Compact Microstrip Patch Antenna with Parasitic Loading for X & Ku Band Applications

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Abstract— Microstrip patch antennas are becoming popular day by day because of the various advantage offered by them such as low cost, less weight, low profile and ease of fabrication [1]. Popularity of patch antenna can be known from the fact that they found their application in various fields like aircraft, space technology [2, 3], mobile communication, biomedical, broadcasting etc.. However narrow bandwidth of patch antenna is one of the major limitation, that researcher around the world have been trying to overcome. Many techniques have been suggested in the past in order to overcome this problem [4]. One such technique is employed in this paper in which parasitic elements are used along with driven patch excited with the help of coax feed for X & Ku band. An equivalent circuit of the proposed antenna is also developed and analyzed. The antenna is designed on FR4 substrate with permittivity 4.4 and having dimension of ground plane $17 \times 19\,\text{mm}^2$. The patch has a dimension of $6 \times 6\,\text{mm}^2$ which is loaded with parasitic elements. The proposed antenna is able to achieve impedance bandwidth of 1.8 GHz from 10.8 GHz to 12.6 GHz thus, covering Ku band as well and has a maximum gain of 3.9 dBi. Comparison between simulated and fabricated results would be presented. The return loss, electric field distribution, radiation pattern of the proposed antenna is presented in this paper. All simulations are done by using HFSS software.

1. RESULTS AND DISCUSSIONS

Figure 1 shows the configuration of the proposed patch antenna consisting of square patch loaded with parasitic elements with a ground plane. The complete description about parameters of proposed antenna structure is given in Table 1. The dimensions of proposed antenna are obtained by using HFSS.

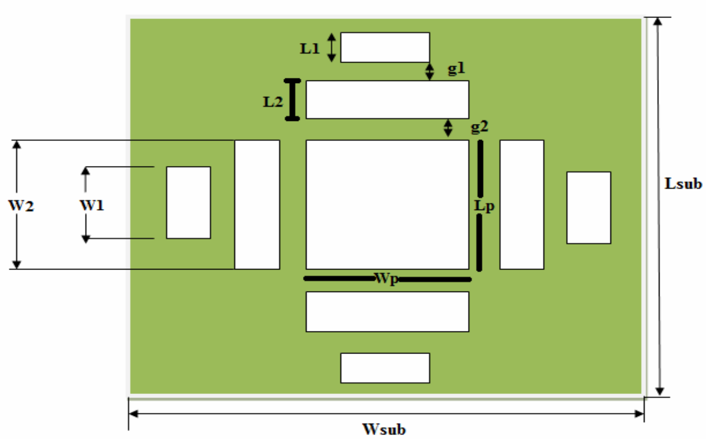


Figure 1. Configuration of the proposed antenna.

Figure 2 shows our proposed antenna from circuit point of view. When the patch antenna is loaded with parasitic elements, they gets coupled with driven patch, i.e., there will be mutual coupling M between parasitic elements and patch as a result of which there will be a mutual inductance. Apart from this, patch and parasitic elements being conducting elements will possess self inductance as well. Beside inductance, there will be a mutual capacitance between the patch and parasitic elements and also between patch and ground plane that need to be taken into consideration while doing complete calculations. As the structure is being excited by coax pin so an additional inductance could be added if pin is long. However, it could be neglected if it is small.

Table 1.

L_{sub}	17 mm
W_{sub}	19 mm
L_p	6 mm
W_p	6 mm
L_1	1 mm
W_1	3 mm
L_2	1 mm
W_2	6 mm
g_1	0.5 mm
g_2	0.5 mm

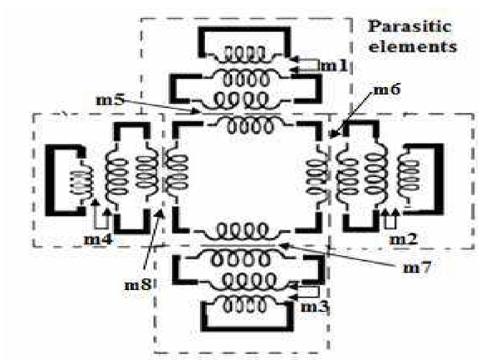


Figure 2. Showing inductive coupling in the proposed antenna.

