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Slotted Circular Patch Structures for C and X Band Resonance

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***Abstract*— The three stage design of a novel microstrip patch antenna that suited for C and X band fixed satellite operations is proposed. The idea has been developed in three stages that include creating a single circular patch, duplication of this geometry and unification with its identical circular counterpart and finally the slotting of the modified circular geometry. A 36 mm x 57 mm x 1.6 mm FR4 epoxy substrate and a coaxial feeding mechanism have been used for the design purpose. The three design stages have been analyzed over HFSS-15 for their 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, C and X Band, Resonance.**

I. Introduction

The widespread use of MPAs for the numerous applications over the past times is quite remarkable. These MPAs have small size, light weight, can be fabricated easily, are compatible to most MMIC designs and are conformal to most non-planar structures. The FCC has allocated the portion of the spectrum that extends from 5.925 GHz to 6.7 GHz and that extending from 7.9 GHz to 8.175 GHz for fixed satellite (earth to space) applications. The MPAs have characteristics supplementing such applications. 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. The quest for better performance with improved characteristics made the researchers to shift gradually towards the circular shaped patch geometries. Tahsin in [3] showed that the proposed circular patch geometry was superior over the rectangular patch geometry when the bandwidth parameter is considered. Also, the mono band microstrip slotted power button antenna proposed by Deepanshu Kaushal in [4] achieves a single band reflection coefficient of -12.7 dB, gain of 4.5 dBi and a bandwidth of 50 MHz.

A unified circular geometry slotted to achieve dual band operation has been proposed in this paper. The development of the proposed design is achieved in iterations of a single circular patch, unification of two identical circular patches and finally the slotting of the modified patch structure. A 36 mm x 57 mm x 1.6 mm FR4 epoxy substrate of relative permittivity 4.4 and a dielectric loss tangent of 0.02 is considered. The coaxial feeding technique that uses an inner conductor soldered to the radiating patch through the substrate and an outer conductor connected to the ground is used. Each of the design stage has been analyzed over HFSS-15 [5] for its reflection coefficient [6], bandwidth [7], radiation pattern [8], gain [9] and VSWR [10] characteristics. The final stage design was fabricated and tested over 10 MHz-40 GHz Rhode & Schwarz ZVA VNA [11] 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.

A brief introduction of the MPAs and the existing literature works related to the conventionally used rectangular shaped patches and the gradual shift towards the use of circular patch geometries is discussed in section 1. The three stage design procedure is discussed in the section II. The section III relates to the major results for the proposed design analyzed over HFSS-15 that include the reflection coefficient, bandwidth, radiation pattern, gain and VSWR has been carried in the section 3. 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.

II. Prototype Design

The proposed antenna design has been developed through a three stage iteration process of a single circular patch, unification of two identical circular patches and finally the slotting of the modified patch structure.

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A. Iteration1: Microstrip Circular Patch Antenna Design

The figure 1 shows a circular patch geometry of 15 mm radius that is built over a 36 mm x 57 mm x 1.6 mm FR4 epoxy substrate. The table 1 lists the specifications of the basic CMPA whose design equations have been listed in table 2.

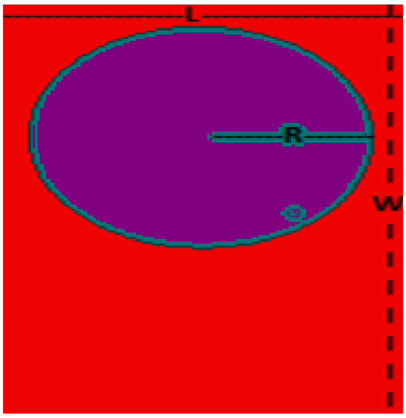

Fig. 1: Basic RMPA Design

Table 1: Specifications of CMPA

Dimensions	**Value (mm)**
L	36
W	57
R	15

Table 2: Design Equations

Parameter	**Formula**
Radius of the patch (a)	$a = \dfrac{F}{\sqrt{\left\{1 + \dfrac{2h}{\pi \varepsilon_r F}\left[\ln\left(\dfrac{\pi F}{2h}\right) + 1.7726\right]\right\}}}$
F	$F = \dfrac{8.791 \times 10^9}{f_r \sqrt{\varepsilon_r}}$

B. Iteration 2: Unification of identical circular geometries

The design in the second iteration results from the unification of two identical circular patches of stage 1.

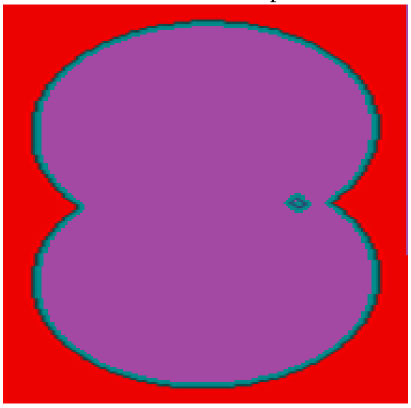

Fig. 2: Modified RMPA Design

C. Iteration 3: Slotting the Modified CMPA Design

The unified circular geometry is slotted using a triangular element and two parallel rectangular elements. The specifications are listed in table 3.

