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Optimized Microstrip Slotted Patch Structure for Ku and Ka Band Operation

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***Abstract*— An optimal sized microstrip slotted patch structure intended to serve Ku & Ka band applications in the frequency range between 19.52 GHz to 31.5 GHz is proposed in this paper. The substrate considered is FR4 epoxy that has optimized dimensions of 10 mm x 8.7 mm x 1.6 mm and employs probe feeding mechanism. The three design stages have been simulated and analyzed over HFSS-15 for the corresponding reflection coefficient, bandwidth, radiation pattern, gain and VSWR. The final stage design was 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 results, so obtained, have been found to be in close approximation to the simulated ones.**

***Index Terms*—Microstrip Patch, Slot, Ku and Ka Band, VNA.**

I. Introduction

Today, the microstrip patch antennas are proliferating in large numbers and have completely revolutionized the antenna industry. Their immense popularity is indeed remarkable and the research on them is intensive. They are widely employed for applications including the satellite and the aviation communication applications and offer 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.

The small sized slotted patch antenna proposed in this paper is developed in three stage iterations of a rectangular patch, modification of length of rectangular patch geometry and slotting of the modified rectangular patch geometry in the final stage. The FR4 epoxy material based substrate has optimum dimensions of 10 mm x 8.7 mm x 1.6 mm, relative permittivity 4.4 and dielectric loss tangent of 0.02. Coaxial/ probe feeding is employed. HFSS-15 has been used to analyze the three design stages for their reflection coefficient [6], bandwidth [7], radiation pattern [8] and VSWR [9] characteristics. The final stage design was 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 results, so obtained, have been found to be in close approximation to the simulated ones.

An overview of the microstrip patch antennas, the research shift from the conventionally used patch structures to extended patches with slots is given in section 1. The design procedure of the proposed antenna has been discussed in the section 2. The comparative results of the three design stages and the fabricated counterpart have been included in the section 3**.**

II. DESIGN Procedure

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

A. Iteration1: 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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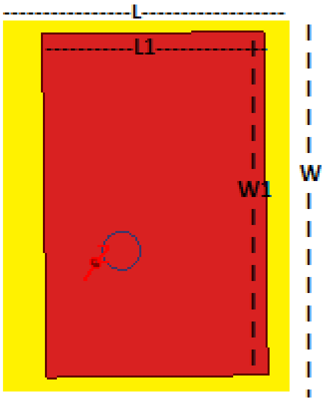


Figure 1: Basic RMPA Design

Table 1: Specifications of RMPA

Dimensions	Value (mm)
L	8.7
W	10
L1	5.8
W1	9

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: Modification of Length of Basic RMPA Design

The increase in the length of the basic RMPA results into the lowering of resonant frequency. Most specifications of this stage design are similar to those of the first stage design and the additional ones have been tabulated below.

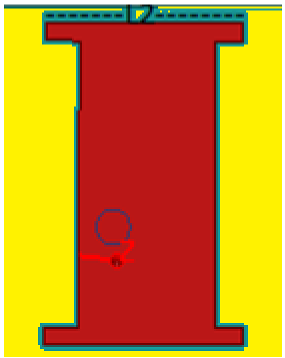


Figure 2: Slotted RMPA Design

Table 3: Specifications of Slotted RMPA

Dimensions	Value (mm)
L2	5.8

C. Iteration 3: Slotting the modified RMPA Design

As shown in the figure 3 below, the final stage witnesses introduction of slots of different shapes into an extended microstrip rectangular patch antenna of stage 2.

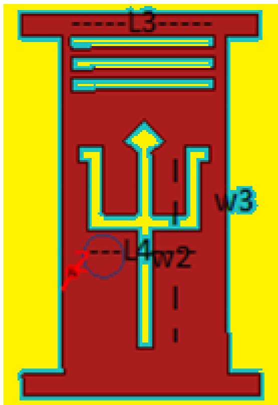
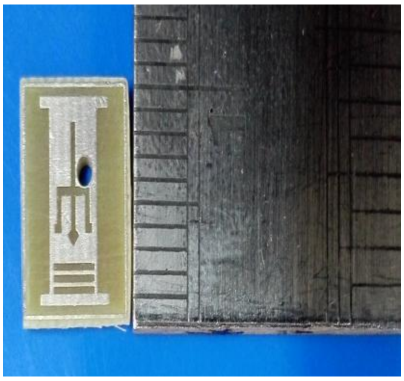


