Effect of Cavity in Substrate on Multiband Circular Micro-strip Patch Antenna

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Abstract— *A compact circular patch antenna consisting of cavity in substrate and micro-strip feed line is proposed in this work. This design consists of a circular patch along with the capability of covering multiple bands 1 to 15 GHz range. The simulation results of circular patch with micro-strip feed arrangement with different cavity size and with the modification in cavity of these different arrangements are presented in this paper. The circular patch antenna designed with FR4b substrate (εr=4.54, h=0.1.6mm). Simulation results of return loss and polar radiation pattern are analyzed in this paper.*

Keywords*—Micro-strip antenna, Return loss, Bandwidth, VSWR, Reflection Coefficient.*

I. INTRODUCTION

As the increasing demand of improvement and more and more development of mobile communication and the emergence of numerous systems, it is imperative to design multiband antennas to consider various applications simultaneously. The biggest challenge is to design the compact and multiband communication antennas. Micro-strip patch antennas have found extensive application in wireless communication system owing to their advantages such as low-profile, conformability, low-cost fabrication and ease of integration with feed networks. However, conventional micro-strip patch antenna suffers from very narrow bandwidth, typically about 5% bandwidth with respect to the centre frequency. This poses a design challenge for the micro-strip antenna designer to meet the multiband antenna techniques. In mobile communication systems many different frequency bands are needed such as global system for mobile communication (GSM800/900), digital communication system (DCS), personal communication system (PCS), universal mobile telecommunication system (UMTS) and the industrial scientific and medical (ISM) band [1-2].

In recent years, many authors have dedicated their investigations to create new designs or variations in the original antenna that to some extent; produce either wider bandwidths or multiple-frequency operation in a single element. Many techniques of are implemented to achieve multi frequency operations.

Multi-band micro-strip antenna was realized by cutting a quarter wavelength or half wavelength slots inside the patch[2] operation also the stacked structure was utilized for multiband structure [3] again by applying fractal shape technique into antenna geometrics, multiband antenna can be constructed [4]–[8]. By using multilayer stacked patch [9] and single layer micro-strip antenna [10] has been paid to little attention for achieving dual-band. In [11] dual frequency is achieved by cutting a square slot in the middle of a rectangular patch where they achieved both compactness and dual frequency operation. Dual frequency with tunable frequency ratio can be attained by loading a pair of narrow slots parallel and close to the radiating edges of a bow tie patch [12]. Pre factual geometry and two short circuits in patch are used to achieve compact dual-band circular polarization antenna [13].

The aim of this article is to design compact multiband circular patch antenna for wireless communication systems and study the different techniques to improve number of bands in 1 to 15 GHz range. Primarily simple circular patch was designed with the required frequency range of 1 to 15 GHz, which was a multiband antenna with five frequency bands in the required frequency range of 1-15 GHz with fine radiation intensity at all the resonance frequencies. Further the cavity insertion technique was studied for the purpose of multiband behavior.

To study the nature of multiband characteristics in the same design on the FR4 substrate (ϵ_r= 4.54, h= 1.6mm), cavities of different size are analyzed. The applied technique to introduce the deformities in the substrate changes the electrical length of the antenna and hence alters the resonance frequency this change in the resonance frequency, allows variable number of operation band to be accommodate in the given range. With the inclusion of this technique the structure was changed and analyzed with different cavity sizes.

II. ANTENNA DESIGN

The proposed antenna has a simple circular patch using a micro-strip line feed; the patch antenna is designed using the basic concepts of the micro-strip technology.

a. Basic theory

Micro-strip patch antennas consist of a metallic patch of metal that is on the top of a grounded dielectric substrate of thickness *h*, with relative permittivity ε_r as shown in Fig. 1.

