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REGULAR ARTICLE

# A Dual-Band F-Slotted Circular Patch Antenna for S-Band and C-Band Wireless Applications

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Due to the low-profile and multiband properties circular patch antennas (CPA's) have become more popular. The proposed F-slotted CPA enhances performance attributes including bandwidth, gain, and miniaturization by using an F-shaped slot in the patch and a partial ground plane. An inset feed is used to design a dual band F-slotted CPA for S-band and C-band applications. F-slotted CPA is fed by using line feeding technique with an impedance of 50 Ω. The top plane of the F-slotted CPA has a modified circular patch, while the ground plane is a partial ground plane. The parametric analysis of the F-slotted CPA is obtained to verify the performance of the proposed antenna. A finite element method tool, Ansoft HFSSv13 is used to simulate the F-slotted circular patch antenna (CPA). The proposed F-slotted CPA resonates at 2.8 GHz and 4.8 GHz frequencies with obtained $S_{11}$ of – 25.8 dB, – 14.6 dB respectively and offers VSWR of 1.1 and 1.4 at 2.8 GHz and 4.8 GHz respectively Fractional bandwidths of 28.5 % (2.5-3.3 GHz) and 10.41 % (4.5-5 GHz) are achieved at 2.8 GHz and 4.8 GHz frequencies respectively, with S11 of – 25.8 dB and – 14.6 dB. 3 dBi gain of 3 dBi has been observed. F-slotted CPA occupies an area of 40 × 40 × 1.6 mm$^3$. These results make the F-slotted CPA suitable for S-band and C-band applications.

**Keywords:** Circular patch antenna (CPA), Reflection co-efficient, Dual band, Gain, Microwave C-band and S-Band.

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## 1. INTRODUCTION

Due to their multi-band properties and circular polarisation, circularly polarised antennas have become increasingly popular. These antennas work well with Bluetooth, WLAN, and RFID, among other wireless technologies that employ S-band as well as C-band [1]. By serving as resonators and generating more modes, the circular slots greatly increase the bandwidth. Additionally, circular polarisation can be accomplished by shifting the feed point on the patch [2]. A high frequency band is employed to transmit the integrated communication data. This is accomplished by utilising the unlicensed 2.4 GHz channel, which is utilised by ISM applications. There has been a progressive evolution from 1G to 4G to meet the need for the requirement for more channel capacity and improved data rates. However, due to the increasing number of people who use mobile devices, there is a yearly increase in the amount of mobile traffic that occurs in global settings. It is certain that the current 4G mobile network will eventually be unable to keep up with the latest advancements in mobile communication technology since its channel capacity and data rate will eventually be insufficient. To connect people, objects, data and applications to an intelligent network environment, 5G is one of the possible ways to do so [2-3]. High data speeds, applications that are reasonably reliable, setting up in remote and rural areas and improved mobile broadband connections are the primary and most likely prospects for 5G [4]. In addition to facilitating personal interactions, the 5G technology can support a broad variety of devices and services [5]. The primary goal of the development of 5G technology is to enhance network capacity while simultaneously providing improved coverage at costs that are more affordable.

In 2018, South Korea was able to effectively establish an experimental 5G service sample at a frequency of 28 GHz using millimetre wave frequency, thereby demonstrating the usefulness of the band [6]. On the other hand, other researchers indicate that the commercial implementation of 5G will take place all over the world in the 21st century. Research communities all over the world have been focussing their attention on mm-wave frequency bands as a viable spectrum for fifth-generation wireless mobile networks. There is a significant issue regarding spectrum allocation for 5G communications. The development of these wireless networks necessitates scientific advancements in the areas of antennas, modulation techniques, and electrical components.

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Since it is the final link in the transmission chain, the antenna is the most authoritative components of wireless networks. Both the theory and technology behind printed antenna design have undergone significant advancements in recent years [11, 12]. The millimetre wave antenna, on the other hand, is designed differently than conventional antennas to lessen the impact of the atmosphere and the amount of signal transmission loss that occurs at millimetre wave frequencies. It is recommended to use antennas with a high gain and a high degree of directionality in order to overcome these mm-wave frequency-related hurdles. When it comes to attaining these requirements (high gain, better efficiency, and broadband operation) with a compact antenna size, however, researchers in the antenna community face a significant obstacle.

