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Design and Compare Different Feed Length for Circular Shaped Patch Antenna

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Abstract **- The demand for antenna in present scenario depends on its size and thus miniaturization has become the need. Microstrip patch antennas meet this requirement and are versatile in terms of realization and easy to fabricate. This paper presents a circular shaped microstrip patch antenna at 1.5 GHz using Computer Simulation Technology (CST) Microwave Studio. We mainly focused on optimizing the size, efficiency, return loss and other parameters of circular shaped patch antenna by varying its feed length. Alongside, these parameters were manually computed and in the end we have compared the various results obtained for different feed lengths of circular shaped microstrip patch antenna.**

Index Terms **- Circular Shaped Microstrip Patch Antenna (CSPA), CST Software, Flame Retardant 4 (FR-4) substrate, Patch Width, Feed Length**

I. INTRODUCTION

Recently, it is necessary to minimize the size of antenna due of tremendous development in the field of wireless communication systems. There are, however, many limitations because the size of antenna increases proportional to wavelength. Microstrip antenna have been widely used in various useful applications, due to their low weight, low profile, conformability, easy and cheap realization [1], [2]. They can be designed to operate over a large range of frequencies (1- 40 GHz) and easily combine to form linear or planar arrays [3]. A microstrip antenna consists of a very thin metallic patch placed on conducting ground plane, separated by a dielectric substrate. Often microstrip antennas are also referred to as patch antennas. The radiating patch may be square, rectangular, thin strip (dipole), circular, elliptical, triangular, or any other configuration.

The most popular configuration is the circular patch or disk. It has also received a lot of attention not only as a single element [4-7] but also in arrays [8], [9]. It has been typically assumed that input resistance of conventional circular microstrip antenna has the same dependence on the radius patch and dielectric constant of the material used [8]. In circular microstrip antenna there is only one degree of freedom to control (radius of the patch). Hence, the order of mode does not changed, but it changes the absolute value of resonant frequency. The configurations that can be used to feed microstrip antennas are microstrip line, coaxial probe, aperture coupling, and proximity coupling [11-13].

The proposed antenna is designed for 1.5GHz with circular shaped patch. The proposed antenna is made by using microstrip line feed and simulated by CST'10. A typical circular microstrip patch antenna is shown in Fig.1 and its side view is shown in Fig.2.

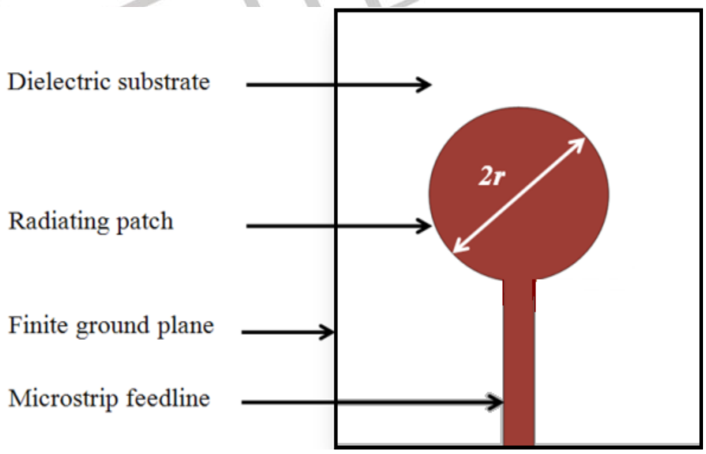


Fig.1. Circular Microstrip Patch Antenna

The operating frequency range used falls under UHF frequency range. Microstrip antennas are preferred due to their numerous advantages such as lightweight, low profile, easy, inexpensive fabrication and simple modeling. They are very versatile when chosen for a particular patch shape in terms of polarization, pattern and resonant frequency. Also, the antenna is designed for L-band application.

II. DESIGN EQUATION AND CHARACTERIZATION

Microstrip patch antenna consists of a radiating patch that may be square, circle, triangle, ring and rectangle etc. on one side of a dielectric material substrate and a ground plane on the other side.

