Design of a Dual-band Shared-Aperture Antenna Based on Frequency Selective Surface

Bo Yan, Yuanming Zhang, Long Li*, *Senior Member*, *IEEE*
School of Electronic Engineering, Xidian University
No.2 South Taibai Road, Xi'an, Shaanxi 710071, China
*Corresponding email: lilong@mail.xidian.edu.cn

***Abstract* - A new design of a dual-band shared-aperture antenna based on frequency selective surface (FSS) for synthetic aperture radar (SAR) applications is presented. Bow-tie patches are used as the radiating elements both at L-band and C-band. The centre frequency of the L-band antenna is 1.3 GHz and the centre frequency of the C-band antenna is 5.2 GHz. The simulated impedance bandwidth ($S_{11} \le -10dB$) of the antenna reaches 16.2% for L- band and 26.8% for C-band. The simulated cross-polarization levels are all less than -48 dB for both L-band and C-band. The work confirms the practicability of the dual-band shared-aperture antenna based on frequency selective surface (FSS) design, and good bandwidth and cross-polarization performance of the antenna has been achieved.**

I. INTRODUCTION

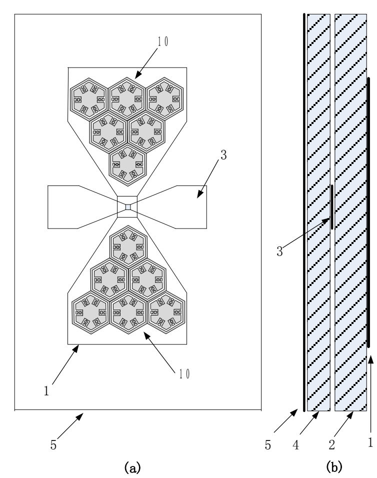
The radar system with a variety of frequency bands can effectively improve the versatility of the radar, especially when combining a high frequency and low frequency, the radar system can provide more information about the imaging region. Synthetic aperture radar SAR not only can be used to obtain the image of a large area on the ground, but also has a strong penetrating power. Now SAR is widely used in resource exploration, major disaster estimates, land surveying, and other fields, and SAR has unique advantages in the military.

Various solutions for shared-aperture dual-band dual-polarized microstrip antenna arrays have been proposed in the last two decades. The typical configurations of array may be roughly classified into two types: 1) perforated structure, including perforated patches/patches [1], [2], which a C/X and L/X shared aperture array designs with the configuration of perforated patches and patches are presented, such as ring/patch [3], [4], cross-patch/patch [5], [6]; 2) interlaced layout, such as interlaced patch with slot/dipole [7-9]. An example is the DBDP array of L/C-band interlaced slots with patches by R. Pokuls et.al [7]. Another example is an S/X-band array composed of interlaced dipoles with patches which is proposed by S. S. Zhong, et.al [9].

In this paper, a new dual-band shared-aperture antenna based on frequency selective surface (FSS) is presented which operates at L- and C-bands. The configuration and design of shared-aperture antenna are described in Section II, and the simulated results of the antenna are discussed in Section III. In Section IV, the simulated results are presented to verify the design approach.

II. ANTENNA DESIGN

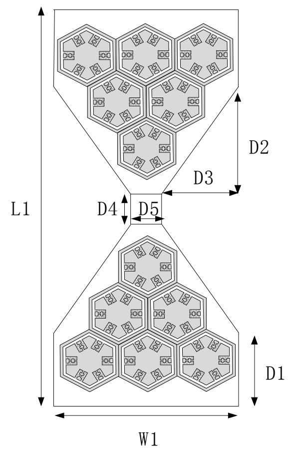
The configuration of the proposed antenna is shown in Fig. 1. The antenna consists of five layers. Starting from the top of the structure, the first layer is the L-band antenna which embedded in twelve frequency selective surface units. This kind of frequency selective surface unit produces the property of band-pass for C-band antenna. The second layer is the ROHACELL HF ($\varepsilon_r = 1.07$) foam, whose thickness is about 43.5mm. The third layer is the C-band antenna. To minimize the volume of antennas, the C-band antenna and the L-band antenna is placed orthogonal to share the aperture of the L-band antenna. To obtain a wide bandwidth, bow-tie patches are selected for L-band and C-band. The fourth layer is about 14.4mm thick ROHACELL HF foam. The last layer is ground plane which serves as reflector plane both in L-band and in C-band. The overall height is about 57.7mm.