To address the issues, an F-slotted CPA with a partial ground plane is proposed in this study. To achieve a broader bandwidth and dual-band, partial ground plane has been utilised with a combination of F-slot in the circular patch. The work that is being presented demonstrates an effective combination of dual band, large operational region, simple geometric configuration, small size.

## 2. ANALYSIS OF F-SLOTTED CPA

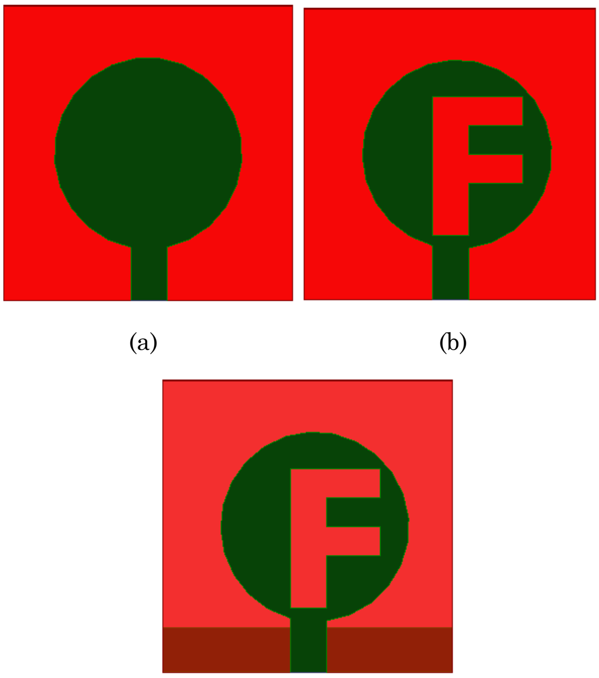
The basic circular patch antenna has been slightly modified to become F-slotted CPA. It also takes up less space and has a simple design. Figure 1 depicts the F-slotted CPA's iteration-based design. Initially, a 13 mm radius circle is attached to the 8 × 5 mm$^2$ microstrip transmission line. Step 2 involves subtracting an F-shaped structure from the antenna design in step 1 with full ground plane. Step 3 antenna is the final iteration antenna, and it is obtained by taking the ground plane as partial with a dimensions of 8 mm × 40 mm. Here, the green color indicates patch and red color indicates dielectric material for the proposed antenna. The FEM tool An-soft HFSSv13 is used to carry out the antenna's evolutionary process. Because it affects an antenna's gain, bandwidth, reflection coefficient, and other important features, the choice of antenna feeding strategy is critical. FR4 material with 1.6 mm thickness, $\delta$ of 0.02, a $\varepsilon_r$ of 4.4, is used to design F-slotted CPA. F-slotted CPA occupies an area of 40 × 40 × 1.6 mm$^3$ and is connected by a 50 Ω microstrip transmission line. Based on these factors and considerations, HFSS is used to model and optimise the antenna dimensions. The primary issue with CPAs is impedance matching, which is brought on by their small size. Both the width of the rectangle in the ground plane and F-slot can be changed to alter the CPA's centre frequencies. A partial ground plane has been chosen as the bottom plane and F-slotted CPA as the patch. F-slotted CPA with top and bottom surface are depicted in Figure 2, along with the dimensions. The following lists the mathematical formulas that were used in the F-slotted CPA design. (1) is used to determine the circular patch's radius.

