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Design and Analysis of Circular Microstrip Antenna at 5.8 GHz with Fr-4 Substrate

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ABSTRACT: The wireless and mobile communication has come a long way since its inception. So for efficient communication we require miniature sized antennas such as microstrip antenna. In this paper, it proposes an efficient wide band circular microstrip antenna. In this design, a circular patch is mounted on FR-4 substrate material (ε_r =4.4). A circular slot is etched on the circular patch to provide wideband operation. Antenna design and simulation were carried out in Finite Element Method (FEM) based High Frequency Structural Simulation (HFSS^{TM}) tool. The antenna was designed to operate in 5.8GHz and the results showed a wider bandwidth of 660MHz and low return loss of -29dB.

KEYWORDS: Circular Microstrip Antenna, FR-4 Substrate, Return Loss, Bandwidth.

I. INTRODUCTION

The growth of wireless technology and mobile communication has come a long way since its inception. There has been a huge rise in the number of wireless and mobile users all over the world over the last decade. The use of wireless technology is now not just limited to wireless telephony but there is now a huge demand of wireless technology for many types of applications like Internet and web browsing, video and other text and multimedia based applications. In the radio frequency arena, the trend is to move from narrow band to wide band. Now a days most of the embedded system are portable devices and these portable devices relies on mobility. Inorder to communicate with these portable device, embedded communication has a major role. A key requirement of such a system is to have an efficient antenna device capable of transmitting bit streams with a low return loss, high data rate, high directivity and bandwidth. Inorder to obtain a wide bandwidth we require an efficient microstrip antenna design.

Micro strip patch antennas are light weight, low profile, low production cost, reliability, and ease of fabrication and integration with wireless technology equipment making them attractive for applications such as high performance aircraft, spacecraft, satellite, missile and embedded applications [1]. However, they possess low radiation efficiency, low power, high Q and very narrow frequency bandwidth [2]. Microstrip patch antennas are named based on the shape of the radiating patch. There are many available shapes of radiating patch such as square, rectangular, circular, elliptical, triangular, circular ring, and ring sector. Square, rectangular and circular microstrip patch antennas are easy to design and analyze all the parameters of antenna. These features make them more common [2]. Circular microstrip patch antenna is more simple compared to rectangular antenna microstrip patch since it has one degree of freedom to control (radius) as compared to rectangular microstrip which has two (length and width) . Therefore, circular microstrip patch antenna is simpler to design and its radiation can be easily controlled [3]. In addition, the physical size of the circular patch antenna is 16% less than that of the rectangular microstrip antenna at the same design frequency [4]. Microstrip patch antenna got a radiating patch on one side of the dielectric substrate and it has a ground plane on the other side of the substrate and the radiation of which occurs from the fringing fields between the periphery of the patch and the ground plane [5]. The thickness of the metallic patch should be, $t << \lambda 0$ (where $\lambda 0$ is free space wavelength). The height of the substrate, $h << \lambda 0$ (usually $0.003\ \lambda 0 = h = 0.05\ \lambda 0$)[2]. There are many substrates available which can be used with dielectric constants which ranges from 2.2 to 12[2]. Thicker substrates with low dielectric constants will result in better antenna performance in terms of efficiency, wider bandwidth and better antenna performance. But they result in larger antenna size. On the other hand, thin substrates with high dielectric constants are best suitable for microwave applications because their fields are tightly bound resulting in minimal undesired radiation and coupling [6]. It is rather very advantageous with its reduced size but the losses will be higher making them less efficient and also they result in narrow bandwidths [7].

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There are several methods to feed a microstrip patch antennas. The frequently used ones are microstrip line, coaxial probe and aperture coupling [2]. The methods can be differentiated into contacting and non-contacting methods. In contacting method, RF power is directly fed to the radiating patch by use of a microsrip line. For the non-contacting case electromagnetic field coupling is used to transfer power between microstrip line and radiating patch. In the proposed circular patch antenna design, a microstrip line feed is used. Microstrip line feed is a contacting method and consists of a conducting strip of a very small width compared to that of the patch (width should be less than that of patch thickness). It is easy to fabricate, simple to match and simple to design,since the impedance of antenna is designed at 50Ohm. Inorder to match the impedance, position of feed line in the patch should be adjusted. Inside the patch geometry different slots can be etched thereby increasing the performance of the antenna. Here a modified circular microstrip patch antenna with circular slot is designed and all its antenna parameters were analyzed using HFSS™ simulator software.