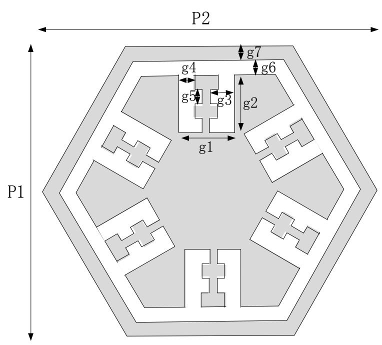
1 L band antenna 2/4 Foam 3 C band antenna
5 Ground 10 Frequency selective surface units

Fig. 1.configuration of the proposed antenna (a) top view, (b) side view

As shown in Fig. 2, L-band antenna is presented, and the antenna consists only of a single bow-tie radiating patch. Due to the larger size of the L-band antenna and placed on the C-band antenna, this means that L-band serves as a reflector plane for C-band antenna. To reduce the effect of the L-band antenna for C-band antenna, FSS units which produce the property of band-pass for C-band antenna are embedded in the L-band antenna. Each of the frequency selective surface unit includes a regular hexagonal metal ring and a regular hexagonal metal patch with six double-F type aperture. And there is a regular hexagonal aperture between the regular hexagonal metal patch and the regular hexagonal metal ring. The details of the L-band antenna dimensions are given in Table 1.



(a)



(b)

Fig. 2. Top view of the L-band antenna (a) L-band antenna, (b) FSS unit cell

TABLE I
DIMENSIONS OF THE ANTENNA UNIT(MM)

L1	W1	D1	D2	D3
73	31	12	22	13
D4	D5	P1	P2	g1
5	5	9.5	11	1.2
g2	g3	g4/g5	g6/g7	
2	0.5	0.2	0.2	

The simulated transmission and reflection of the FSS unit are shown in Fig. 3.To meet the requirements of bandwidth, bow-tie patch is used for the C-band antenna, as shown in Figure 4. The key dimensions of the antenna are as follows: L2=18.2mm, W2=9mm, S1=3.1mm, S2=5mm, S3=3.5mm, S4=2mm, S5=2mm.

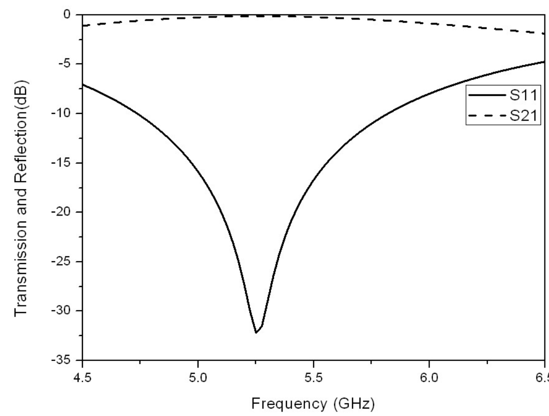


Fig. 3. Transmission and Reflection of the FSS unit

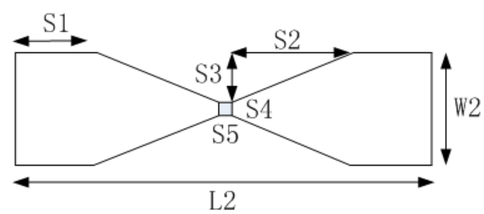
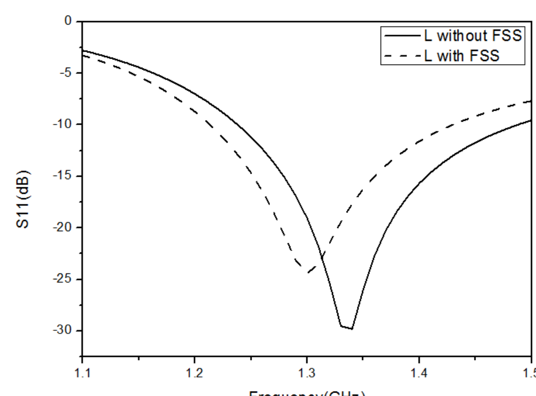


Fig. 4. Top view of the C-band antenna

III. Simulated Results

In this section, the simulation and design of the proposed antenna was done by using HFSS based on the finite-element method (FEM), and the performance of the array presented. The simulated S-parameters of the L-band and C-band in comparison with the ones without FSS units embedded in L-band of shared-aperture antenna are shown in Figure 5a and b, respectively. The simulated frequencies of the L-band and C-band are slightly shifted down compared with the ones without FSS units. The simulated relative bandwidth that the reflection coefficient is better than -10 dB is 16.2% in L-band. For the C-band antenna, there is a 26.8% relative bandwidth within the operating band. The reflection coefficient of the C-band antenna is improved by embedding the FSS units in the L-band antenna.