$$a = \frac{F}{\sqrt{1+\frac{2h}{\Pi\varepsilon_r}\left[\ln\left(\frac{\Pi f_r}{2h}\right)+1.7726\right]}}$$

$$F = \frac{8.791*10^9}{f_r\sqrt{\varepsilon_r}}$$

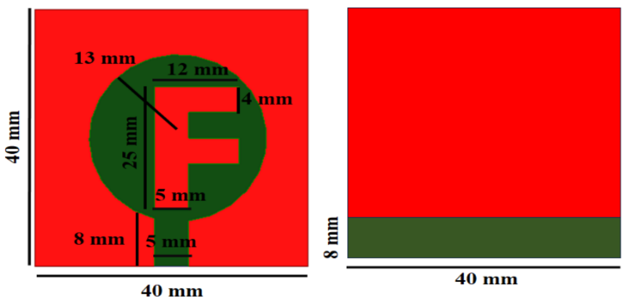
$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+\left[\frac{12h}{w}\right]\right]^{-1/2}$$

Where $a$ is the radius of the ring resonator and is obtained by using equation (1), $h$ is the thickness of the material. $F$ is obtained by using equation (2). $f_r$ is the center frequency of the substrate. Figure 3 represents the $S_{11}$ of F-slotted CPA at various evolutions. Step 1 CPA is resonating at 2.40 GHz and it offers a reflection co-efficient value of – 32 dB. Step 2 antenna is resonating at 2.45 GHz and 4.91 GHz and it offers reflection co-efficient values of – 20 dB and – 32 dB respectively. Step 3 antenna is the final antenna iteration and is resonating at 2.8 GHz and 4.8 GHz and it offers reflection co-efficient values of – 25.8 dB and – 14.6 dB respectively.



(a) (b) (c)

**Fig. 1** – Step wise design of F-slotted CPA (a) Step 1 (b) Step 2 (c) Step 3




(a) (b)

**Figure 2.** F-slotted CPA (a) Top plane (b) Bottom plane

## 3. RESULTS AND DISCUSSIONS

Figures 4 and 5 represents the parametric analysis of the F-slotted CPA by varing the length of the microstrip rectangle which serves as a partial ground plane.

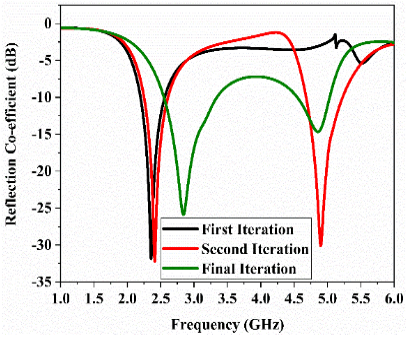



**Fig. 3** – $S_{11}$ of F-Slotted CPA at different evolutionary stages

$S_{11}$ and VSWR improves by increasing the length of the rectangle from 7 mm to 9 mm, high amount of $S_{11}$ is obtained when the it is 8 mm. $S_{11}$ of the antenna is obatined at 2.8 GHz and 4.8 GHz and best amount of $S_{11}$ is obtained when it is 8 mm. Reflection co-efficient of – 25.8 dB and – 14.6 dB at 2.8 GHz and 4.8 GHz respectively. Figure 6 represents the reflection coefficient and VSWR of the F-slotted CPA. F-slotted CPA resonates at 2.8 GHz and 4.8 GHz with an $S_{11}$ of – 25.8 dB, – 14.6 dB respectively. F-slotted CPA offers VSWR of 1.1 and 1.4 has been observed at 2.8 GHz and 4.8 GHz respectively and these results make the F-slotted CPA applicable for S-band and C-band wireless communication applications.