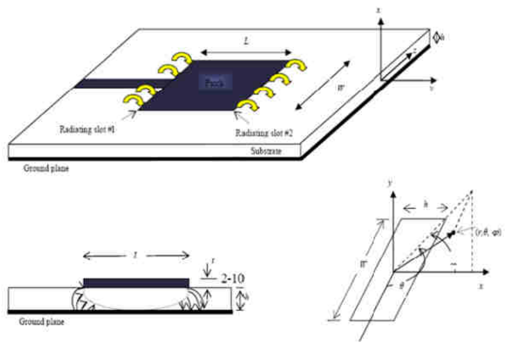


Fig. 1 Geometry of micro-strip patch antenna

Proposed Design of circular patch

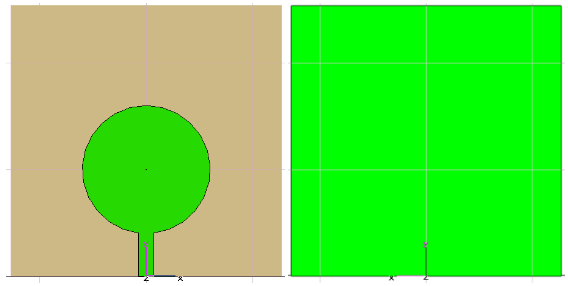
The proposed antenna is composed of a PEC (Perfect Electric Conductor) ground plane, substrate which is FR-4

The dimensions of the patch are calculated using the standard design equations [14] and optimized to a value of radius of the patch 15 mm , the substrates have dimension 50.8 x 50.8 mm^2, length of the micro-strip feed line is optimized to 20 mm with a calculated width of 3 mm.

Simulation result of S_{11} and vswr of the circular patch antenna

The metallic patch may be of various shapes, with rectangular and circular being the most common; the geometry of a Rectangular Micro-strip Patch Antenna (RMPA) is shown in Figure 1. The patch of length 'L', width 'W' and thickness 't' is printed on RT- Duroid (ε_r = 2.22) substrate.

(ε_r = 4.54, h = 1.6 mm) above which a circular patch is printed with inset feed line.



(a) (b)

Fig. 2 Top (a) and bottom (b) view of circulator patch antenna

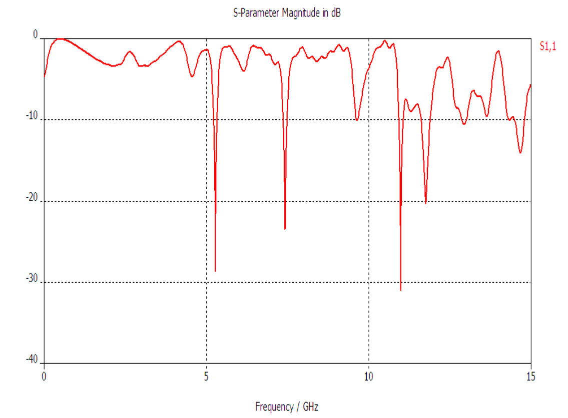


Fig.3 S11 of the circular patch antenna

With the given design and dimensions of the circular microstrip patch antenna obtained results of the S_{11} are summarized in the table below:

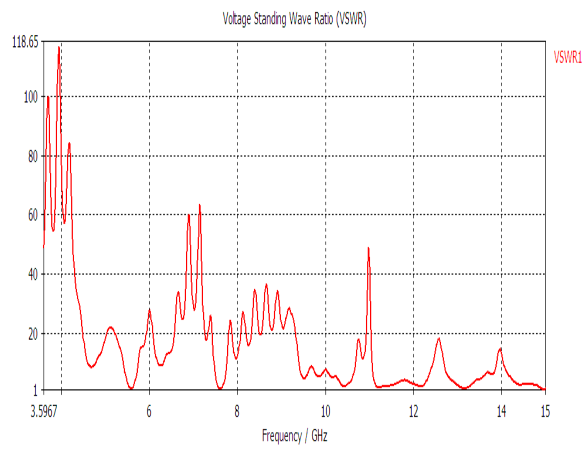


Fig.4 VSWR of the circular patch antenna

no. of bands	Central Frequency (GHz)	Return loss at central freq	frequency range(GHz)	fractional bandwidth %
5	5.28	-29	5.23-5.33	1.8939394
	7.42	-24	7.37-7.49	1.6172507
	11	-31	10.93-11.06	1.1828935
	11.8	-20	11.62-11.90	2.3829787
	14.7	-14	14.5-14.8	2.0435967

III. CIRCULAR PATCH ANTENNA WITH CAVITY

With the motivation of the study of the behavior of the circular patch antenna, the design is simulated with inserting a cavity in the substrate. The patch used to make the above structure of multi band antenna is observed with circular cavity in the substrate at the center of the patch. A high permittivity substrate will make the metal patch look electrically larger by changing the wave propagation speed; another method used in tuning a micro-strip antenna is loading the patch with slots. There are two helpful models that can be used to explain change in resonant frequency.