Figure 3: Final Stage Design

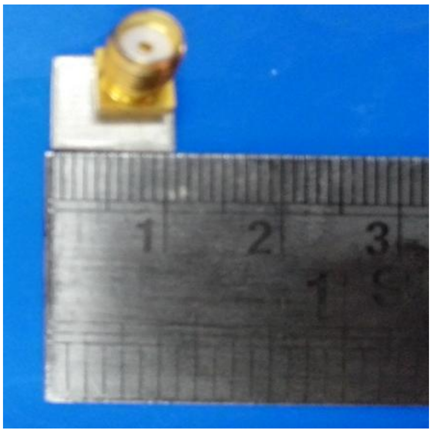
Table 4: Specifications of Slotted RMPA

Dimensions	Value (mm)
W2	4.4
L3	3.5
W3	1.6
L4	2.5

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



(a)



(b)

Figure 4: Fabricated Prototype a) Top side view and b) Flip side view

Table 4: Comparison Results

III. RESULTS AND DISCUSSION

The three design stages have been simulated and analyzed over HFSS-15 for their standard parameters including the reflection coefficient, bandwidth, gain and VSWR. 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 4-7 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.

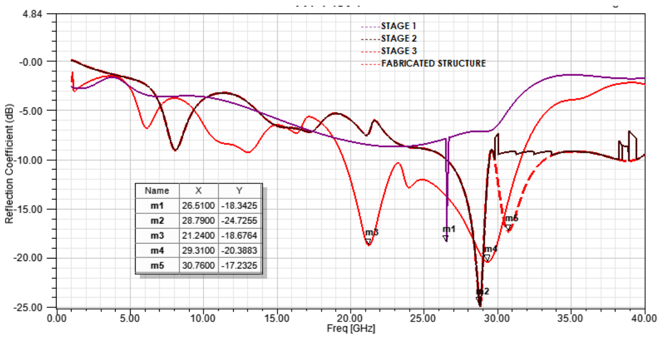


Figure 5: Comparative Reflection Coefficient Plot

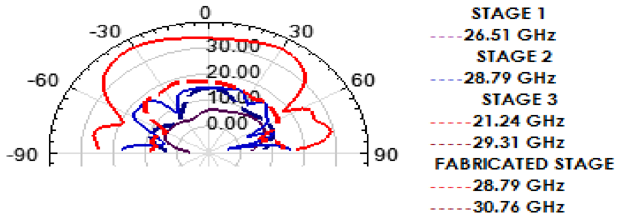


Figure 6: Comparative Radiation Pattern Plot

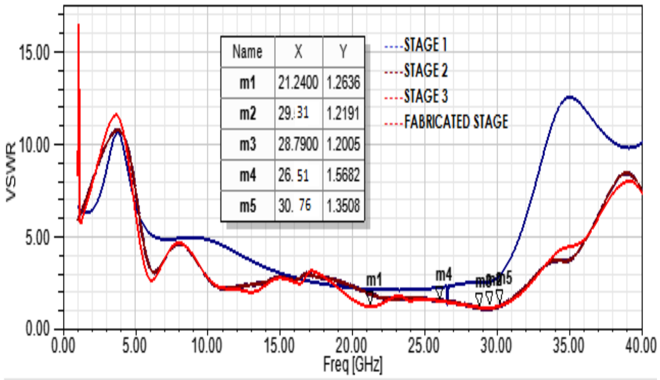


Figure 7: Comparative VSWR Plot

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.

IV. CONCLUSION

A An optimal sized microstrip slotted patch structure intended to serve Ku and Ka band applications in the frequency range between 19.52 GHz to 31.5 GHz is proposed in this paper. The substrate considered is FR4 epoxy that has optimized dimensions of 10 mm x 8.7 mm x 1.6 mm and employs probe feeding mechanism. The three design stages have been simulated and analyzed over HFSS-15 for the corresponding reflection coefficient, bandwidth, radiation pattern, gain and VSWR. The final stage design was 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 results, so obtained, have been found to be in close approximation to the simulated ones.

Table 5: Tabulated Results

Parameters	**Stage 1**	**Stage 2**	**Stage 3**	**Fabricated Structure**
Number of Bands	Single (1)	Single (1)	Double (2)	Double (2)
Operating Frequency (GHz)	26.51	28.79	f1=21.24 f2=29.31	f1'=28.79 f2'=30.76
Reflection Coefficient (dB)	-18.34	-24.72	-18.67 (f1) -20.38(f2)	-24.72 (f1') -17.23(f2')
VSWR	1.37	1.2	1.26(f1) 1.21(f2)	.2 (f1') 1.35 (f2')
Bandwidth (MHz)	170	2880	11980 (f1) 990 (f2)	2880 (f1') 2200 (f2')
Gain (dBi)	11.39	16.08	17.6(f1) 20.6 (f2)	9.9 (f1') 1.8(f2')

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