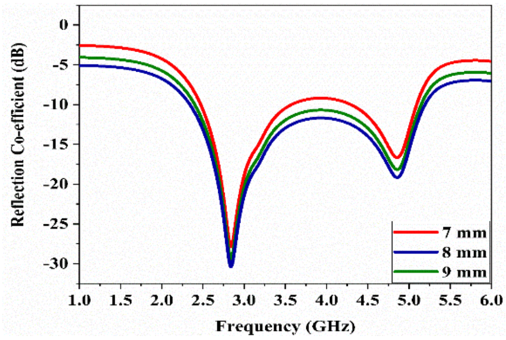



**Fig. 4** – Parametric analysis of F-slotted CPA by varying ground plane length

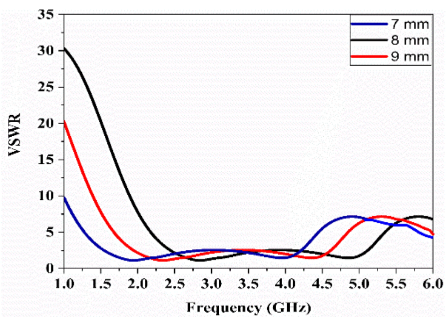



**Fig. 5** – Parametric analysis of the F-slotted CPA by varying ground plane length

The gain of the F-slotted CPA is depicted in Figure 7, and it has been observed that the highest possible value occurs at 3 dBi. Figure 8 illustrates the current distribution of the antenna at two different frequencies, 2.8 GHz and 4.8 GHz respectively. The greatest field distribution is represented by the colour red at the resonant frequencies; values of 200 Am-1 and 250 Am-1 have been recorded as the highest possible values obtained. The E-field distributions of the F-slotted CPA are displayed in Figure 9. A representation of the radiation effectiveness of the crescent-shaped CPA may be found in Figure 10. A radiation efficiency of 90% has been achieved at 2.8 GHz, while a radiation efficiency of 77 % has been achieved at 4.8 GHz.

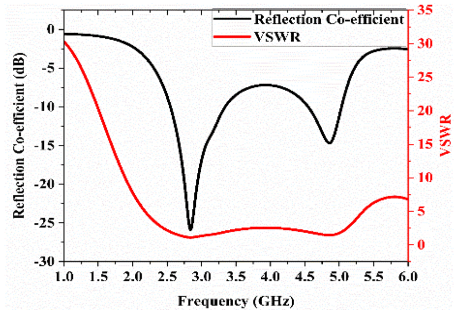



**Fig. 6** – Reflection co-efficient and VSWR of the F-slotted CPA

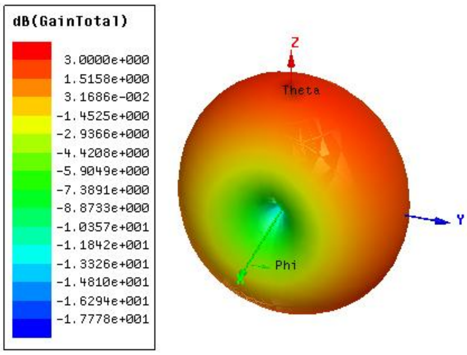
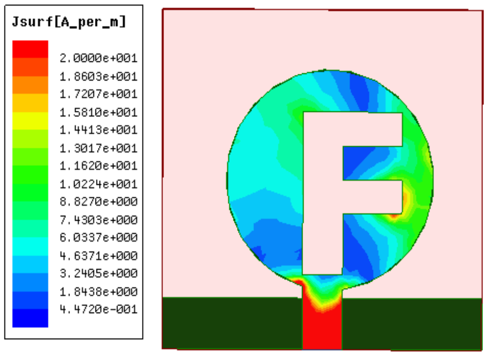
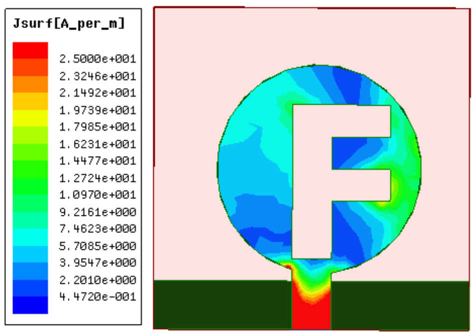



**Fig. 7** – 3 dBi gain of crescent-shaped CPA

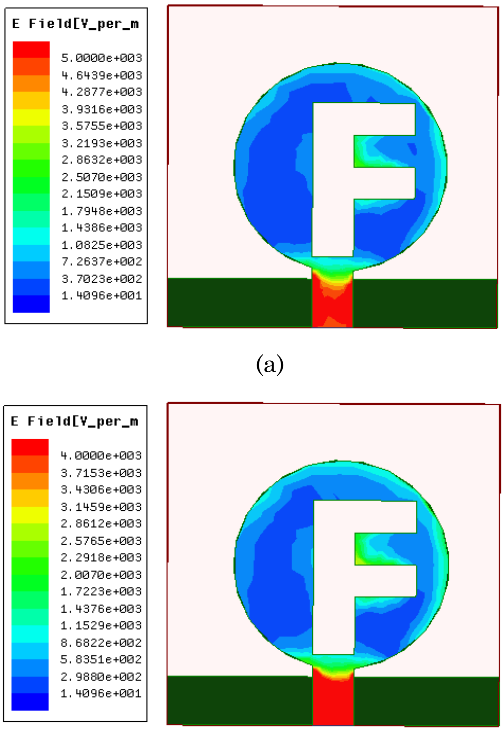



(a)




