200mx 0.8mm. In this proposed antenna, they achieved the gain of 3.7dBi and circular polarized at operating frequency 1.09 GHz.

As the aforementioned related works show, all of them are generally designed with frequencies lower than 5.8 GHz. However, our antenna is intended for use with an array in the 11–27 GHz frequency range. When compared to our suggested design, the literature review's results show little differences, and multiband antenna design that operates at diverse frequencies is a promising breakthrough in technology.

## III. METHODOLOGY

In this section, a multiband rectangular form patch antenna with slot and slit added and operating is different frequency is designed. The performance of the designed antenna was determined. In this work patch antennas are used because of different advantages over other type of antennas such as low profile and manufacturing costs.

### *A. Single band rectangular shape multiband antenna*

To design the antenna the specifications are presented in Table 1. First the single rectangular shape patch antenna operating at 27GHz was designed, and to achieve multiband, we used slots and slits in the patch. Finally, we designed 1x4 element array antennas with planar and linear configurations and examine different parameters in the design antenna.

Table 1. Design Specifications for Single Patch Antenna.

| | |
|---|---|
| Operating Frequency | (10-40GHz) |
| Substrate material | Rogers RT 5880 |
| Patch and ground material | Copper |
| Height | 1.09 mm |
| Relative Permittivity | 2.2 |

*B. Dimension calculations*

The length L of a rectangular patch is typically $0.3\lambda_0 \leq L \leq 0.5\lambda_0$, where $\lambda_0$ is the free-space wavelength. The dielectric substrate height h is generally $0.003\lambda < h < 0.05\lambda$ addition to this the dielectric substrate constant $\varepsilon_r$ is commonly in the range of $2.2 \leq \varepsilon_r \leq 12$. [2] As shown Eq. (1)

$$W = \frac{\lambda_o}{2\sqrt{0.5(\varepsilon_r + 1)}}$$

(1)

Step 2: Calculating the length of the patch before calculating effective permittivity of the substrate as represented in Eq. (2).

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(\frac{1}{\sqrt{1 + 12\,h/w}}\right)$$

(2)

In Eq. (3) shows the length of the patch antenna as Hall and Wood patch approximation antenna element with a substrate thickness smaller than 0.08151λ.

$$L = \frac{c_o}{2f_r\sqrt{\varepsilon_{eff}}}$$

(3)

The rectangular shape patch antenna is designed by using CST software. The height of the copper for both the ground and the patch is 0.035mm. The calculated parameters of dimension for rectangular shape patch antenna are presented in Table 2.

Table 2. Calculated Parameters of Dimension for Rectangular Shape Patch Antenna.

| | |
|---|---|
| Operating frequency | 27GHz |
| Inset feed gab | 0.6 mm |
| (Wp) Width of the patch | 4.38mm |
| (Lp) Length of the patch | 2.957mm |
| Width of ground and substrate (Wg) | 9.032mm |
| Length of ground and substrate (Lg) | 7.850mm |
| Feeding method | Inset feeding |
| Length of the feed (lf) | 3.76mm |
| Width of the feed (Wf) | 0.6mm |

*C. Proposed antenna design*

In this work, patch antenna for multiband is designed and planar and linear array reconfiguration was proposed. As some literature review shows different shape making and getting multiband antenna. In this work a shape of rectangular slots with 4x3 and slit of 4x1 in patch were removed and their performance evaluated to identify which of then provide multiband and to achieve better bandwidth and efficiency. The proposed design shape is indicates as shown below Figs. 3, 4 and 5.

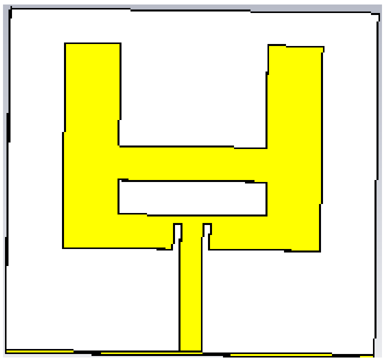


Fig. 3. The proposed multiband patch antenna.

Fig. 4 shows the linear array antenna design for the rectangular shape. The array has 4 elements connected linearly and the overall size of the antenna is 59.8mm x 10 mm x 1.09mm. The distance between the two elements is λ/2 which is 7.95mm.

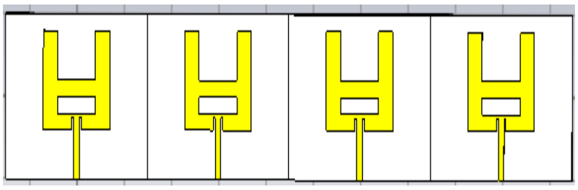


Fig. 4. Rectangular shape linear array antenna.

Fig. 5 shows the planar shape configuration array antenna. The array has 4 elements feed with separately was proposed, and the overall size of the antenna is 20mm x 20 mm x 1.09 mm.

