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Y-Shaped Microstrip Patch Antennas for L and S Band Using Shared Aperture

Jonny Dhiman[1] · Sunil Kumar Khah[1]

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Abstract
Microstrip patch antennas are designed and investigated in L/S bands simultaneously using the sharing of aperture. The antenna is designed on commercially available dielectric material FR4 with εr = 4.3. In the present communication two cases of design (horizontal and vertical layout) are analyzed and tested. In both configurations, the resonant frequencies lie in L and S band. The antenna characteristics measured and simulated are in agreement. Orientation of antenna layout from horizontal to vertical also enhances co/cross-polarization. The present work is important for cost effective applications.

Keywords Co/cross-polarization · L and S band · Microstrip patch antennas

1 Introduction

Aperture sharing has been the topic of research studies in recent years. Aperture sharing is fundamentally method of layout for designing antennas for multifunctionality of the antenna systems. It consists of a collection of elementary radiators that can be integrated simply or in antenna array configuration. In aperture sharing designs one can use identical radiators or different radiators using same surface. However, the overall design depends upon our basic requirement, i.e. mode of operation or application basis. Microstrip patch antennas working in L-band have wide applications such as in mobile satellite, terrestrial cellular and personal communication [1–3], Antennas working in S-band have applications in Microwave, nano-satellite, radar for missiles and GPS [4–6] etc.

Shared aperture microstrip patch antennas were analyzed previously by different authors [7–11]. In all these structures discussed, have wide application in different fields due to the availability of shared space for different bands and due to low-cost profile. These structures, mainly includes perforated-patch [8–12], circular [13] and cross-patch [14]. The base of shared aperture antennas design is the availability of space for both bands of operation. Which in turn is the direct consequence of frequency ratio of both bands. Lower the frequency ratio, higher is the ease to design the antennas as for lower ratios the variations is dimensions for

✉ Sunil Kumar Khah
sunil_khah@rediffmail.com

[1] Department of Physics and Materials Science, Jaypee University of Information Technology, Waknaghat, Solan, HP, India

both bands is high. The common designs are based on frequency ration of greater than 1:4. Designing the antennas where the difference in the dimensions is very low is a challenger. The challenge is the motivation for the present design. In the present communication we have used, shared aperture to design microstrip patch antennas operating in L and S band simultaneously. Very few researchers [10, 15] have designed antennas of L and S band due to space constraint as the frequency ratio of both bands is 1:2. In the present designed structure, upper surface of conducting material is used to design both the antennas, which is not in case of reported works [10, 15]. The reported design is based on FR-4 substrate having dielectric constant εr=4.3. The fabricated antenna is investigated for two different configurations or arrangements of patches. The antenna for L-band can be used for mobile communication while the antenna of S-band can be used for radar and some satellite communications.

2 Antenna Design and Parameters

The geometry of the shared aperture microstrip patch antenna consists of two different arrangements of Y-shapes, i.e. horizontally and vertically arranged Y-shapes are shown in Figs. 1 and 2 respectively. Using standard formula the basic dimensions were calculated [16]

$$\text{L} = \text{length of the patch} = \frac{c}{2f\sqrt{\varepsilon_e}} - 0.824h\left(\frac{(\varepsilon_e + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_e - 0.258)\left(\frac{W}{h} + 0.8\right)}\right) \tag{1}$$

$$\text{W} = \text{width of the patch} = \frac{c}{2f\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{2}$$

$$\varepsilon_\text{e} = \text{effective permittivity of medium} = \frac{\varepsilon_r + 1}{2} - \frac{\varepsilon_r - 1}{2}\left[\frac{1}{\sqrt{1 + 12\left(\frac{h}{W}\right)}}\right] \tag{3}$$

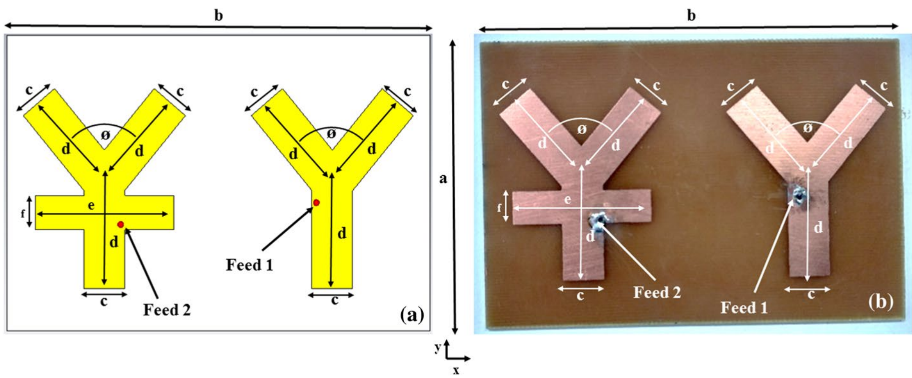

Fig. 1 Geometry of horizontally arranged Y-shapes, **a** simulated, **b** fabricated

