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Penta Band Inset-Fed Circular Microstrip Antenna For Wireless Communications

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Abstract : *This paper presents a penta-band inset-fed circular micostrip patch antenna with insertion of a pair of inverted L-shaped slits on the radiating circular patch and H-shaped slot in the ground. Simulation work is carried out by using Ansys HFSS electromagnetic simulation tool and measured practically. The proposed antenna is fabricated on commercially available low cost FR-4 substrate material with relative permittivity of 4.4 having physical dimension of 55.4 × 44 × 1.6 mm^3. The antenna resonates at five frequencies 2.13 GHz, 5.18 GHz, 6.3 GHz, 9.3 GHz and 10.5 GHz. The proposed antenna shows the virtual size reduction of 44.73% when compared to conventional antenna which is designed to operate at 3.8 GHz. The antenna shows broad side radiation patterns with maximum gain of 5.4 dB and finds application in wireless technologies.*
Keywords *- Inset-fed, penta-band, circular patch, wireless communication*

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I. INTRODUCTION

Nowadays, rapid development in wireless technologies, satellite communications and targeting radars is observed in the microwave band. Microstrip patch antenna (MSA) plays a relevant role in these communication systems. MSAs have gained popularity because of their inherent features like light weight, low cost, simple design and capacity to resonate at more than one frequency bands [1-2], which can avoid the use of multiple antennas for different wireless applications. Several methods and techniques have been reported in the literature. The miniaturization of antenna and multiple frequency bands can be achieved by different geometries of slots like rectangular, triangular, I, U, V, T-shape etc., on radiating patch [3–6].

Moreover, in the modern communication era, it would be a difficult task to design the single antenna capable of performing transmission and reception operations. A similar study is made for multi-band operation and virtual size reduction using slits on rectangular microstrip antenna [7]. In this paper, a simple technique has been proposed to achieve multiple frequency operations by loading slits on the radiating circular microstrip patch antenna. This kind of technique is found to be rare in the literature.

II. Antenna Design

The geometry of a conventional inset-fed circular microstrip patch antenna is shown in Fig. 1. A substrate with a thickness of h=1.6 mm and loss tangent tanδ=0.0245, and dielectric constant of ε_r=4.4 is used. The proposed antenna is designed to operate at 3.8 GHz with physical dimensions of circular radiating patch with radius R=11.5 mm is fed by simple 50Ω inset-fed having dimensions of length Lf=17.18 mm and W_f=3.17 mm on the top side of the substrate and bottom of the substrate as ground plane with L_g = 55.4 mm and Wg=44 mm. For a better impedance matching between radiating patch and simple 50Ω inset-fed, a microstrip feed-line with width I_W=1.53 mm and length of I_L=5.78 mm are chosen to achieve the optimum results.

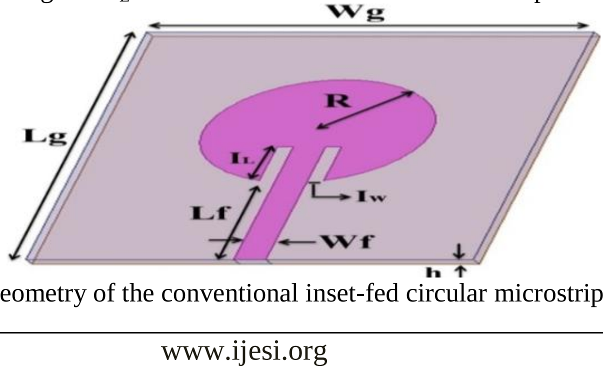


Fig. 1 Geometry of the conventional inset-fed circular microstrip antenna

Fig. 2 shows the geometry of the proposed penta-band antenna. Here by keeping all the physical dimensions of the conventional antenna as it is, a pair of L-shaped slits with dimensions L_1= 7.9 mm, L_2= 5 mm, L_3=2 mm and H-shaped slot in the ground plane with H_1= 5.7 mm H_2= 4 mm, and H_3=1 mm are considered. The proposed antenna models were simulated by commercially available Ansys HFSS Electromagnetic simulation tool [8].