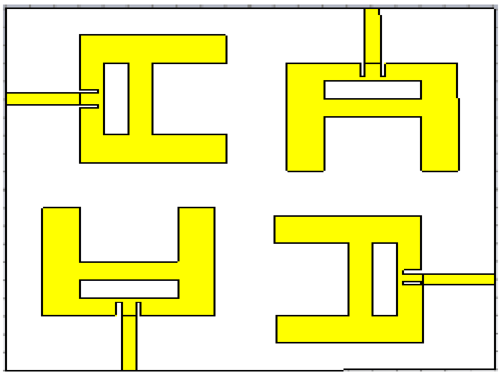


Fig. 5. Rectangular shape planer configuration array antenna

## IV. Results and Discussion

### A. *Radiation efficiency*

The antenna's radiation efficiency indicates how much power is radiated into space by the antenna. The radiation efficiency of the design antenna is 70% to 80% for different operating frequencies as shown in Fig. 6. As the simulation result shows the radiation and the total efficiency is equal which shows the mismatch loss is very small or approach to zero.

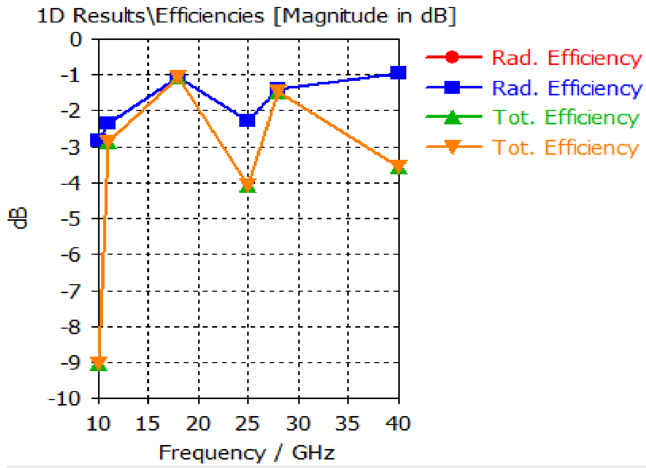



Fig. 6. Radiation efficiency of multiband single element antenna

The response of the power radiated of the return loss in S11 parameter is shown in Fig. 7. The modeling results show that at different operating frequencies 11GHz, 18 GHz and 27 GHz, the return loss is less than -30dB for the substrate height 1.09 mm. For the simulation, we take different heights and show the effect of increasing height. As shown in the graph, as the substrate height increases, the operating frequency shifts to a lower operating frequency, increasing the bandwidth, and at an operating frequency of 1.09 mm, an S11 of less than -30 dB is achieved.

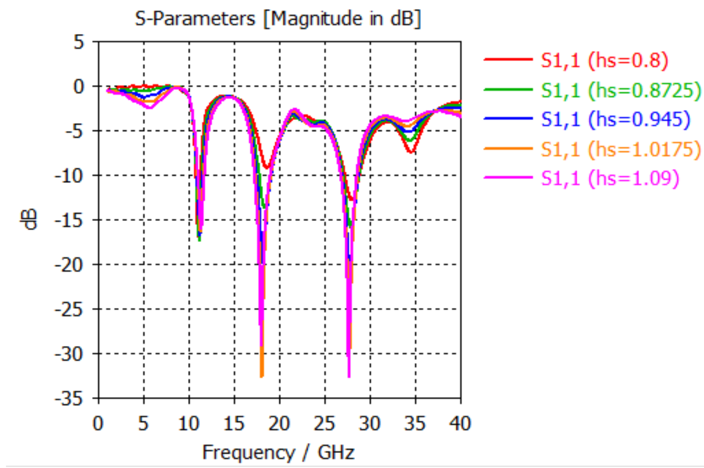



Fig. 7 Return loss of multiband single band antenna

The radiation band width is simply the bandwidth that is measured by the S11 and the space between the two spots, as shown in Fig. 8. The band width for the designed antenna is 0.716, 1.695 and 1.808 GHz at the operating frequency of 11, 18 and 27 GHz frequencies. .

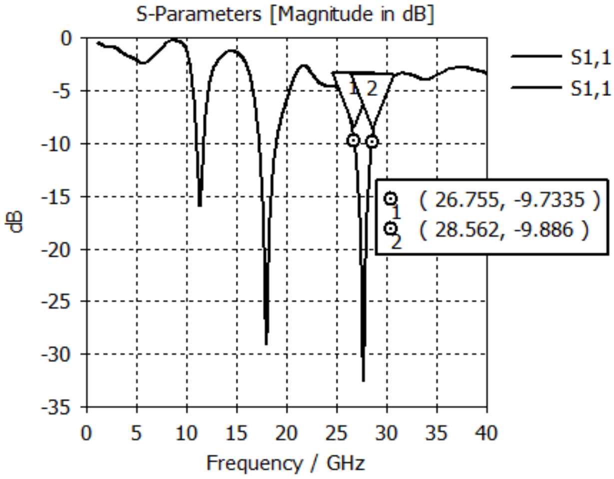



Fig. 8. Radiation bandwidth of the proposed antenna

*B. Gain of single and array multiband antenna*

The simulation result of the gain of the proposed antenna with polar and 3D pattern is shown in Figure 9. The proposed antenna has a gain of 6.48 dBi and an angular breadth of 73.8 degrees (half power width). The simulation results show that the side lobe level is -11.2dB at the main lobe direction of 120 degree. However, when we used the proposed array antenna, the gain reaches 10.4 dBi and is 0 degree at the operating frequency of 11 GHz.

