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Slotted Microstrip Rectangular Patch Antenna Design for Multiband Operation

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***Abstract*— The multiband operation of a MRPA in response to the three-way slotting achieved in the four stage design process is proposed. The design stages include a basic rectangular patch antenna design, introduction of a rectangular slot open ended at the two sides, introduction of a circular slot at the center of stage 2 design followed by the rectangular extensions of the circular slots in the end stage. A 1.6 mm thick FR4 epoxy substrate and coaxial feeding technique is employed. The different design stages have been analyzed over HFSS-15 for the major parameters including the reflection coefficient, bandwidth, radiation pattern and gain. The final stage structure was fabricated and the experimentally verified for its standard parameters including the reflection coefficient and bandwidth and which were found to closely approximate the simulated ones.**

***Index Terms*—Microstrip Patch, Slot, Multiband, Space applications.**

I. Introduction

Ever since the time their use was started, the MPAs continue to dominate the domain of antenna engineering and serve numerous applications including the satellite and the aviation communication applications. The inherent advantages of these MPAs include 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 [2] 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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The proposed design is developed through a four stage procedure with the final stage geometry involving the use of three different slotting techniques. Initially, a conventional rectangular patch antenna is developed followed by the introduction of a two-side open ended rectangular slot in the stage 2, incorporating a circular slot at the center in the design of stage 3 and finally a rectangular extension of the circular slot in the final stage. The substrate used is of 45 mm x 55 mm FR4 epoxy material that is 1.6 mm thick. The feeding technique employed is coaxial feeding mechanism. The simulation software used is HFSS-15 [6]. The different design iterations have been analyzed for major parameters including the reflection coefficient [7], bandwidth [8], radiation pattern [9] and gain [10]. The final stage structure was fabricated and the experimentally verified for its standard parameters including the reflection coefficient and bandwidth which were found to closely approximate the simulated ones.

An introduction to the microstrip patch antennas and the existing literature works over the transitions from conventionally used rectangular patches to modified slotted structures has been given in the section 1. The geometry of the proposed antenna and its specifications are discussed in the section 2. The comparative results of the three design stages and the fabricated counterpart have been included in the section**.**

II. Design Procedure

The proposed antenna design has been developed through a three stage iteration process of a basic rectangular patch, extended rectangular patch geometry and finally the slotting of the modified patch in the end stage.

A. Iteration1: Basic RMPA Design

The figure 1 shows a 50 mm x 40 mm rectangular patch built over a 55 mm x 45 mm FR4 epoxy substrate that is 1.6 mm thick. 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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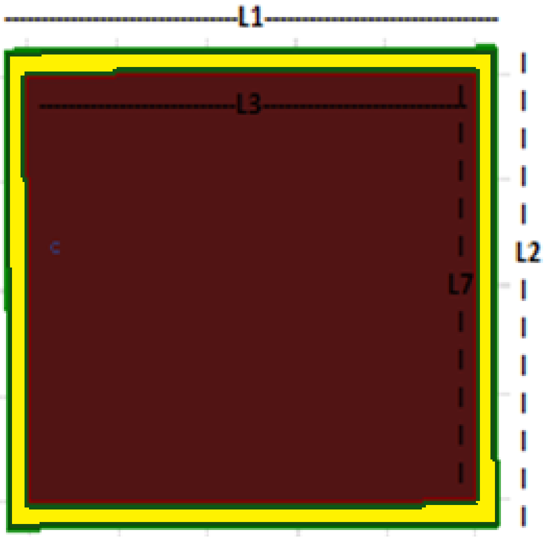

Figure 1: Basic RMPA Design

Table 1: Specifications of RMPA

Dimensions	Value (mm)
L1	55
L2	45
L3	50
L7	40

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: Introducing a Two-way Open Ended Rectangular Slot

As shown in figure 2, a two -way open ended rectangular slot is introduced into the initially designed MRPA.