A. *Parameter Characterization*

There are three essential parameters for design of a circular shaped microstrip patch antenna [1]. Firstly, the resonant frequency (f_r) of the antenna. The resonant frequency selected for this design is 1.5 GHz. The frequency range used is 0 GHz – 3 GHz and the design antenna must be able to operate within this frequency range. Secondly, the dielectric material of the substrate. There are numerous substrates that can be used for the design of microstrip antennas, and their dielectric constants are usually in the range of $2.2 \leq \epsilon_r \leq 12$. For this design, the dielectric substrate used is FR-4(lossy) which has a dielectric constant of 4.3 and loss tangent equal to 0.025. Low dielectric constant is used in the design because it gives better efficiency and higher bandwidth, and lower quality factor Q. The low value of dielectric constant increases the fringing field at the patch periphery and thus increases the radiated power. Lastly, the substrate thickness. In this design, we have kept the thickness 1.6 mm.

B. *Model Selection*

There are three popular models for the analysis of microstrip antennas - transmission line model, cavity model, and full wave model[1], [9]. The transmission line model is the simplest. It gives a good physical insight but is less accurate. The cavity model, which is used in this work, is quite complex but gives good physical insight and is more accurate. The full wave model is the most complex. It is very accurate in the design of finite and infinite arrays or stacked structures. The circular patch antenna can only be analyzed conveniently using the cavity model [5], [6], [14].

Based on the cavity model formulation, a design procedure is outlined which leads to practical designs of circular microstrip antennas for the dominant TM^z_{110} mode. The resonant frequency for dominant mode TM^z_{110} is given by Eq.1 as [1] :

$$(f_r)_{110} = \frac{1.8412}{2\pi a\sqrt{\mu\epsilon}} = \frac{1.8412\upsilon_0}{2\pi a\sqrt{\epsilon_r}} \tag{1}$$

The actual radius a of the patch is given by Eq.2,

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi\epsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}} \tag{2}$$

where,

$$F = \frac{8.791 \times 10^9}{f_r\sqrt{\epsilon_r}} \tag{3}$$

where, υ_0 = speed of light in free-space,
ϵ_r = dielectric constant of the substrate,
f_r = resonant frequency,
h = the height of the substrate.

C. *Feed Selection*

In this work, microstrip line feed is used as its main advantage is that it is easy to fabricate, simple to match by controlling the inset position and rather simple to model. It is a patch added to the radiating patch and feed is given at its edge. On simulating the designs for various feed lengths, it is observed that the feed can be placed at any place within the patch length to match with its input impedance (usually 50 ohm) as the difference in the values of the parameters is negligible [9]. Figure 2, describes the microstrip feed line. An equivalent circuit of microstrip feed line is shown in Fig.3.

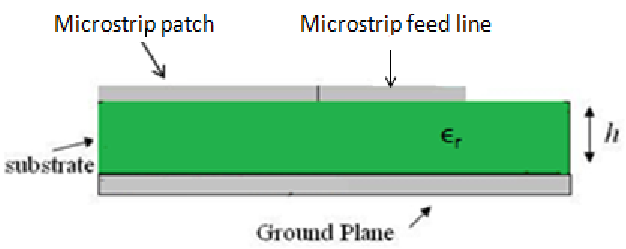


Fig.2. Side view of CSPA with microstrip feed line

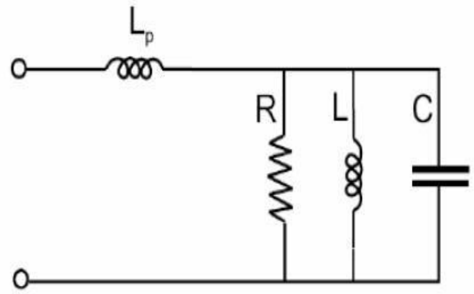
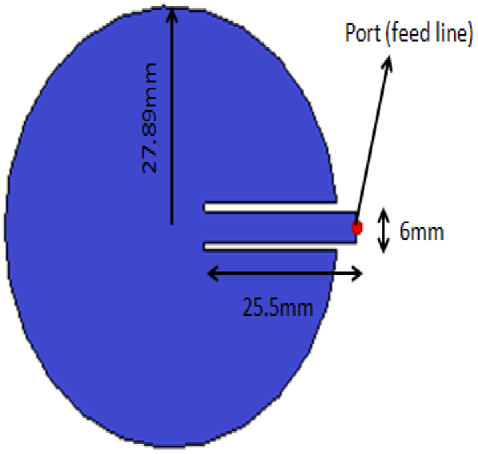


Fig.3. Equivalent circuit for microstrip line feed

III. GEOMETRY AND ANALYSIS

In this paper, the well known technique of a circular patch is designed [14], [15]. The geometry of circular shaped patch antenna is shown in Fig.4. The perspective view of the CSPA that is simulated in the CST'10 software is shown in Fig.5.