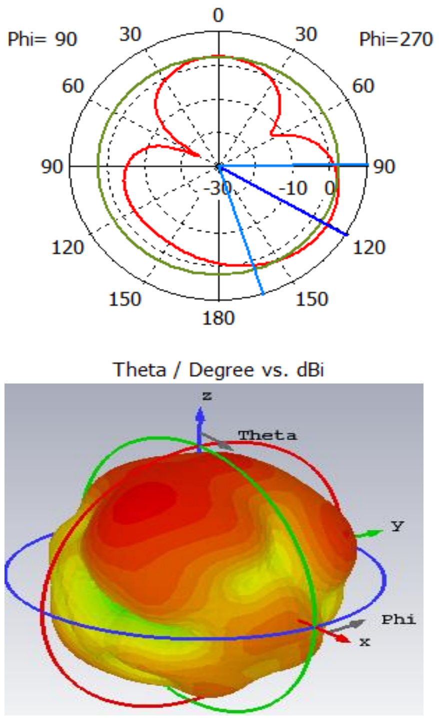



Fig. 9 .The gain of the proposed multiband antenna polar and 3D pattern

Figure 10, shows the 3D plot of the designed array antenna for linear and planer configurations, as the result indicates, in linear antenna the gain is 10.4 dBi, but in planer the archived gain is 10.1 dBi have difference of 0.3 dBi between the two configurations.

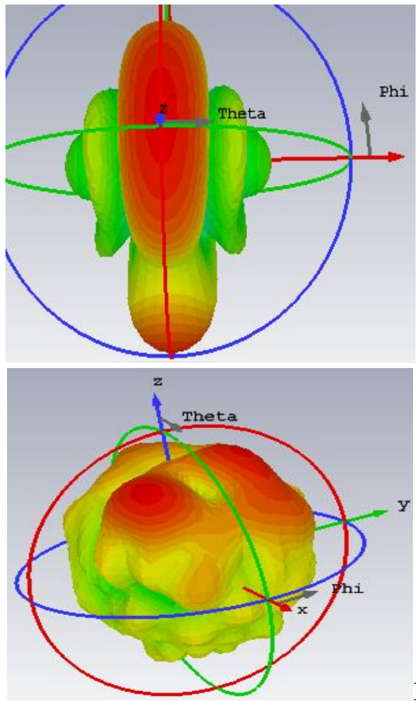


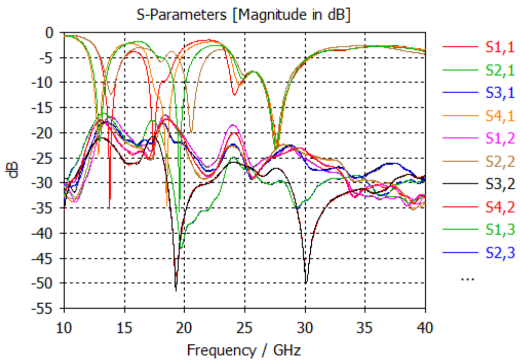

Fig.a

Fig b

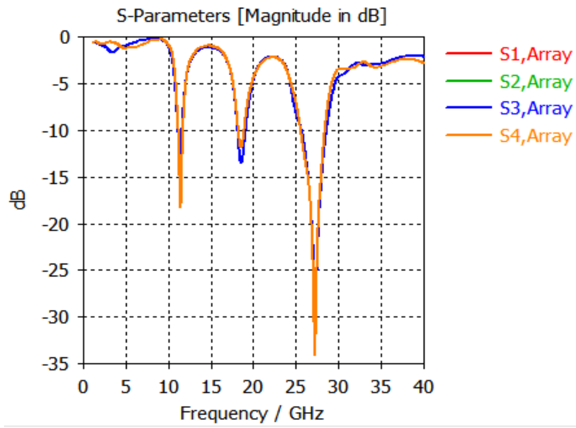
Fig. 10. The gain of the a) linear and b) planer configuration array antenna 3D plot

*C. Return loss of the proposed multiband antenna array antenna*

The simulation of the return loss S11 of for both linear and planer configuration of array antenna is shown below in figure 11. As the result indicates the return loss of the design antenna is shift in the operating frequencies to the right when the configuration is planer.




b)




a)

Fig. 11 a) the S parameter for linear array configuration b) planer configuration

## V. Conclusions

In this paper, a multiband phased array patch antenna for unmanned aerial vehicle communication was designed and simulated. The designed antenna resonates at 11 GHz, 18 GHz and 27 GHz which are prospective frequencies for drone communications.in the proposed linear and planer phased array antenna, four elements are used and the gain is increased from 6 dBi to 10.4 dBi.

Addition to this the radiation bandwidth of the proposed antenna shows that 0.716 GHz, 1.695 GHz and 1.808 GHz respectively for the operating frequencies stated. Generally, the simulated result is good in beam steering, Gain, directivity, radiation bandwidth and S –parameters, so this antenna shape is good for drone communications.

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