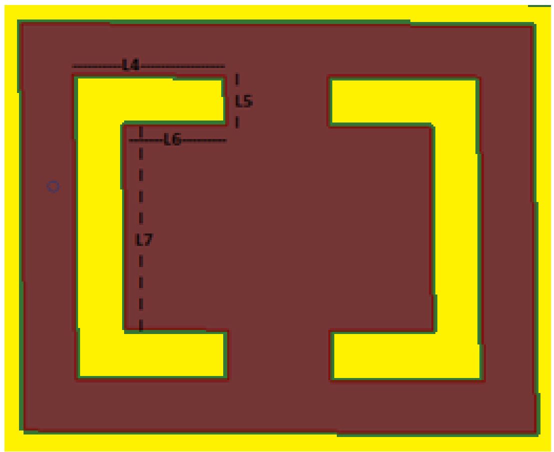

Figure 2: Modified RMPA Design

Table 3: Specifications of Modified RMPA

Dimensions	Value (mm)
L4	15
L5	5
L6	20
L7	10

C. Iteration 3: Introduction of a Circular Slot in the Modified RPA

The figure 3 shows a circular slot of 5 mm radius incorporated into the modified RPA.

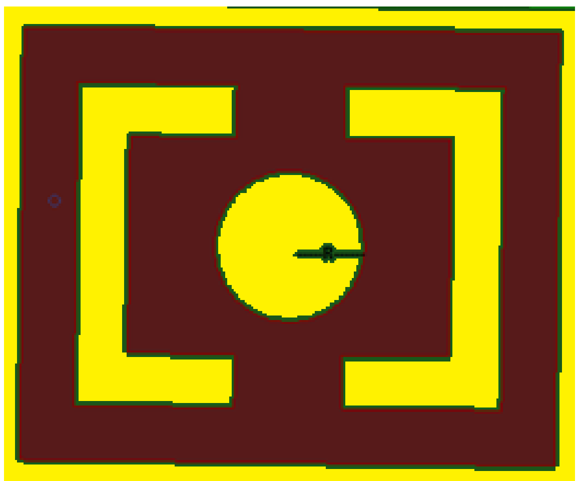

Figure 3: Third Stage Design

D. Iteration 4: Further Modification of Circularly Slotted Modified RPA

This stage witnesses adding rectangular extensions to the third stage design.

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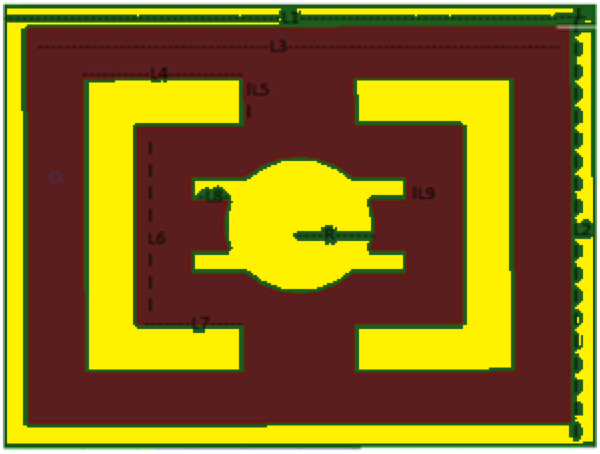
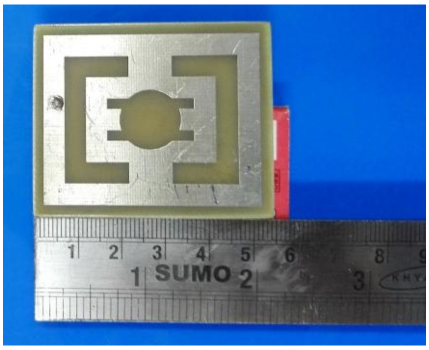
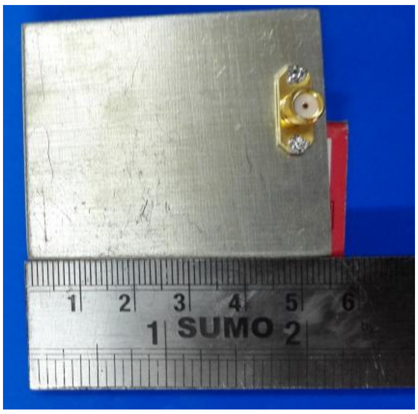