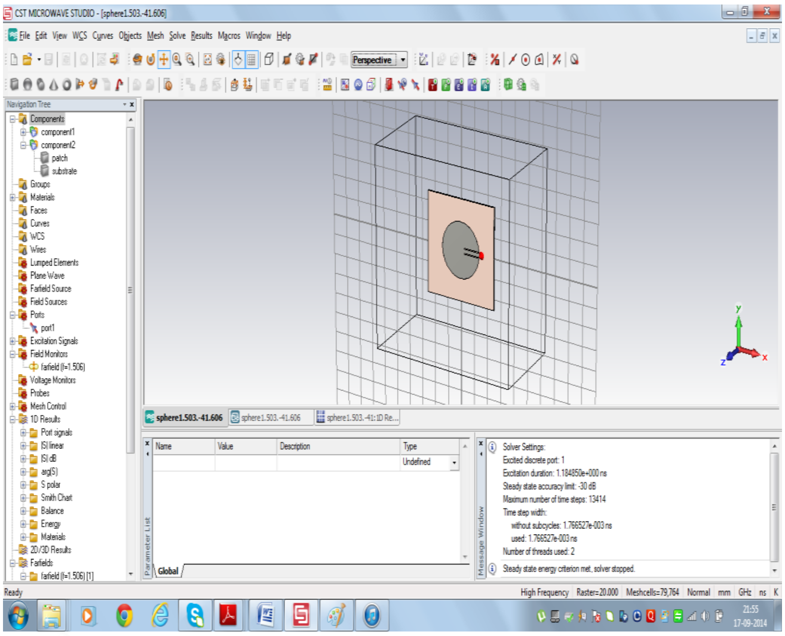


Fig.4. Geometry showing the dimensions of CSPA

Fig.5. 3D view of CSPA in CST 2010 Software

The software model of CSPA is designed using Microwave studio CST 2010 software. A circular shaped patch antenna is easily formed by cutting a rectangular slot from a circular patch and adding a microstrip feed line to it. By cutting a slot from a circular patch, gain and bandwidth of microstrip antenna can be enhanced. For this proposed antenna, size of ground plane and substrate is (L X W) 50 X 50 mm and thickness of dielectric substrate is 1.6 mm. The substrate material used is FR-4 (lossy) with dielectric constant ϵ_r = 4.3 which is less expensive for fabrication [17-18]. These values were kept constant throughout the work.

A feed was given at the edge of the patch length. The designs were simulated for frequency range 0 – 3 GHz. The radius of circular patch and its feed length is varied until a circular shaped patch antenna is obtained with operating frequency = 1.5 GHz. Now, the feed length is its to obtain best values for different parameters such as return loss, efficiency, etc.

IV. RESULT

After obtaining all results, a comparison was made between all designs and it was found that the CSPA with patch length = 31mm was with highest return loss = - 41.606 dB and efficiency = 70.99% . Also, it was seen that as we increase the patch length the return loss starts decreasing on an average. The comparison between different patch length is shown in Table I.

Table I Comparison between different patch length of CSPA

S.No.	Parameters	Patch length 30	Patch length 31	Patch length 32	Patch length 33	Patch length 34	Patch length 38
1.	Patch Length (in mm)	30	31	32	33	34	38
2.	Return Loss (in dB)	- 30.433	- 41.606	- 36.953	- 41.413	- 32.809	- 32.253
3.	Efficiency (in percent)	71.02 %	70.99 %	70.95 %	70.75 %	70.69 %	70.21 %
4.	Frequency (in GHz)	1.5	1.503	1.503	1.503	1.503	1.506

From the table I, it can be seen that the maximum efficiency was obtained for patch length 30mm that is 71.02% while its return loss is comparatively less than that obtained for patch length 31mm. The graphical representation of the tabular form is shown in Fig.6.

The s-parameter polar plot of the CSPA with patch length 31mm is shown in Fig.6. Also, the return loss graph with radiation pattern is shown in Fig.7 and Fig.8.