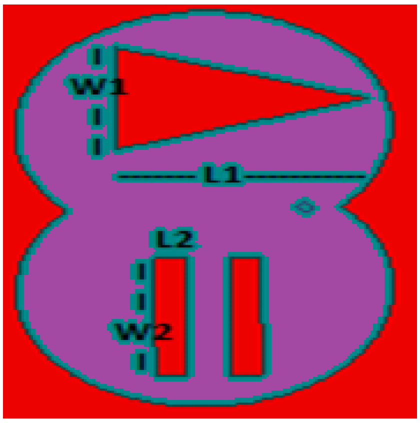

Fig. 3: Final Stage Design

Table 3: Specifications of CMPA

Dimensions	**Value (mm)**
L1	20.88
W1	13
L2	2.5
W2	15

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

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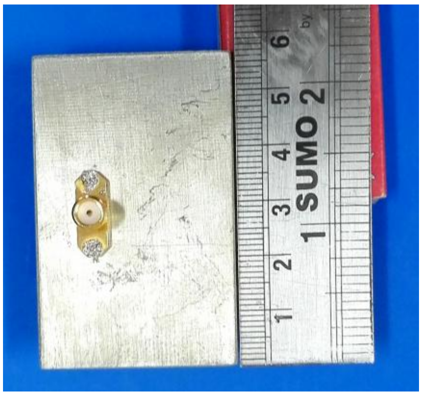
(a)



(b)

Fig. 4: 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	Stage 3	Fabricated Stage
Number of Bands	Single (1)	Single (1)	Dual (2)	Dual(2)
Operating Frequency (GHz)	6.41	6.25	6.64 (f1) 8.02 (f2)	6.68 (f1') 8.08 (f2')
Reflection Coefficient (dB)	-11.58	-23.3	-20.1 (f1) -12.31 (f2)	-18.19 (f1') -11.41 (f2')
VSWR	1.15	1.68	1.26 (f1) 1.70 (f2)	1.27 (f1') 1.73 (f2')
Bandwidth (MHz)	530	220	270 (f1) 120 (f2)	268 (f1') 118 (f2')
Gain (dBi)	2.3	6.96	9.69 (f1) 14.67 (f2)	11.11 (f1) 12.52 (f2)

III. RESULTS AND DISCUSSION

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

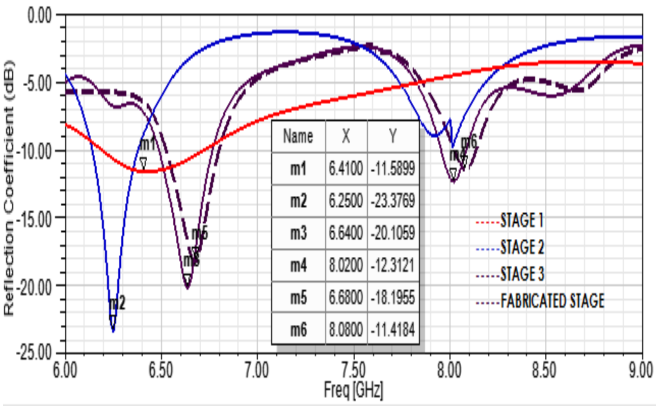


Fig. 5: Comparative Reflection Coefficient Plot

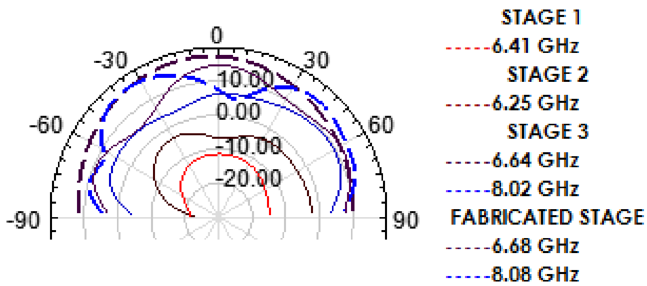


Fig. 6: Comparative Radiation Pattern Plot

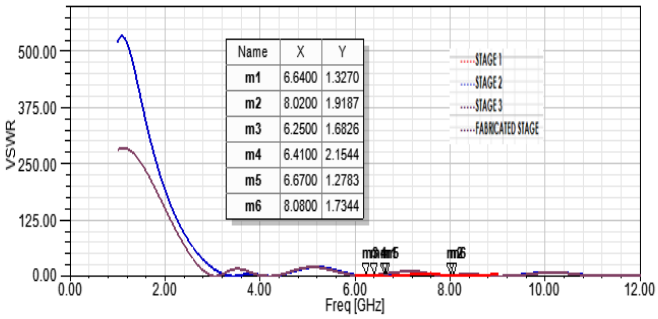


Fig. 7: Comparative VSWR Plot

IV. CONCLUSION

A The three stage design of a novel microstrip patch antenna that suited for C and X band fixed satellite operations is proposed. The idea has been developed in three stages that include creating a single circular patch, duplication of this geometry and unification with its identical circular counterpart and finally the slotting of the modified circular geometry. A 36 mm x 57 mm x 1.6 mm FR4 epoxy substrate and a coaxial feeding mechanism have been used for the design purpose. The three design stages have been analyzed over HFSS-15 for their 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.

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