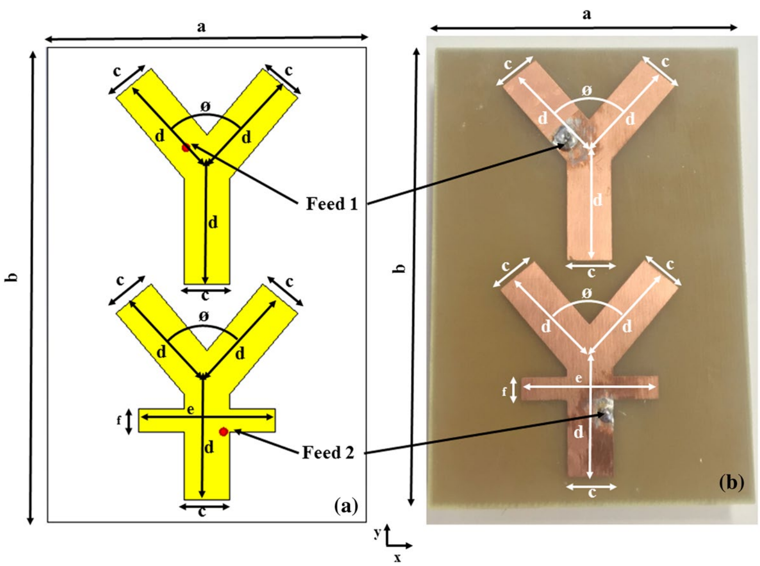

Fig. 2 Geometry of vertically arranged Y-shapes, **a** simulated, **b** fabricated

ε_r = dielectric constant of the medium, h = height of substrate, c = velocity of light (3×10^8 m/s).

The final design of the antenna is obtained by optimization with the help of simulation tools. The proposed Y shaped structures were designed on FR-4 ($\varepsilon_r = 4.3$) (substrate of dimensions ratio a:b) of constant height (h = 1.6 mm). Both Y-shapes have been designed using three strips, each having width of c and that of height d. The feeding of the antennas is done by 50 Ω coaxial feed. The selection of feed point is done by optimizing return loss results to maximum negative value and matching input impedance by the simulation tools. All the parameters are shown in Table 1. The dimensions units used in both arrangements is same, one extra strip used in one of the shapes to obtain desired results. The simulation is carried out by CST studio suite has been used to simulate the parameters such as return loss, gain, and co-/cross-polarization. The prototype of the antennas is fabricated and the results are measured and compared with the simulated results. The results in both the cases, namely horizontally arranged Y-shapes and vertically arranged Y-shapes such as the radiation pattern, antenna gain and return loss are thus discussed for both the designs separately.

Table 1 Parameter values for patch antenna

Sr. no.	Parameter	Value
1.	a	70 mm
2.	b	104 mm
3.	c	10 mm
4.	d	25 mm
5.	e	30 mm
6.	f	5 mm
7.	ø	40°