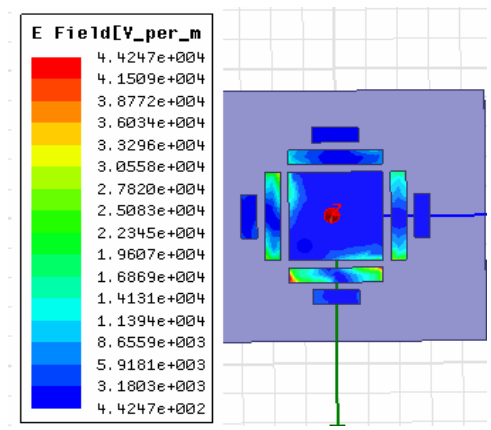


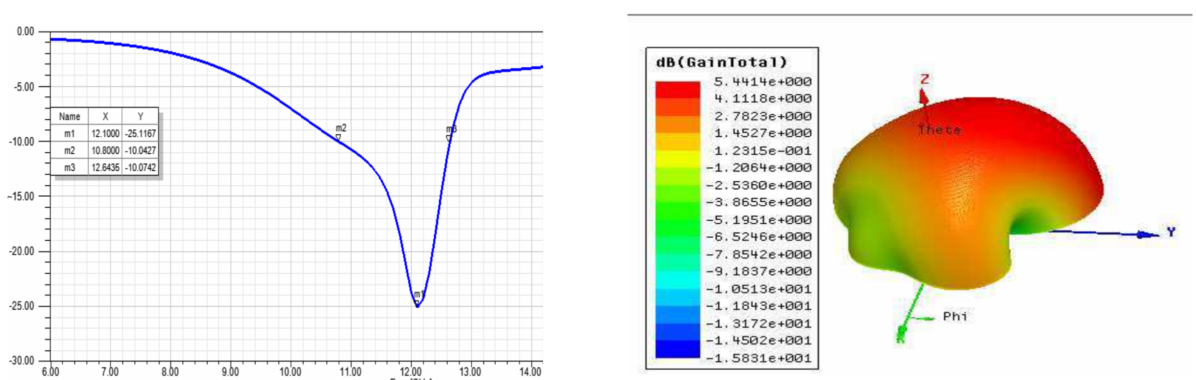
Figure 3. E field distribution.

Equations [5] given below could be used to find mutual inductance & self inductance

$$M = -\frac{\mu l}{2\pi}\left[\ln\left(1+\sqrt{2}\right)+1-\sqrt{2}+w^2\sqrt{2}/24l^2\right] \tag{1}$$

$$S = \frac{\mu l}{2\pi\left[\ln\left(\frac{2l}{w}\right)+0.5+\frac{w}{3l}-\frac{w^2}{24l^2}\right]} \tag{2}$$

The mutual inductance between parasitic elements is calculated using above Eq. (1) and is found as $m_1 = m_2 = m_3 = m_4 = 0.295$ nH and $m_5 = m_6 = m_7 = m_8 = 0.656$ nH. The self inductance

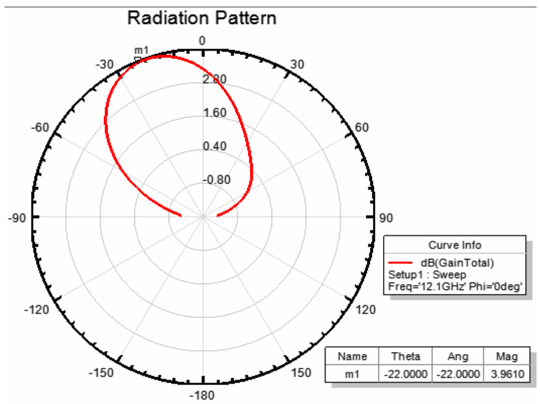


(a) (b)

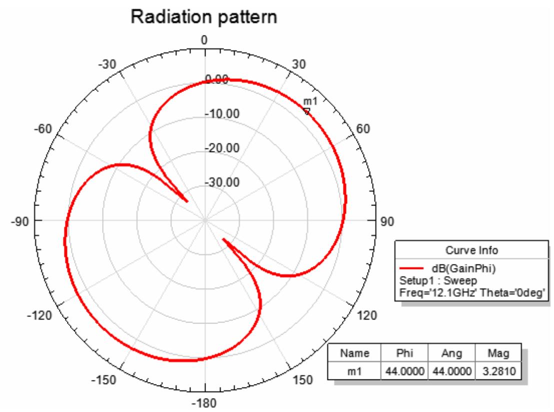
Figure 4. (a) Return loss of the proposed antenna. (b) 3D polar plot.

is also being calculated and is given as: $S_1 = 1.88\,\text{nH}$, $S_2 = 3.5\,\text{nH}$, $S_3 = 1.43\,\text{nH}$. The simulated return loss and polar plot of the proposed antenna are depicted in Figures 4(a) & 4(b) respectively which clearly indicates that the impedance bandwidth of antenna is 1.8 GHz for return loss less than −10 dBi.

Radiation pattern of the proposed antenna is also studied and is shown in Figures 5(a) & 5(b). It is clear from the figure that a maximum gain of 3.9 dBi is achieved at resonant frequency in elevation plane and 3.2 dBi in azimuth plane.



(a)



(b)

Figure 5. (a) Elevation plane. (b) Azimuth plane.

2. CONCLUSION

A compact Microstrip patch antenna for X and Ku band is successfully designed, simulated and analyzed. It has been found that the antenna achieved an impedance bandwidth of 1.8 GHz and was able to provide a maximum gain of 3.9 dBi in elevation plane and 3.28 dBi in azimuth plane. Good matching is obtained at desired frequency without any use of external tuning circuit. Further the structure can be tuned to operate at various frequencies by varying gap between parasitic elements and thus provides flexibility to our structure.

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