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Novel Slotting of a Microstrip Rectangular Patch Antenna for Dual Band Operation

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***Abstract*— A novel slotting of a MRPA to achieve dual band characteristics intended to serve the C-band mobile applications except aeronautical mobile and the X-band satellite, aviation and space research applications has been proposed. The proposed design considers a 46 mm x 42 mm x 1.6 mm FR4 epoxy substrate and uses a coaxial feeding mechanism. The two design stages have been analyzed over HFSS-15 for their reflection coefficient, bandwidth, radiation pattern and gain. The final stage design was fabricated and tested over 10 MHz-40 GHz Rhode & Schwarz ZVA VNA for its reflection coefficient and bandwidth and in anechoic chamber for its radiation pattern and gain. The results, so obtained, have been found to be in close approximation to the simulated ones.**

***Index Terms*—Microstrip Patch, Slot, Dual Band, Space applications.**

I. Introduction

Since the time of their introduction, the MPAs have continued to dominate and revolutionize the antenna industry. They have immense popularity and continue to serve numerous applications including the satellite and the aviation communication applications. These MPAs have inherent advantages of small size, light weight, low profile, compatibility with most MMIC designs and conformability to the host satellite structures. The basic rectangular patch antenna that was initially designed by T. Shanmuganantham in [1] exhibited a single band resonance at 6.29 GHz offering a bandwidth of 110 MHz. Another rectangular patch antenna geometry that was designed by Deepanshu Kaushal at the initial stage achieved a reflection coefficient of -13.46 dB and a bandwidth of 300 MHz. Most conventional rectangular patches have been recorded to exhibit a single band resonance with performance indicators of limited values. Techniques including the modification of the basic patch by introduction of slots has often been suggested for an improved parametric performance. The introduction of slots into the initially designed rectangular patch antennas by T. Shanmuganantham in [3]- [5] has resulted into not only an increased number of sidebands along with the resonance at the solution frequency but also into significantly improved performance indices of reflection coefficient, gain and bandwidth.

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This paper proposes the novel slotting of a microstrip rectangular patch antenna to achieve dual band operation in the C-band and the X-band respectively. A FR4 epoxy substrate that has dimensions of 46 mm x 42 mm x 1.6 mm, a relative permittivity of 4.4 and a dielectric loss tangent of 0.02 is used. The coaxial feeding mechanism with an inner conductor soldered to the radiating patch through the substrate and an outer conductor remaining connected to the ground is used. The proposed design has been built through a two stage design iteration each of which has been analyzed for reflection coefficient, bandwidth, radiation pattern, gain and VSWR characteristics. The final stage design was fabricated and tested over 10 MHz-40 GHz Rhode & Schwarz ZVA VNA for its reflection coefficient and bandwidth and in anechoic chamber for its radiation pattern and gain. The results, so obtained, have been found to be in close approximation to the simulated ones

The section I of this paper introduces microstrip patch antennas and the existing literature works over the conventionally used rectangular shaped patches to modified slotted structures. The section II discusses the two stage design procedure. An analysis of the major results for the proposed design including the reflection coefficient, bandwidth, radiation pattern and gain has been carried in the section 3.

II. DESIGN Procedure

The proposed antenna design has been developed in a two stage iteration process of a basic rectangular patch followed by its slotting in the end stage.

A. Iteration 1: Basic RMPA Design

The figure 1 shows a 46 mm x 42 mm rectangular patch built over a FR4 epoxy substrate of same dimensions. The table 1 lists the specifications of the basic RMPA whose design equations have been listed in table 2 while the utilized design equations are listed in table 2.

