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A Novel Reflectarray Antenna with Reduced RCS

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Abstract

A novel frequency selective surface (FSS) configuration in the reflectarray antenna is proposed for the reduction of radar cross section (RCS) level in this work. Double-layer FSS structure is located behind the reflectarray antenna as a ground. A 9×9 elements FSS with variable size patches has same geometry with the reflectarray antenna. The RCS reduction performance of reflectarray antenna for both ground plane backed and FSS backed is compared. The results of simulation are obtained by using CST Microwave Studio. The simulation results show that RCS level of FSS backed reflectarray antenna is reduced both in-band (8-12 GHz) and out-of-band (2-7 GHz and 13-18 GHz). In the literature, RCS reduction of reflectarray antenna with FSS structure has only been achieved out-of-band. Furthermore, the gain and radiation performance of the ground plane backed reflectarray antenna and FSS backed reflectarray antenna are compatible with each other.

1. Introduction

High gain antennas are used in communication systems and radar applications. In recent years, reflectarray antennas have commonly been preferred instead of the conventional parabolic reflectors when the high gain antennas are required [1]. It has several advantages such as which are low profile, low cost, light weight, no any feeding networks, easy fabrication and electronically beam direction [2-4].

It is well known that the use of high gain antennas increases the RCS level on military applications (aircraft, ships and so on) and the platform detectability [5]. The numbers of studies to reduce RCS in the reflectarray antennas are limited in the literature. Especially, RCS reduc tion of reflectarray antenna with FSS structure has only bee n achieved out-of-band.

General methods for reducing RCS included in the literature are radar absorbing material (RAM) coating [6], passive or active cancellations [7], antenna forming [8] and using FSS [9-11]. In particular, the studies on RCS reduction of microstrip reflectarray antennas with FSS structure are both very narrow and only out-of-band. In the following works, RCS cannot be reduced in the operating band of reflectarray antenna [5], [11], [12]. In this study, it has been selected a new type FSS structure for the RCS reduction of reflectarray antenna. As compared with the previous works, current method can strongly reduce the RCS both in-band and out-of-band with same gain and radiation performance.

In this paper, 9×9 elements reflectarray antenna with double-layer FSS, which are located behind the reflectarray antenna, is designed and simulated. FSS structure has the same size and arrangement with the reflectarray antenna. We showed that RCS level of the reflectarray antenna has been reduced in-band and out-of-band when ground plane is replaced with FSS. The similar RCS reduction method with [13] is used in this study. But using different geometry of unit cell and FSS settlement, more RCS reduction is achieved in the operating band as compared to [13]. RCS level is reduced by 14.8 dB in-band at 9 GHz and by 17 dB out of the operation band at 5 GHz. Gain and radiation performance of the original reflectarray antenna is preserved and so the results are nearly similar between FSS backed and ground plane backed reflectarray antenna.

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2. Design Procedure of the Proposed Work

2.1. Reflectarray Antenna Structure

In this study, a reflectarray antenna that is previously presented in reference [15] is used for reduction of RCS level. This reflectarray antenna has 9 × 9 elements with the length of 17 × 17 mm in xy-plane. The unit cell of the reflectarray is composed of double rings and it is shown in Fig. 1. Based on parametric study, the parameters of the unit cell are chosen as follow: R_1 =variable (2 mm – 6.5 mm), R_2=b×R_1, L_1=a×R_1, L_2=a×R_2, a=1.4, b=0.6, air=5.5 mm and length of unit cell D=17 mm. The substrate of unit cell is chosen Arlon AR 600 (ε_r =6.15) with thickness h=0.508 mm. The air gap of between substrate and ground plane is 5.5 mm. The phase range of reflectarray antennas is desired generally more than 360º [14]. In this unit cell design, 410º phase range is obtained by varying of patches size at the center frequency f=10 GHz. Fig. 2 shows smooth and linear reflection phase curve at 10 GHz by varying of R_1, which could help to extend the bandwidth.