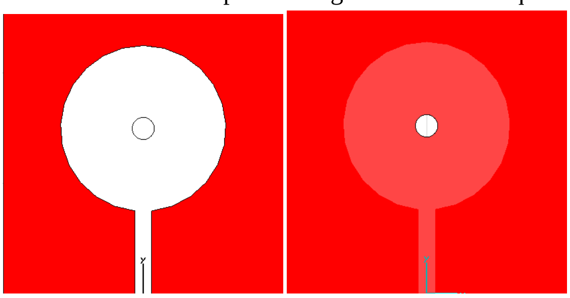


Fig.5. Structure with cavity

The above figure show top and bottom view of the micro-strip patch antenna, in the substrate a cavity is there. The effect of modification in substrate can be directly observed as the bands are changing with the changing the radius of cavity. The table below summarizes the performance of the antenna with different cavity radius.

AS we can observe from the above table the number of band increases from five to seven for cavity radius of 2mm but it reduces to four for radius of cavity equal to 3mm and the constant to three for cavity radius of 4mm and 5mm respectively also with the increase in the cavity radius the lowest frequency also increases which proves the alteration in electric width of the antenna.

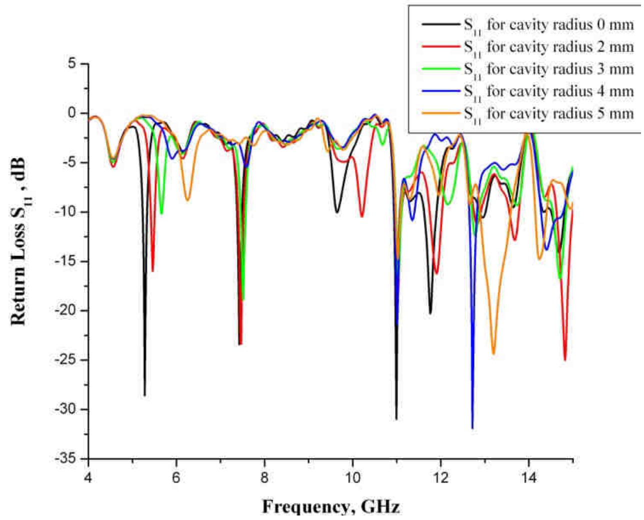
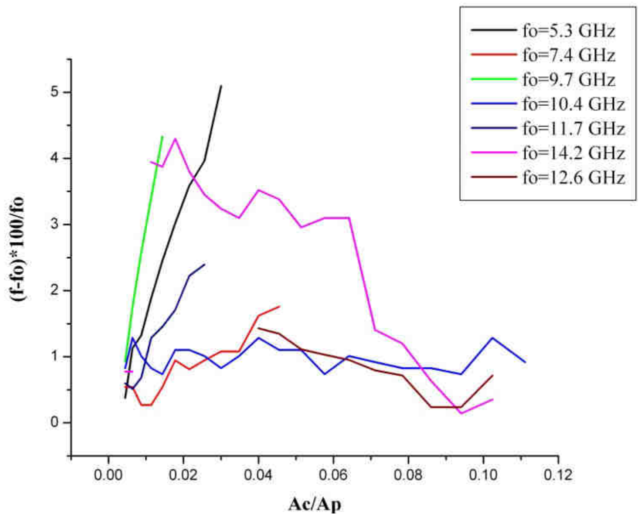


Fig. 6 Comparison of S11 for different cavity radius

The above figure 6 represents the return loss of the antenna for all the experiments return loss. The fig.7 represents the comparison of normalized frequency on the scale of ratio of