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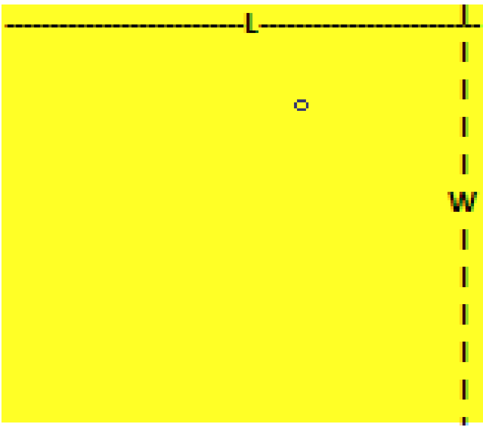


Fig. 1: Basic RMPA Design

Table 1: Specifications of RMPA

Dimensions	Value (mm)
L	46
W	42

Table 2: Design Equations

Parameter	Formula
Width of the radiating patch (W)	$w = \left(\frac{c}{2\times f_r}\right)\left(\sqrt{\frac{\varepsilon_r+1}{2}}\right)$
Effective dielectric constant of the substrate ε_{reff}	$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \times \sqrt{\left(1+\left(\frac{12h}{w}\right)\right)}$
Effective length of the radiating patch (L)	$L = \frac{c}{2\times f_r \times \varepsilon_{reff}} - 2\Delta l$
Extension Length for patch (ΔL)	$\Delta l = .412\times h\times\left[\left(\frac{\varepsilon_{reff}+0.03}{\varepsilon_{reff}-.258}\right)\times\left(\frac{w+0.264h}{w+.8h}\right)\right]$

B. Iteration 2: Novel Slotting of RMPA

As shown in figure 2, a novel shaped slot into the patch thus modifying it. The specifications of this geometry have been tabulated.

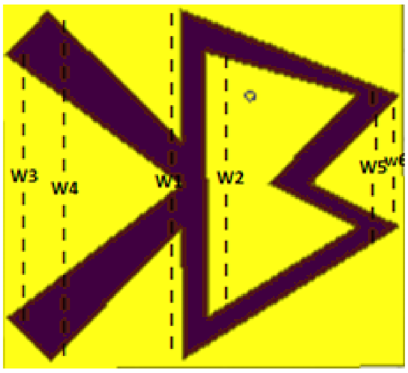
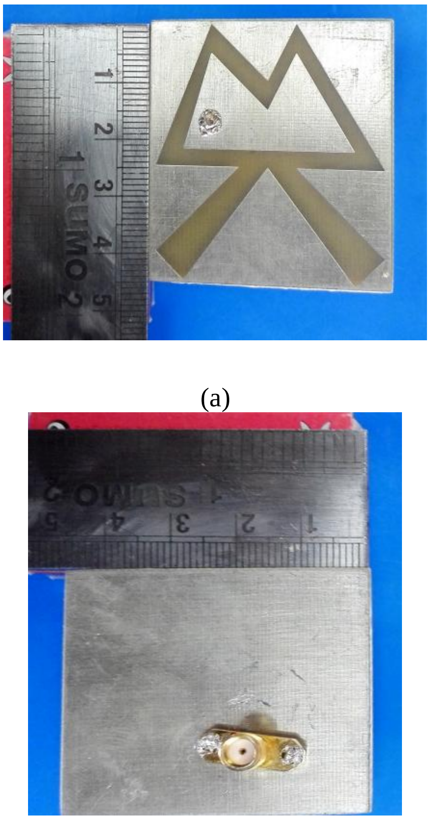


Fig. 2: Slotted RMPA Design

Table 3: Specifications of Slotted RMPA

Dimensions	Value (mm)
W1	40
W2	30
W3	30
W4	40
W5	12.5
w6	15

The following figure shows the top side and the flipside view of the fabricated prototype.



(a)

(b)

Fig. 3: Fabricated Prototype a) Top side view and b) Flip side view

The comparison of the three design iterations in terms of number of bands, resonant frequency, reflection coefficient, bandwidth, and gain has been tabulated as under.