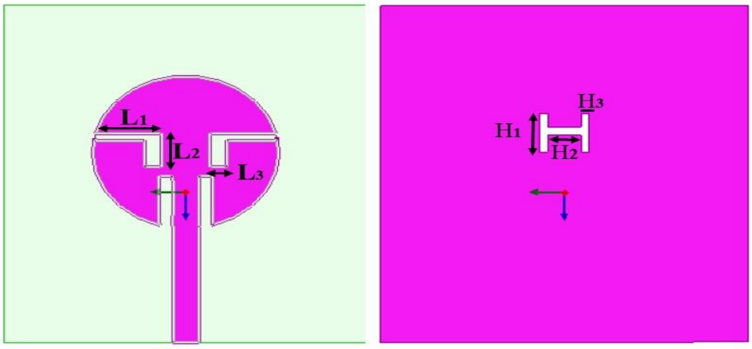


Fig. 2. Geometry of the proposed penta-band antenna

III. Result And Discussion

The comparison of simulated and measured return loss characteristics of conventional circular patch antenna is shown in Fig. 3. The impedance bandwidth is defined as,

$$Impedance\,Bandwidth(\%) = \left(\frac{fH - fL}{fC}\right) \times 100 \qquad (1)$$

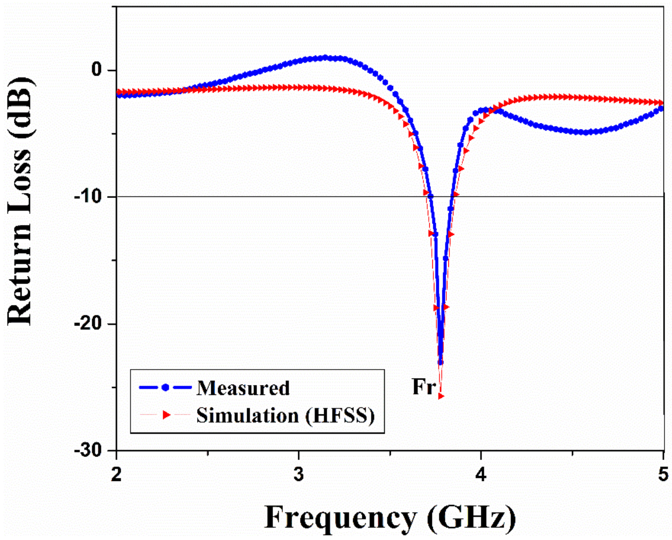


Fig. 3: Comparison of simulated and measured return loss characteristics of conventional circular patch antenna

From Fig. 3 it is observed that the conventional antenna resonates at Fr= 3.75 GHz with -10 dB return loss having impedance bandwidth of BW= 4.26%.

To achieve multi-band operations we have loaded the conventional antenna with optimized L-shaped slits on the radiating patch and H-shaped slot in the ground plane. The comparison of simulated and experimental return loss characteristics of modified inset-fed circular microstrip patch antenna is shown in Fig. 4. From this figure it is observed that, the antenna resonates at five different frequencies i.e., Fr_1 =2.13 GHz, Fr_2=5.18 GHz, Fr_3=6.3 GHz, Fr_4=9.3 GHz and Fr_5=10.5 GHz with -10dB return loss with impedance bandwidths of BW1=4.5% , BW2= 9.29, BW3= 5.79% , BW4=8.87% and BW5= 11.73% respectively.

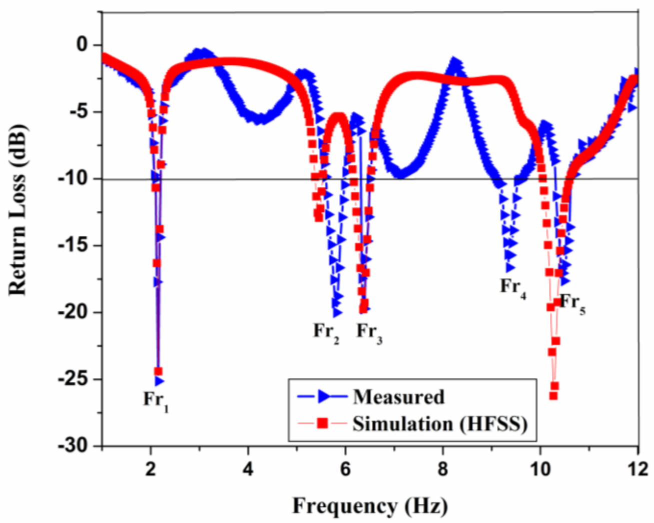


Fig. 4: Comparison of simulated and experimental return loss characteristics of modified circular patch antenna

For better understanding, the radiation mechanisms have been studied. The simulated surface current distribution of the conventional antenna at 3.8 GHz is shown in Fig. 5 and the surface current distributions of the proposed penta-band antenna observed at (a) 2.13 GHz, (b) 5.8GHz are shown in Fig. 6. From the Fig. 5, the conventional antenna resonates at 3.75 GHz and the surface current density is uniformly distributed along the radiating patch. From the Fig. 6 , it is observed that for the proposed penta-band antenna the surface current density is mainly accumulated across the L-shaped slits at 2.14 GHz and 5.18 GHz.