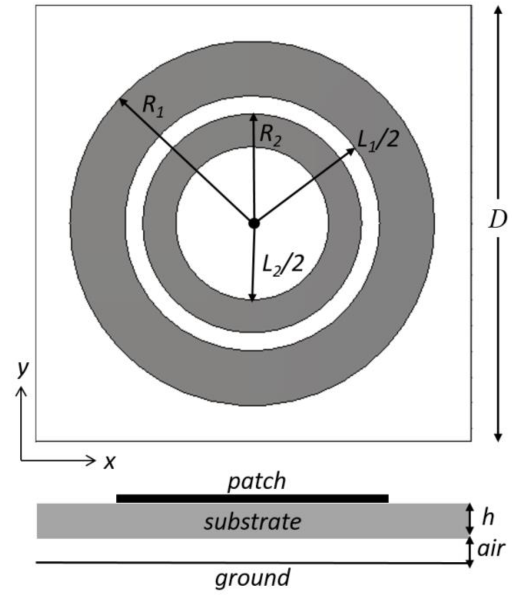

Figure 1. The view of reflectarray unit cell.

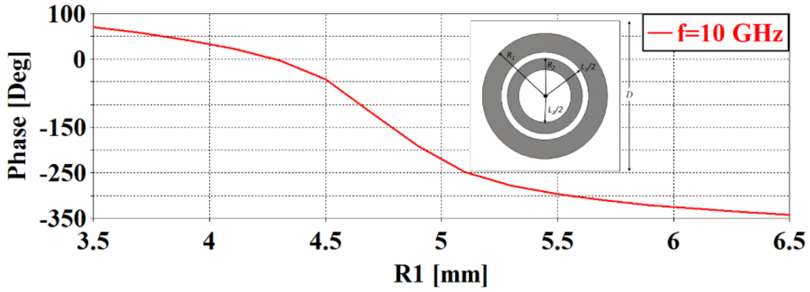

Figure 2. Reflection phase curve of the unit cell.

Table 2. The list of parameters.

D= 17 mm	a=1.4
R_1= variable	b=0.6
R_2= b×R_1	ε_r =6.15
L_1= a×R_1	h=0.508 mm
L_2= a×R_2	air=5.5 mm

2.2. FSS Backed Reflectarray Antenna

RCS reduction is achieved by using double-layer FSS which are located behind the reflectarray antenna. The identical reflectarray settlement is used as a FSS ground plane. Between reflectarray surface and each layer has 5.5 mm air gap as shown in Fig. 3. Double-layer arrangement behind the reflectarray is illuminated by pyramidal horn antenna (Fig. 4). The pyramidal horn antenna is a horn antenna with 61 mm × 45 mm aperture size and has 120 mm tapering length. It is located at F=264 mm focal distance between array surface and horn aperture. Also simulated radiation patterns of horn antenna are given at 10 GHz for E-plane and H-plane (Fig. 5). As seen from the Fig. 5 the pyramidal horn antenna has 3-dB beam-width approximately 30˚.

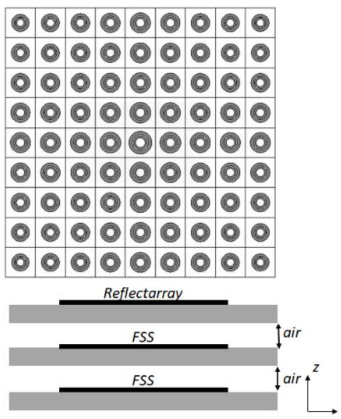

Figure 3. Reflectarray structure and double-layer settlement behind the reflectarray antenna used for FSS layer.

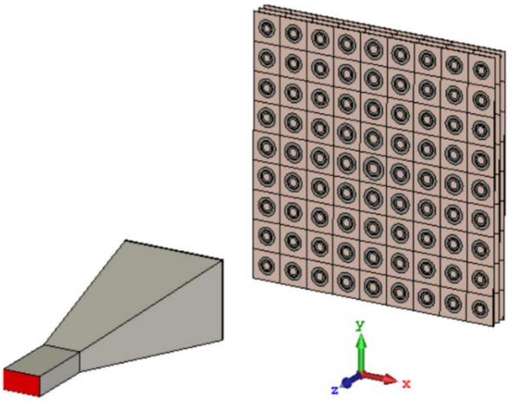

Figure 4. Reflectarray antenna with FSS backed.