Table 4: Comparison Results

Parameters	Stage 1	Stage 2	FABRICATED
Number of Bands	Single (1)	Dual(2)	Dual(2)
Operating Frequency (GHz)	6.29	5.68 (f1) 9.42 (f2)	5.64 (f1') 9.41 (f2')
Reflection Coefficient (dB)	-28.12	-30.34 (f1) -25.46 (f2)	-16.67 (f1') -15.84 (f2')
Bandwidth (MHz)	110	200 (f1) 250 (f2)	199(f1') 250(f2')
Gain (dBi)	-1.95	2.47 (f1) 5.58 (f2)	4.55 (f1') 7.27 (f2')

III. RESULTS AND DISCUSSION

The two design stages have been simulated and analyzed over HFSS-15 [6] for their standard parameters including the reflection coefficient [7], bandwidth [8], gain [9] and VSWR [10]. The final stage design has been fabricated and tested over 10 MHz-40 GHz Rhode & Schwarz ZVA VNA for its reflection coefficient, bandwidth and VSWR and in anechoic chamber for its radiation pattern and gain

The simulations over HFSS-15 revealed that the initially designed RMPA exhibited a single band resonance. The introduction of slots at the final stage resulted into dual band performance with significantly improved characteristics.

The fabricated design exhibited results close to those of the simulated stage design. The variations in the results may be accounted to the faults in fabrication. The figures 4-6 show the comparative plot of the standard parameters of the three design stages and the fabricated prototype. A tabulated comparison of the different stages and the fabricated structure in terms of their standard parameters has been provided towards the end of this section.

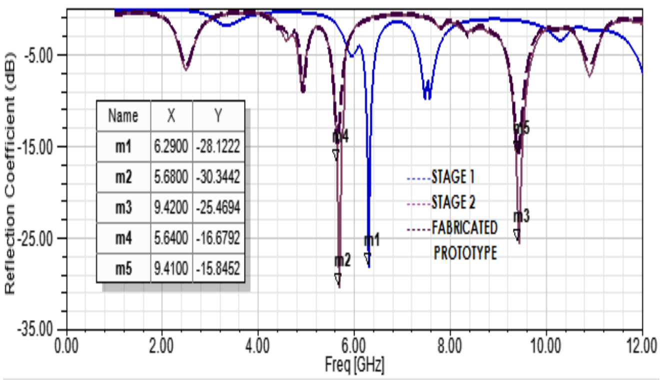


Fig. 4: Comparative Reflection Coefficient Plot

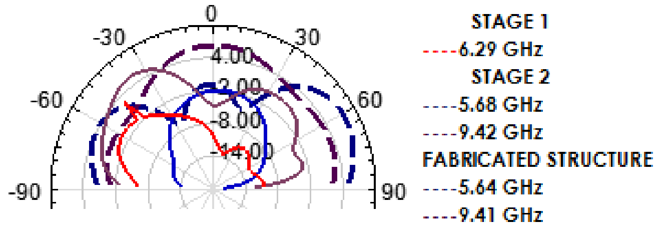


Fig. 5: Comparative Radiation Pattern Plot

IV. CONCLUSION

A novel slotting of a MRPA to achieve dual band characteristics intended to serve the C-band mobile applications except aeronautical mobile and the X-band satellite, aviation and space research applications has been proposed. The proposed design considers a 46 mm x 42 mm x 1.6 mm FR4 epoxy substrate and uses a coaxial feeding mechanism. The two design stages have been analyzed over HFSS-15 for their reflection coefficient, bandwidth, radiation pattern and gain. The final stage design was fabricated and tested over 10 MHz-40 GHz Rhode & Schwarz ZVA VNA for its reflection coefficient and bandwidth and in anechoic chamber for its radiation pattern and gain. The results, so obtained, have been found to be in close approximation to the simulated ones.

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Deepanshu Kaushal completed his B.Tech.in Electronics & Communication from Punjab Technical University in 2014. He is currently a second year M. Tech (E.C.E.) student of Pondicherry University and is doing his project on 'Microstrip Slotted Patch Antennas for Multiband Operation' under the guidance of Dr. T. Shanmuganantham (Assistant Professor, Department of Electronics Engineering, Pondicherry University, Pondicherry). His area of interest includes Antennas, Fractals and Metamaterials. He has 19 conference papers and 7 journals till date.