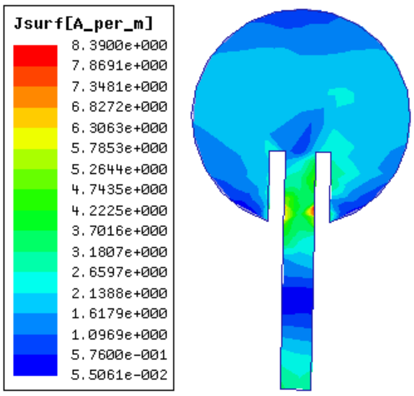
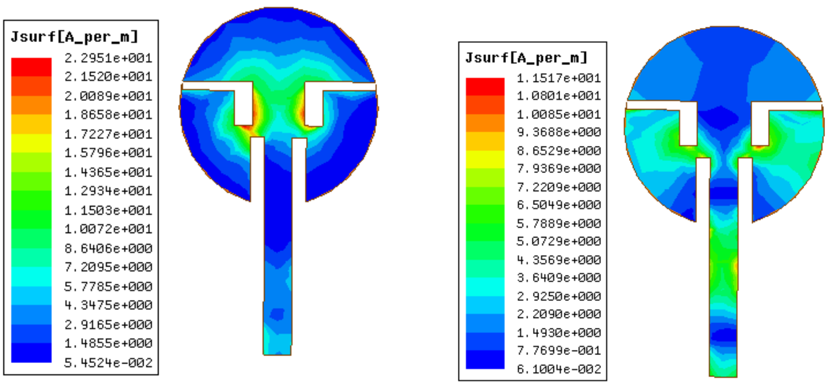


Fig. 5: Simulated surface current distribution of the conventional antenna at 3.75GHz



(a) (b)

Fig. 6: Simulated surface current distributions of the proposed penta-band antenna observed at (a) 2.13 GHz, (b) 5.18 GHz

The far field normalized E-plane co-polar and cross-polar radiation patterns of the conventional antenna and the proposed penta-band antennas are measured at their resonating frequencies and are shown in the Fig. 7 and Fig. 8 respectively. From these figures, it is observed that the antennas are linearly polarized and broad side in nature.