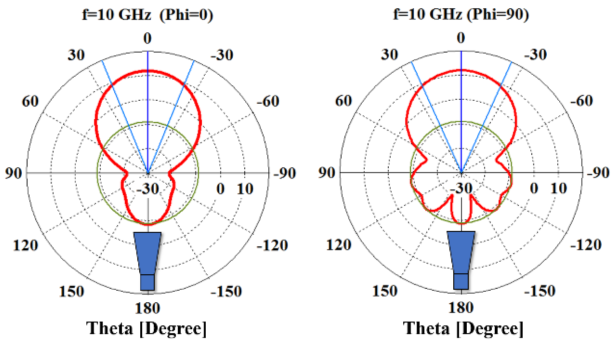

Figure 5. Simulated radiation patterns of horn antenna at 10 GHz for E-plane and H-plane.

3. Simulation Results

In order to reduce of RCS level, ground plane of reflectarray antenna is replaced with FSS. In Fig. 6, it is been demonstrated the comparison of the reflection coefficient of reflectarray antenna with ground plane backed and FSS backed. Reflection characteristics are not completely different from the each other in each case. Simulation results show the relationship between the monostatic RCS levels of the ground plane backed reflectarray antenna and FSS backed reflectarray antenna in Fig. 7. Double-layer FSS backed on the reflectarray reduced the RCS level in-band and out-of-band visibly. RCS reduction is obtained up to 14.8 dB in-band at 9 GHz and up to 17 dB out-of the operation band at 5 GHz.

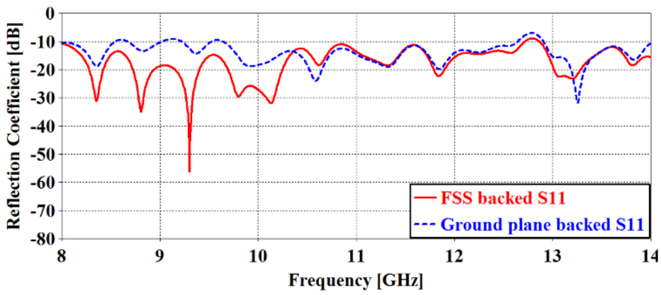

Figure 6. S_{11} parameter of reflectarray antenna with ground plane backed and FSS backed.

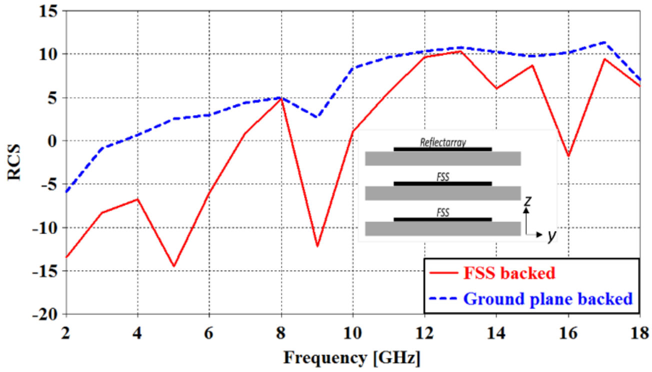

Figure 7. Relationship between the monostatic RCS levels of the ground plane backed and FSS backed reflectarray antennas.

Gain results between FSS backed and ground plane backed reflectarray antennas can observed from Figure 8.

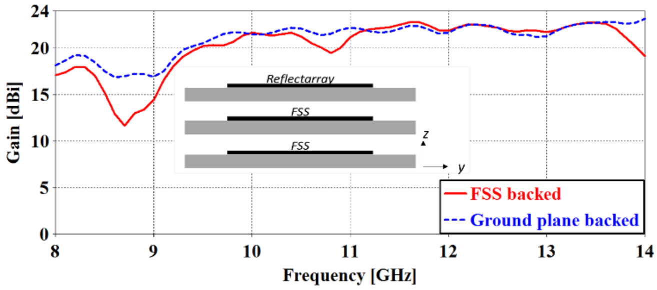

Figure 8. Gain curves for the ground plane backed reflectarray antenna and FSS backed reflectarray antenna.