(a)

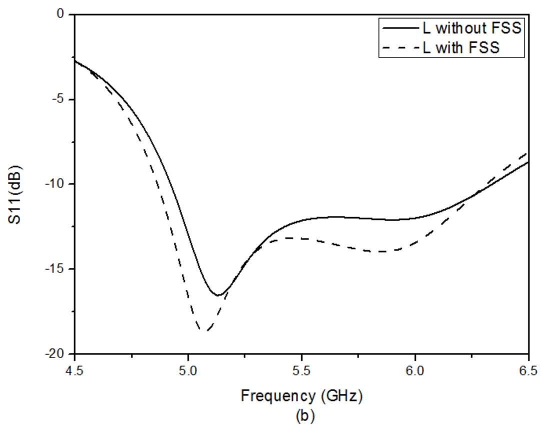
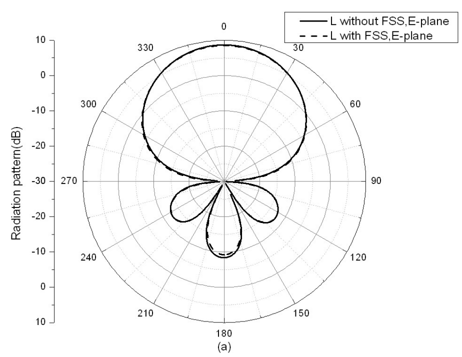
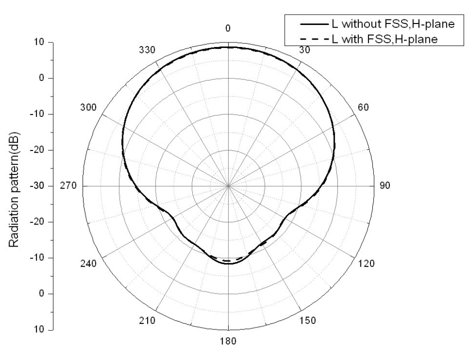
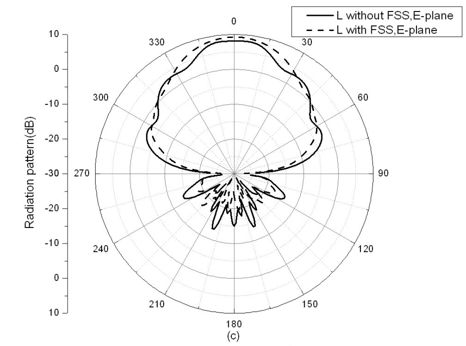


Fig. 5.Simulated S11 of the proposed antenna (a) L-band, (b) C-band

The simulated radiation patterns of the antenna in comparison with the ones without FSS units embedded in L-band of shared-aperture antenna are given in Fig. 6, which shows the E-plane and H-plane patterns at 1.3GHz for L-band and 5.2GHz for C-band. It is seen that good radiation patterns are obtained in L-band. Due to the FSS units which produce the property of band-pass for C-band antenna embedded in the L-band antenna, the front and back patterns of C-band antenna are improved. The gain increases from 8.1 to 9.3 dB in C-band. This paper focuses on a design to integrate L-band antenna and C-band antenna (or antennas) in a compact planar aperture. This means that some of C-band antennas are placed under the L-band radiation patch. These C-band antennas are obtained worse radiation pattern in H-plane pattern. In this situation, FSS units embedded in the L-band antenna make a great impact for C-band antenna, as shown in Fig. 6.







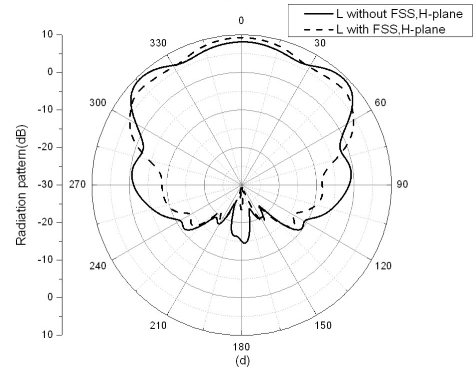
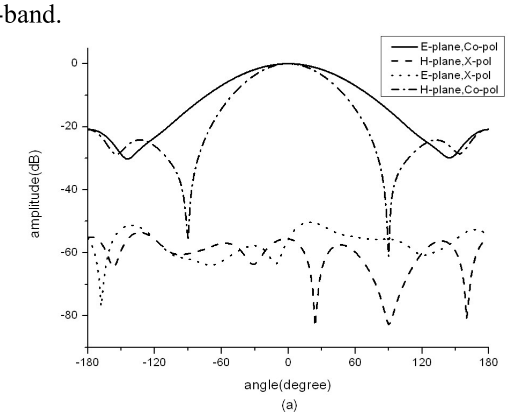


Fig. 6. Simulated radiation patterns of the proposed antenna (a) L-band E-plane, (b) L-band H-plane,(c) C-band E-plane and (d) C-band H-plane

Both the co-polarization and cross-polarization patterns of L-band and C-band are shown in Fig. 7, which include the E-plane and H-plane patterns at 1.3 GHz for L-band and 5.2 GHz for C-band. It can be seen that radiation patterns are good and the cross polarization is less than -48dB both in L-band and C-band.