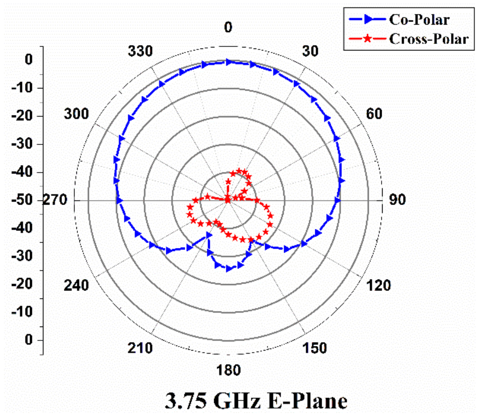
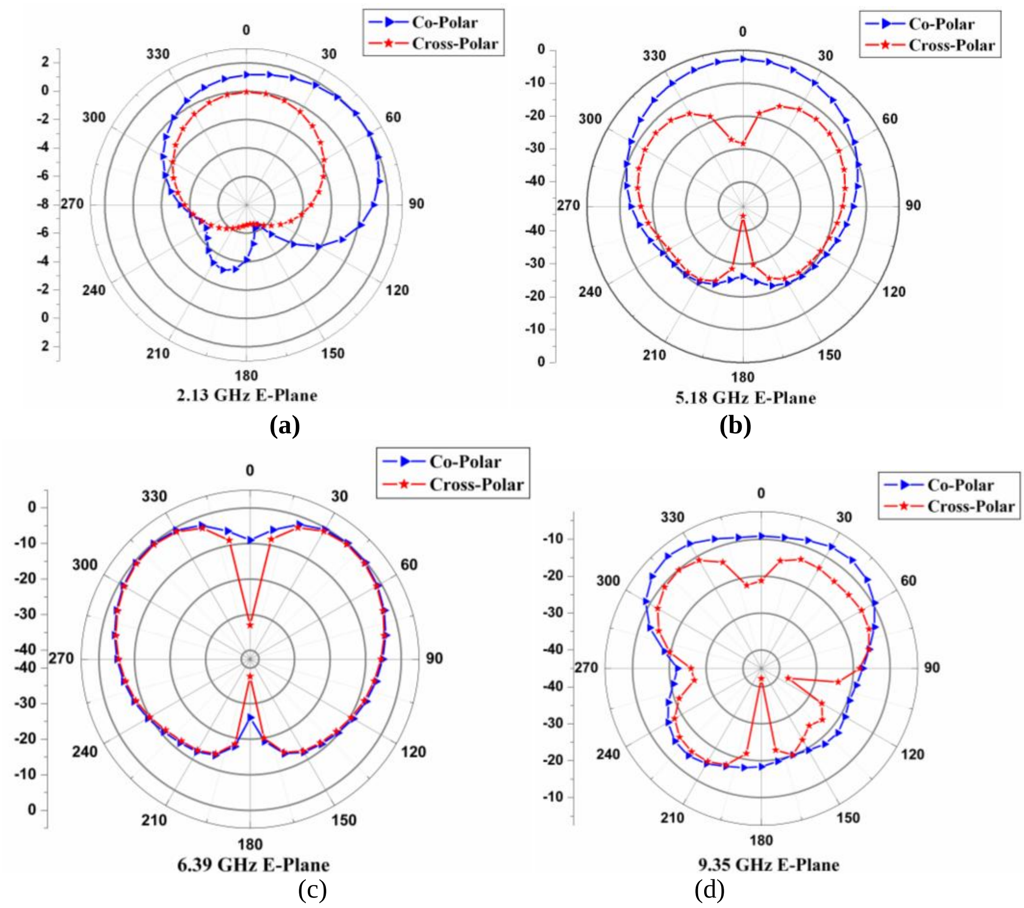
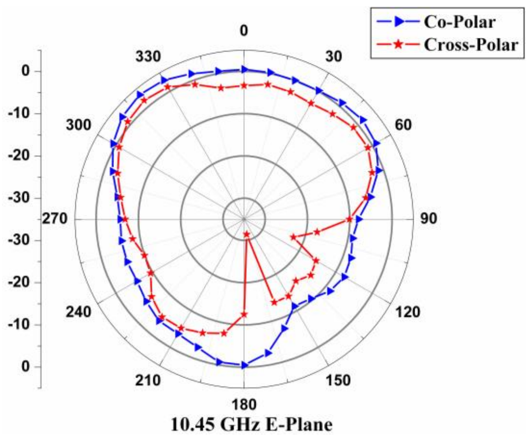


Fig. 7 Typical E-plane co and cross- polarization radiation patterns of the conventional circular microstrip patch antenna measured at 3.75 GHz





(e)

Fig. 8: Typical E-plane co and cross- polarization radiation patterns of the proposed antennas measured at (a) 2.13 GHz, (b) 5.18 GHz, (c) 6.39 GHz, (d) 9.35 GHz and (e) 10.45 GHz

The gain of proposed antenna is calculated by using absolute gain method given by equation [9]

$$G(dB) = 10\log\left(\frac{\mathrm{Pr}}{\mathrm{P}t}\right) - (Gt)dB - 20\log\left(\frac{\lambda 0}{4\pi R}\right) \qquad (2)$$

where, Pt and Pr are transmitted and received powers respectively, Gt is the gain of the pyramidal horn antenna and R is the distance between transmitting antenna and antenna under test. The calculated gain of the antenna is 5.4 dB.

IV. CONCLUSION

In this paper, a novel design of penta-band circular inset-fed microstrip antenna is designed and developed. The measured results show good agreement with the simulated results. By inserting a pair of L-shaped slits on the radiating patch and H-shaped slot in the ground patch, the antenna is resonating at five frequencies and achieved a virtual size reduction of 44.73%. The proposed antenna exhibits a linearly polarized and broadside radiation pattern with a maximum gain of 5.4 dB. Due to simplicity in its design the antenna can be considered as a potential candidate for cost effective wireless communication applications.

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