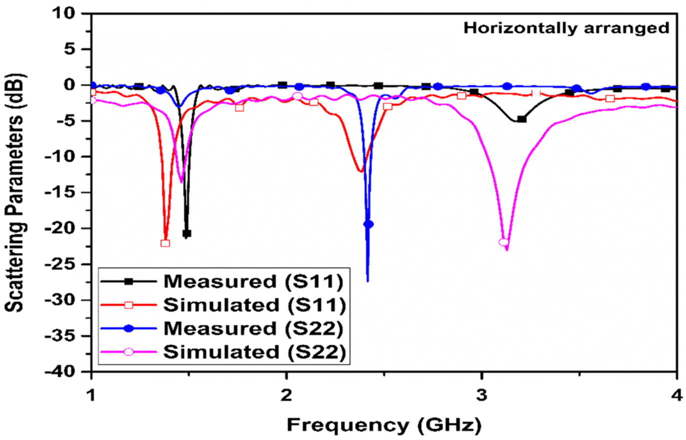

Fig. 3 Scattering parameters for horizontally arranged Y-shapes

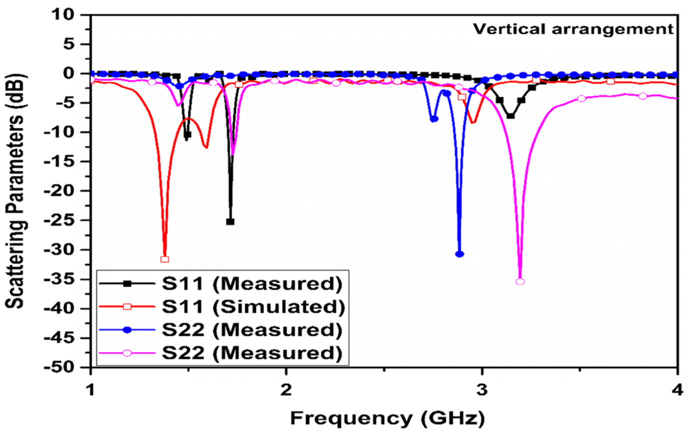

Fig. 4 Scattering parameters for vertically arranged Y-shapes

3 Results and Discussion

In this section the experiments results obtained from the prototype design are presented and compared with the simulated results. The results of both the designs are presented and discussed separately. The design parameters of both the antennas are reported in the preceding section and the optimal values of the design are reported in Table 1. In Figs. 3 and 4 the measured and simulated of S-parameters for both antenna designs. For horizontally arranged antennas (Fig. 1) simulated results show the resonant frequencies of 1.37 GHz (L-band) and 3.12 GHz (S-band) respectively. While measured results show the resonant frequencies of 1.48 GHz (L-band) and 2.41 GHz (S-band).

Both measured and simulated results are confined to the desired bands. There are certain simulation limitations which are responsible for some variations in both results. For L-band measured results are almost closed to simulated values. For the vertically aligned antenna (Fig. 2) the pattern is rotated vertically by keeping the dimension same with an

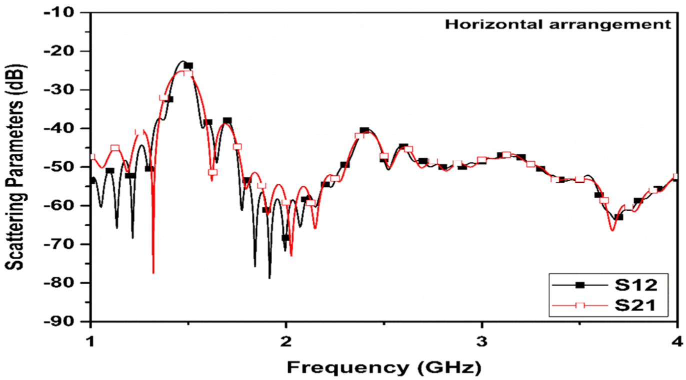

Fig. 5 Isolation for horizontal arrangement

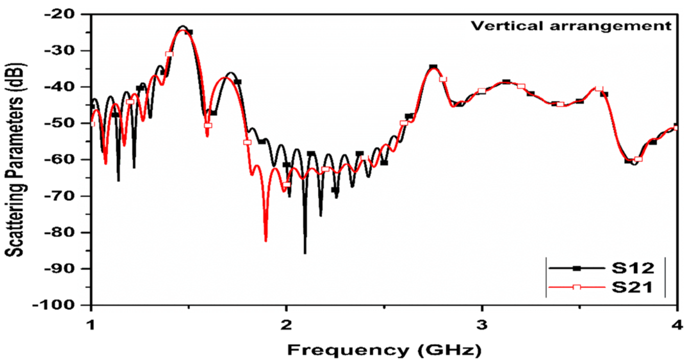

Fig. 6 Isolation for vertical arrangement

angle of 90 degrees. For better match the feed location of one of the patch is also changed. This rotation not only affects the resonant frequency values but also resulted change in co/cross-polarization. The new resonant frequency values for simulated results are 1.37 GHz and 3.19 GHz corresponding to L and S bands for both antennas are respectively. For this design measured values of resonant frequency are 1.715 GHz and 2.885 GHz for both bands. Figures 5 and 6 Shows that isolation is better than 70 dB in both arrangements.

Bandwidth (BW) is also calculated from both S11 and S22 parameters for both antenna arrangements using as shown below in Eqs. (4) and (5)

$$BW = \frac{fH}{fL} \tag{4}$$

$$BW\,(\%) = \left\{ \frac{fH - fL}{fC} \right\} \times 100. \tag{5}$$

where fH = the upper frequency, fL = the lower frequency, fC = the centre frequency.