II. CIRCULAR MICROSTRIP ANTENNA

In our proposed work, a circular microstrip antenna resonating at 5.8 GHz was designed. The major disadvantage of a microstrip antenna is its narrower bandwidth. So the design focused on improving the bandwidth and achieving low return loss with maximum efficiency. Inorder to overcome the above mentioned problems, a circular microstrip antenna with circular patch of radius a was designed and is shown in figure1. Circular patch is mounted on FR-4 epoxy substrate (ε_r =4.4) with dimension 25*25mm and thickness h=1mm. The thickness of the substrate should be within in the limit of 0.003 λ0 ≤ h ≤0.05 λ0.The designed circular microstrip antenna is fed by microstrip line feed [8]. The width of the line feed should be less than the thickness of the patch.

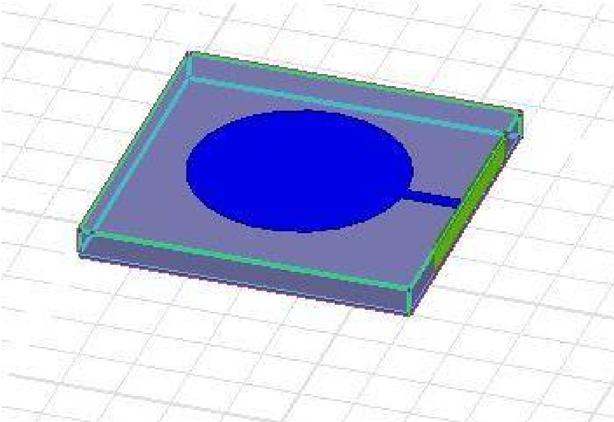

Fig. 1: Circular Microstrip Antenna

A. Antenna Design

Circular microstrip patch antenna (CMSA) is more simple compared to rectangular microstrip patch antenna since it has only one parameter to control i.e. radius as compared to rectangular microstrip which has two i.e. length and width.The modified circular microstrip patch antenna was designed using FR-4 epoxy substrate. FR-4 epoxy has a dielectric constant of 4.4. Choosing this substrate provides better antenna performance and also it has less loss tangent. In this design, the height of the substrate was taken to be 1mm. Based on the design equations of circular microstrip patch antennas, radius obtained was 6.96mm.

$$\text{Circular patch radius a} = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{\frac{1}{2}}} \quad (1)$$

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where

$$F = \frac{9.791 \times 10^9}{f_r \sqrt{\varepsilon_r}} \quad (2)$$

ε_r -Dielectric constant of substrate
h- Height of substrate
a- Radius of the patch
f_r - Resonant frequency

TABLE I: ANTENNA DESIGN PARAMETERS

Parameter	Values
Operating Frequency	5.8GHz
Radius of Circular Patch	6.96mm
Substrate dielectric material	FR-4 epoxy
Substrate dielectric constant	ε_r = 4.4
Substrate thickness	1mm
Feeding technique	Line feed
Ground Plane	25mm*25mm

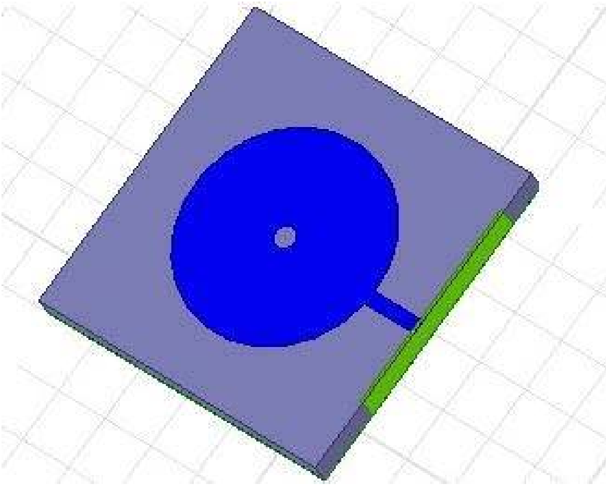

Fig. 2: Circular Slotted CMSA

III. CIRCULAR MICROSTRIP ANTENNA WITH CIRCULAR SLOT

The proposed circular microstrip patch antenna with circular slot is designed according to the dimensions detailed in Table1. The simulation is done in finite element method (FEM) based structural simulator (HFSS simulator software). The S parameters of the proposed antenna simulated results are given in Fig.3. The return loss is in the order of -20.5dB with a 3 dB bandwidth of about 180 MHz in the case of CMSA with circular slot .The bandwidth is obtained with the above dimension of patch and the substrate. The obtained bandwidth shows that the designed CMSA has high data rate applicability for embedded applications [10]. Fig.5 shows the VSWR plot of the designed antenna. The VSWR of the proposed model is found to be almost 1.21 at 5.8 GHz and a directivity of 7.087 dB along the elevation plane. The gain of the proposed circular patch antenna is also simulated using HFSS and it is found to be around 4.6186 dB for the far field pattern. Fig.7 shows the directivity plot and Fig.6 shows the gain plot of the proposed antenna. The low return loss

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of -20.5dB, wider bandwidth of 180MHz, VSWR, gain and directivity of the proposed antenna at 5.8 GHz makes it to be an efficient design in the ISM band for a wider range of applications [11].