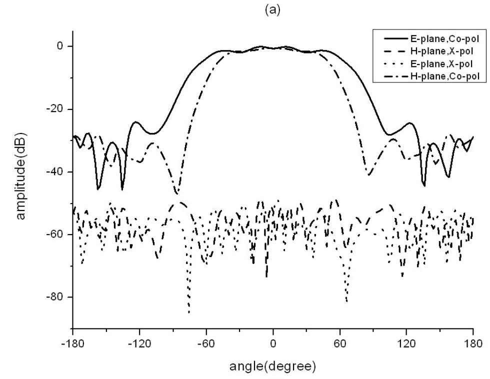


Fig. 7. Normalized simulated patterns of the antenna (a) L-band, (b) C-band

IV. CONCLUSION

This paper presents a kind of dual-band shared-aperture antenna with wideband and low cross-polarization. The bow-tie patches are selected for L- and C-band design and frequency selective surface units which produce the property of band-pass for C-band antenna are embedded in the L-band antenna. The simulated results show that the bandwidths of $S_{11} \leq -10dB$ for the L-band and C-band are 16.2% and 26.8%, respectively. The level of cross-polarization patterns is lower than -48dB both in L-band and C-band, and the antenna achieved good patterns over the whole frequency bands.

ACKNOWLEDGEMENTS

This work is supported by National Natural Science Foundation of China under Contract No. 61072017, and supported partly by the Program for New Century Excellent Talents in University of China, by Natural Science Basic Research Plan in Shaanxi Province of China (No. 2013JZ019), National Key Laboratory Foundation, Fundamental Research Funds for the Central Universities (K5051202051, K5051302025).

REFERENCES

[1] L. L. Shafai, W. A. Chamma, M. Barakat, P. C. Strickland, and G. Séguin, "Dual-band dual-polarized perforated microstrip antennas for SAR applications," *IEEE Trans. Antennas Propag.*, vol. 48, no. 1, pp. 58-66, Jan. 2000.

[2] D. M. Pozar and S. D. Targonski, "A shared-aperture dual-band dual – polarized microstrip array," *IEEE Trans. Antennas Propag.*, vol. 49, no. 2, pp. 150-157, Feb. 2001.

[3] C. Mangenot and J. Lorenzo, "Dual band dual polarized radiating subarray for synthetic aperture radar," in *Proc. IEEE Antennas Propag. Soc. Int. Symp.*, vol. 3, pp. 1640-1643, 1999.

[4] S. H. Hsu, Y. J. Ren, and K. Chang, "A dual-polarized planar-array antenna for S-band and X-band airborne applications," *IEEE Trans. Antennas Propag.*, vol. 51, no. 4, pp. 70-78, Aug. 2009.

[5] C. Salvador, L. Borselli, A. Falciani, and S. Maci, "Dual frequency planar antenna at S and X bands," *Electron. Lett.*, vol. 31, no. 20, pp.1706-1707, Sep. 1995.

[6] A. Vallecchi, G. B. Gentili, and M. Calamia, "Dual-band dual polarization microstrip antenna," in *Proc. IEEE Antennas and Propagation Society Int. Symp.*, vol. 4, pp. 134-137, 2003.

[7] R. Pokuls, J. Uher and D. M. Pozar, "Dual-frequency and dual polarization microstrip antennas for SAR applications", *IEEE Trans. Antennas Propag.*, vol. 46, no. 9, pp.1289-1296, 1998.

[8] X. Qu, S. S. Zhong and Y. M. Zhang, "Dual-band dual-polarized microstrip antenna array for SAR applications," *Electronics Letters*, vol.42, no. 24, pp. 1376-1377, 2006.

[9] S. S. Zhong, X. Qu, Y. M. Zhang and X. L. Liang, "Shared-aperture S/X dual-band dual-polarized microstrip antenna array", *Chinese Journal of Radio Science*, vol. 23, no. 2, pp.305-309, 2008. .