While solving this problem effect of mutual coupling is also observed. Due to mutual coupling effect value of return loss parameters was affected, which may result in cross

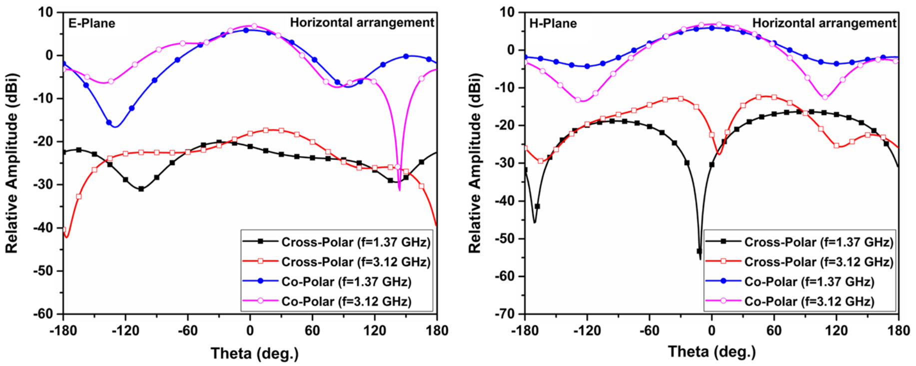

Fig. 7 Far-field parameters of horizontal arrangement

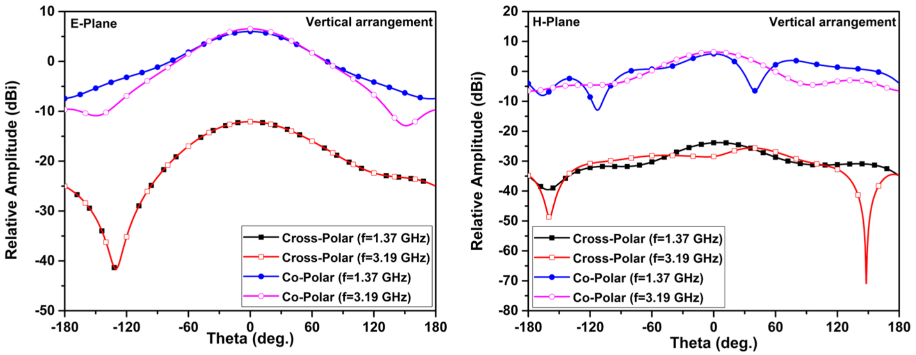

Fig. 8 Far-field parameters of vertical arrangement

talk while in operation. The isolation of both antenna is maintained by choosing the feed point location, the same are reported in Fig. 2 for upper Y-shape. The far-field pattern for both arrangements i.e. horizontally and vertically placed Y-shapes are also calculated and are presented in Figs. 7 and 8. Comparative study of various parameters is shown in Table 2.

4 Conclusion

Aperture sharing is used here to design microstrip patch antennas for L and S band for multitasking. We have used two different configurations consisting of horizontally and vertically arranged Y-shapes. Due to aperture sharing technique, this type of antennas has wide application in communication systems. One main thing about antenna design is that due to the simple design, it is easy to design this type of antennas. A significant increase in gain is also observed while changing the orientation as well as the location of the substrate and the Y-shapes respectively. Which shows that one can use its Y-shapes location for frequency tuning purpose also. Due to the presence of two antennas on same substrate, design

Table 2 Various parameters obtained from patch antenna

Parameters	Horizontal arrangement		Vertical arrangement	
	L-band	S-band	L-band	S-band
Resonant frequency (GHz)				
Simulated	1.37	3.12	1.37	3.19
Measured	1.48	2.41	1.71	2.88
Return loss (dB)				
Simulated	−22.03	−23.00	−31.70	−35.45
Measured	−21.35	−27.36	−25.22	−31.06
Bandwidth (%)				
Simulated	4.16	6.66	7.81	5.17
Measured	3.19	2.42	3.05	3.69
Voltage standing wave ratio (VSWR)	1.26:1	1.12:1	1.11:1	1.05:1
Normalized impedance (R ± jX)	1.18–j0.18	1.09–j0.07	1.11–j0.02	0.96–j0.04
Co-polar (dBi)				
E-plane	5.87	6.87	6.00	6.54
H-plane	5.87	6.88	5.86	6.48
Cross-polar (dBi)				
E-plane	−21.13	−18.13	−12.08	−12.08
H-plane	−30.40	−22.48	−23.85	−28.44

have wide applications. Such as one can use same antenna for mobile communications as well as satellite communication at same time.

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Jonny Dhiman received the B.Tech degree in electronics engineering and M.Tech degree in Nanoscience & Technology from Kurukshetra University, Kurukshetra, India. His current researches include antenna theory and application, especially on design of Microstrip patch antennas and array based structures.

Prof. Sunil Kumar Khah received B.Sc. (Electronic Sciences) from Kashmir University; M.Sc., M.Phil., and Ph.D. from Agra University. He did his postdoctoral research in the field of high power microwave component design. Presently, he is working as a Professor in the field of electromagnetics at Department of Physics and Material Sciences, Jaypee University of Information Technology. He is visiting researcher at School of electrical and Computer Engineering, University of Dayton, USA. Moreover, he is working on high efficiency low sidelobe level antenna design, shared aperture antenna systems and wideband dual band antenna designs. His research interest is design and modeling of high frequency antenna designs. He is senior member of PSSI, MRSI, and member of IEEE.