Figure 4: Final Stage Design

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



(a)



(b)

Figure 5: Fabricated Prototype a) Top side view and b) Flip side view

III. RESULTS AND DISCUSSION

The four design stages were simulated over HFSS-15 [6] and analyzed for their standard parameters including the reflection coefficient [7], bandwidth [8] and gain [9]. The final stage design was fabricated and tested over 10 MHz-40 GHz Rhode & Schwarz ZVA VNA [10] for its reflection coefficient and bandwidth.

The simulations over HFSS-15 revealed that the initially designed RMPA exhibited a single band resonance. The modification of length in the second stage resulted into not only the lowering of the resonant frequency but also the design offered an improvement of characteristics of reflection coefficient, bandwidth and gain. 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 figure 6 shows the comparative reflection coefficient plot of the different design stages and the fabricated structure. The figure 7 shows the radiation pattern plot of the final simulated stage. For clarity of understanding, only final simulated stage design has been considered and the gain results of others have been tabulated. 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.

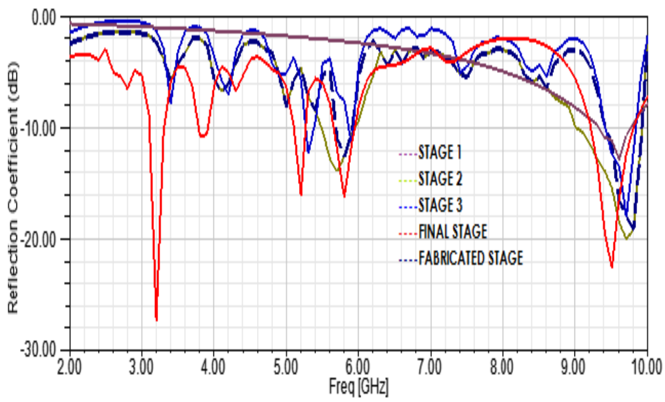


Figure 6: Comparative Reflection Coefficient Plot

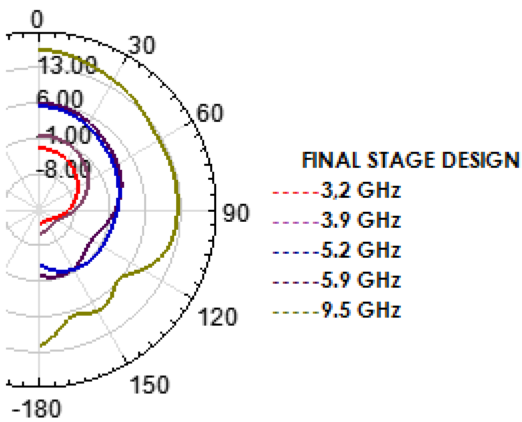


Figure 7: Radiation Pattern Plot of the Final Stage Design

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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	**Iteration 1**	**Iteration 2**	**Iteration 3**	**Final Design**	**Fabricated Design**
Number of Bands	Single (1)	Dual (2)	Triple (3)	Pent (5)	Pent (5)
Operating Frequency (GHz)	9.6	5.8/9.8	5.3/ 5.9/9.7	3.2/3.9/5.2/5.9/ 9.5	3.1/4/5.2/ 5.91/ 9.54
Reflection Coefficient (dB)	-13.46	-12.53/-19.05	-12.29/ -11.57/ -18	-27.18/-10.66/-16.02/ -16.02/-22.5	-28.86/-12.12/-14/ -15.59/-20.5
Bandwidth (MHz)	300	300/300	60/300 / 300	250/230/ 200/180/ 400	248/233/199/180/384
Gain (dBi)	3.4	9.2/9.5	2.95/9.9/9.8	9.4/5.34/ 9.4/9.9/8.4	No Test

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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