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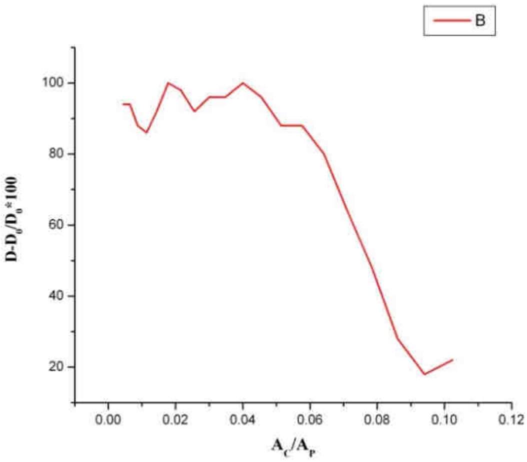
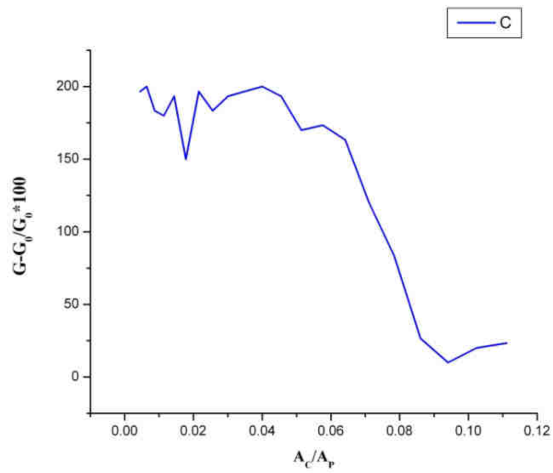
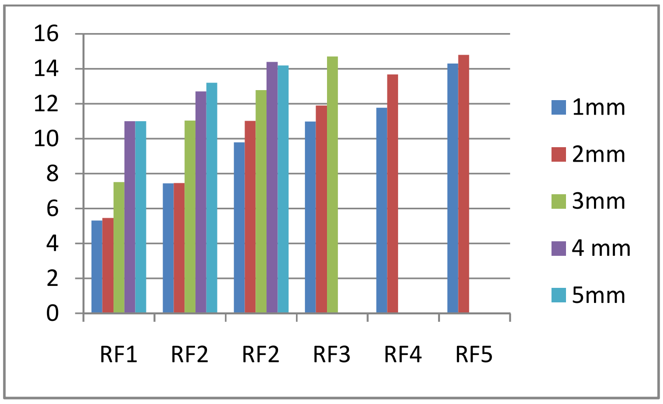
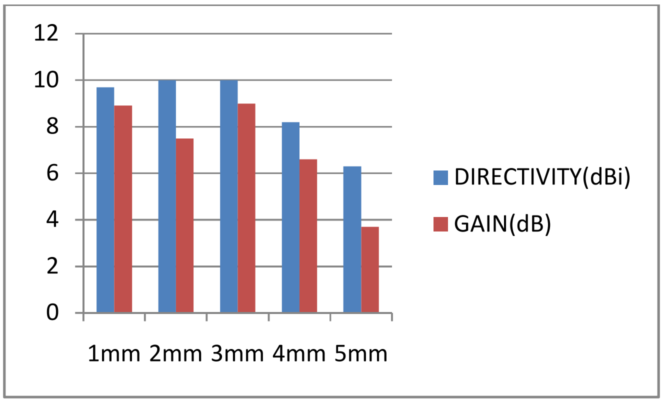
Radius of the cavity	no. of bands	Central Frequency (GHz)	Return loss at central freq	frequency range(GHz)	fractional bandwidth%
0 mm	5	5.28	-29	5.23-5.33	1.8939394
		7.42	-24	7.37-7.49	1.6172507
		11	-31	10.93-11.06	1.1828935
		11.8	-20	11.62-11.90	2.3829787
		14.7	-14	14.5-14.8	2.0435967
2mm	7	5.46	-16	5.41-5.52	2.014652
		7.47	-23	7.4-7.52	1.6064257
		11	-18	10.95-11.11	1.4519056
		11.9	-16	11.73-12.04	2.605042
		12.8	-11	12.75-12.91	1.2480499
		13.7	-13	13.55-13.77	1.6081871
		14.8	-25	14.62-15	2.5641026
3mm	4	7.51	-19	7.45-7.56	1.4647137
		11	-17	10.98-11.10	1.087942
		12.8	-12	12.71-12.86	1.1737089
		14.7	-17	14.54-14.85	2.1088435
4 mm	3	11	-22	10.95-11.07	1.0899183
		12.7	-32	12.64-12.82	1.4150943
		14.4	-14	14.27-14.78	3.5416667
5mm	3	11	-15	10.97-11.08	0.9981851
		13.2	-24	12.87-13.61	5.6060606
		14.2	-15	14.11-14.41	2.1082221







Variation in resonance frequency with cavity radius



Variation in gain and directivity with cavity radius

IV. CONCLUSION

Design, simulation and comparative analysis of cavity micro-strip circular patch antenna is presented in this paper come out to be very efficient and utilizable antenna. Initial results draw an interest for study of slotted structure an important technology in designing of compact multiband patch antenna. Insertion of cavity has a utility in designing the compact antennas; it needs some research and focus to emerge as a milestone in compact antenna technology.

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