(b)

**Fig. 8** – J-surface distribution (a) 2.8 GHz (b) 4.8 GHz




(a)

(b)

**Fig. 9** – E-field Distribution (a) 2.8 GHz (b) 4.8 GHz

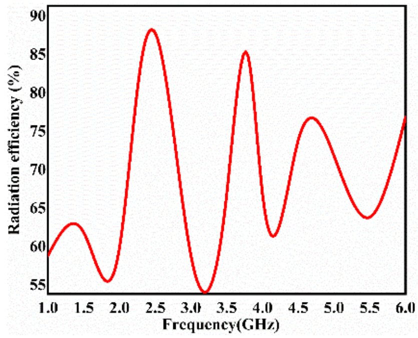



**Fig. 10** – Radiation efficiency of the F-slotted CPA

## 4. CONCLUSION

A dual-band F-slotted circular patch antenna is designed and analysed for S-band and C-band applications. Ansoft HFSSv13, a tool based on finite element techniques, is utilised to simulate the F-slotted CPA. Fractional bandwidths of 28.5 % (2.5-3.3 GHz) and 10.41 % (4.5-5 GHz) are achieved at frequencies of 2.8 GHz and 4.8 GHz, respectively, with reflection coefficients of – 25.8 dB and – 14.6 dB. A gain of 3 dBi has been observed at both resonant frequencies. The F-slotted CPA has dimensions of 40 × 40 × 1.6 mm$^3$. The results indicate that the F-slotted CPA is appropriate for S-band and C-band wireless communication applications.

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## Дводіапазонна кругла патч-антена з F-подібними прорізами для бездротових застосувань в S- та C-діапазонах


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Завдяки низькопрофільним та багатодіапазонним властивостям, круглі патч-антени (CPA) стали більш популярними. Запропонована F-подібна патч-антена (CPA) покращує характеристики продуктивності, включаючи пропускну здатність, коефіцієнт посилення та мініатюризацію, завдяки використанню F-подібного паза в патчі та часткової заземлювальної площини. Для проектування дводіапазонної F-щілинної CPA для застосувань у S- та C-діапазонах використовується врізне живлення. F-щілинна CPA живиться за допомогою методу лінійного живлення з імпедансом 50 Ом. Верхня площина F-щілинної CPA має модифікований круглий патч, тоді як заземлювальна площина є частковою заземлювальною площиною. Для перевірки продуктивності запропонованої антени було проведено параметричний аналіз та використано інструмент методу скінченних елементів Ansoft HFSSv13. Запропонований F-подібний CPA резонує на частотах 2,8 та 4,8 ГГц з отриманим S11 – 25,8 дБ та – 14,6 дБ відповідно та пропонує КСХН (коефіцієнт хвалевої хвилі) 1,1 та 1,4 на частотах 2,8 та 4,8 ГГц відповідно. Часткові смуги пропускання 28,5 % (2,5-3,3 ГГц) та 10,41 % (4,5-5 ГГц) досягаються на частотах 2,8 та 4,8 ГГц відповідно, з S11 – 25,8 дБ та – 14,6 дБ. Спостерігалося посилення 3 дБі. F-подібний CPA займає площу 40 × 40 × 1,6 мм$^3$. Ці результати роблять F-подібний CPA придатним для застосування в S-діапазонах та C-діапазонах.

**Ключові слова:** Кругова патч-антена (CPA), Коефіцієнт відбиття, Дводіапазонна, Коефіцієнт підсилення, Мікрохвильові C- та S-діапазони.