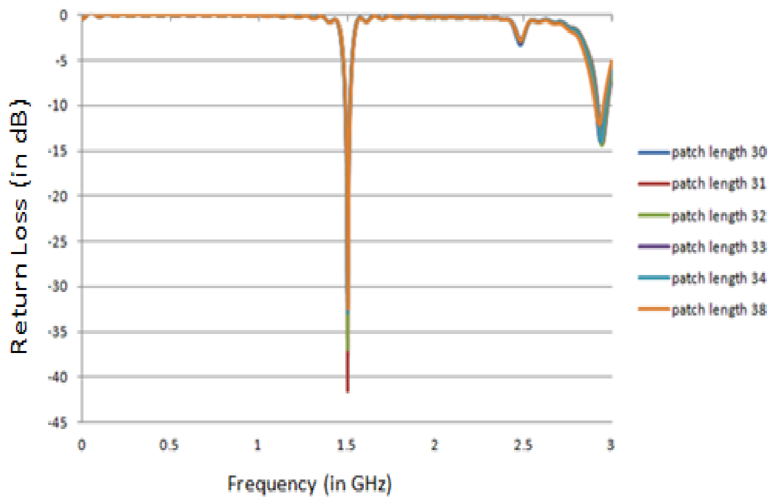


Fig.6. Graph plot between return loss and frequency for different CSPA

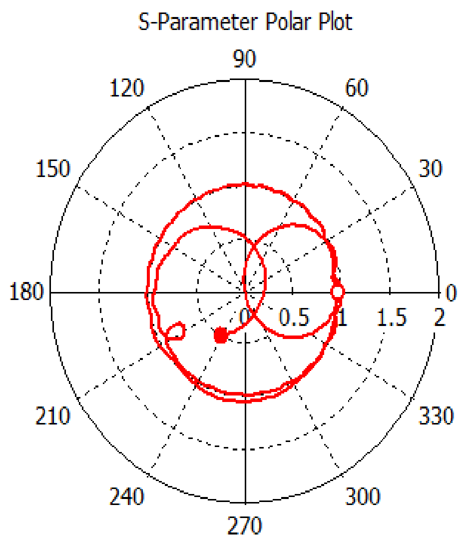


Fig.7. S-parameter polar plot of CSPA with feed length 31mm

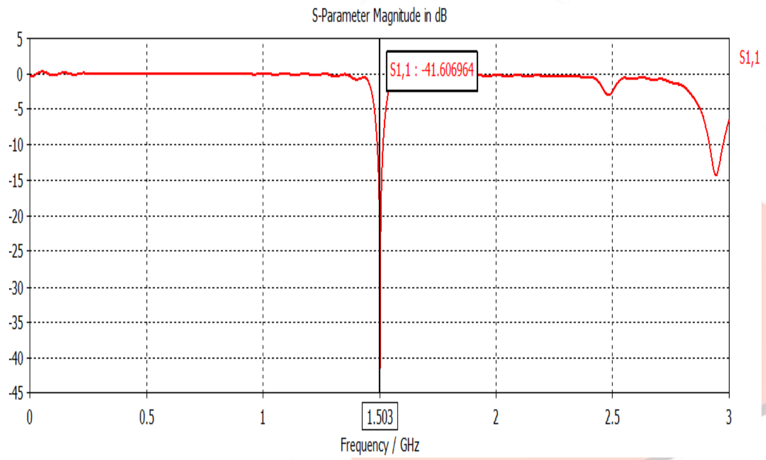


Fig.8. Graph showing simulated response for CSPA

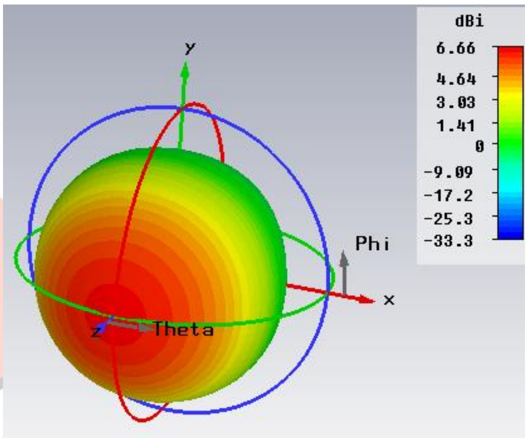


Fig.9. Radiation pattern of CSPA

V. CONCLUSION

In high-performance aircraft, spacecraft, satellite, and missile applications, where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints, microstrip patch antennas (low-profile) may be required [1]. From the above results, we can say that the circular shaped patch antenna with feed length 31mm provides the best results with good trade-off between return loss and efficiency for miniaturization at 1.5GHz that has wide applications in military telemetry, GPS (Global Positioning System), mobile phones GSM (Global System for Mobile Communication) and amateur radio. The simulated antenna using FR-4 (lossy) material as substrate and microstrip line feeding technique in CST 2010 software is shown in Fig.5.

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