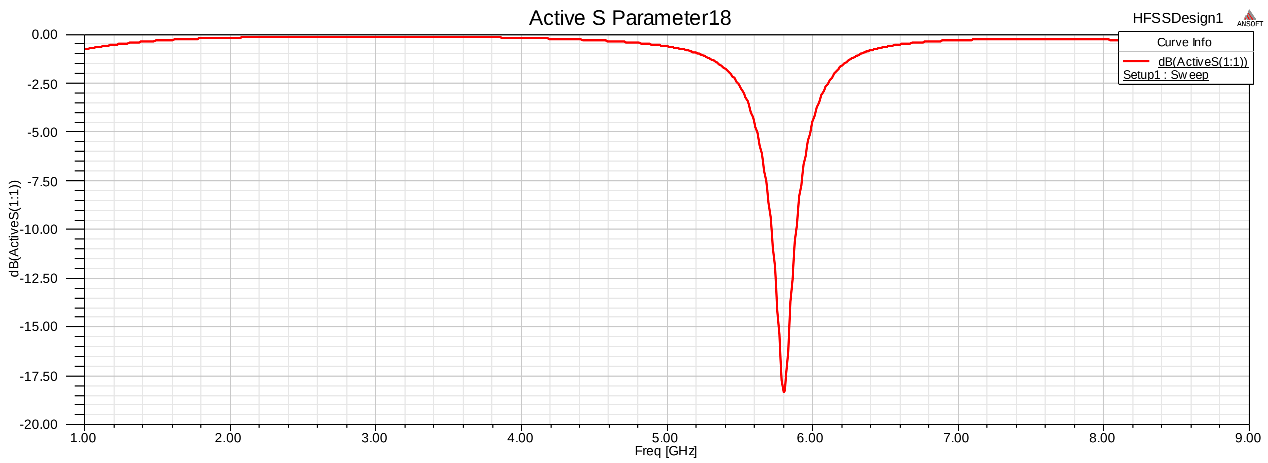

Fig. 3: Active S Parameter

Fig. 4: 3-D Radiation Pattern

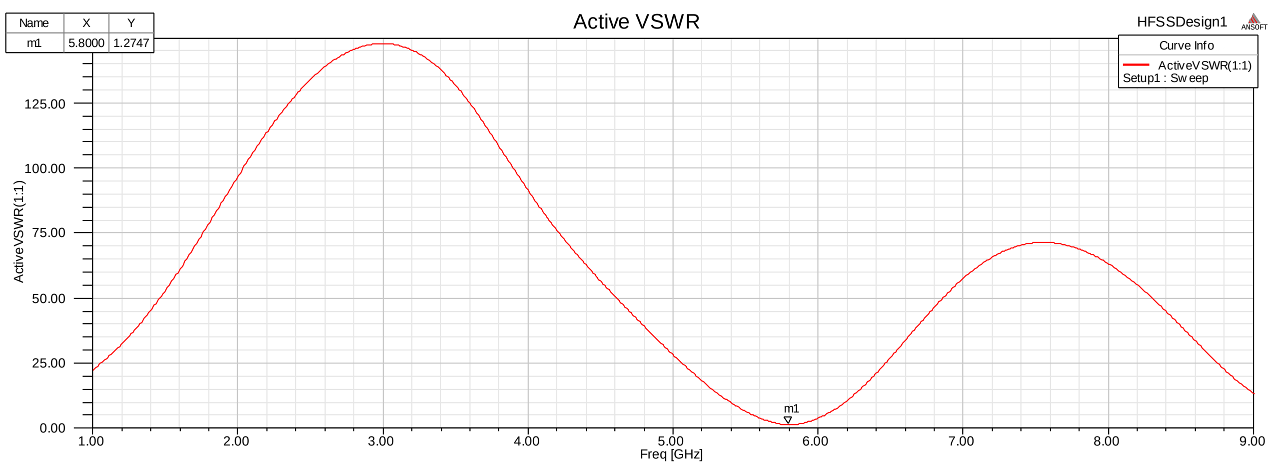

Fig. 5: Active VSWR plot

Fig. 6: 3D Gain Plot

Fig. 7: 3D Directivity Plot

V. CONCLUSION

In this paper we have proposed a Circular micro strip antenna with circular slot resolving the existing problem of narrow bandwidth. The parametric study showed that wideband characteristics can be achieved for a smaller antenna only with the appropriate choice of parameters. The proposed antenna was designed at 5.8GHz with wider bandwidth and huge return loss. Hence this antenna can be used widely for high data rate embedded applications. The physical implementation of this antenna can be integrated with embedded devices permit it to operate in wider range of applications.

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