A suitable FSS is integrated into the reflectarray antenna as a ground for lowering the RCS level without any changes of radiation performance. So the effects of the FSS backed reflectarray design are investigated on performance of the reflectarray. For this purpose, gain curve of ground plane backed and FSS backed are compared to each other. Fig. 8 shows that the gain curves of the reflectarray antennas in two cases are in a harmony with each other.

Fig. 9 shows the comparison of the radiation pattern of the FSS backed and ground plane backed reflectarray antenna at 11.5 GHz and 12 GHz respectively. As seen from the figures, directivity of the FSS backed and ground plane backed reflectarray antenna has been stable.

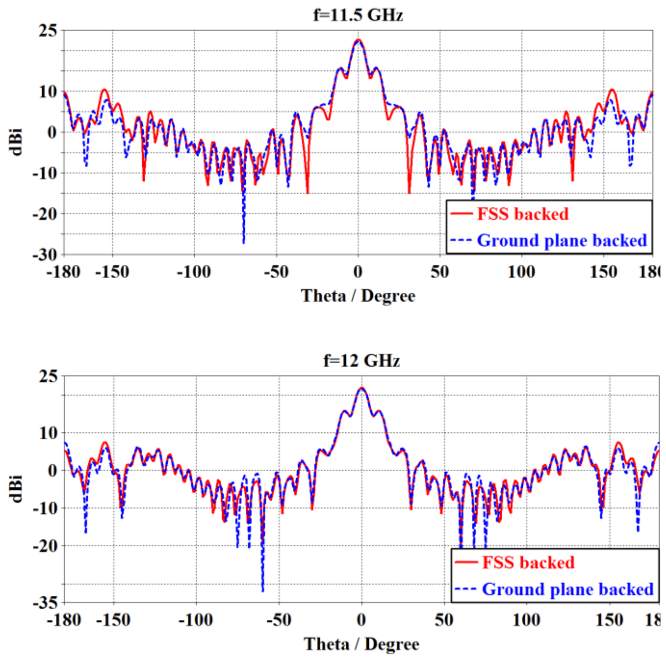

Figure 9. Radiation patterns of FSS backed and ground plane backed reflectarray antenna at 11.5 GHz and 12 GHz (**φ**=90º).

4. Conclusions

A novel double-layer FSS structure has been located behind the reflectarray antenna as a ground for RCS reduction. CST Microwave Studio is used for simulation of the traditional reflectarray with ground plane backed and new configuration of reflectarray. The simulation results show that the FSS-ground has reduced the RCS level in-band as well as out-of-band as compared to the only ground-plane backing, while the gain and radiation performance of the antenna is almost maintained the same for both configurations.

Acknowledgements

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References

[1] Huang J., Encinar J.A., 2008. Reflectarray Antennas, IEEE Press/Wiley, Piscataway, NJ, USA.

[2] Carrasco E., Barba M., Encinar J.A., Arrebola M., 2013. Design, manufacture and test of a low-cost shaped-beam reflectarray using a single layer of varying-sized printed dipoles. IEEE Trans. On Antennas and Propagation **61**, 3077-3085.

[3] Zubir F., Rahim M.K.A., Ayop O.B., Majid H.A., 2010. Design and analysis of microstrip reflectarray antenna with Minkowski shape radiation element. Progress In Electromagnetics Research Letters **24**, 317-331.

[4] Tahir F.A., Aubert H., Girard E., 2010. Equivalent electrical circuit for designing MEMS-controlled reflectarray phase shifters. Progress In Electromagnetics Research Letters **100**, 1-12.

[5] Fakharian M.M., Rezaei P., Orouji A., 2014. A Reflectarray based on the folded SIR patch-slot configuration cacked on FSS for low RCS. Progress In Electromagnetics Research Letters **47**, 119-124.

[6] Peixoto G.G., De Paula A.L., Andrade L.A., Lopes C.M.A., Rezende M.C., 2005. Radar absorbing material (RAM) and shaping on radar cross section reduction of dihedral comers. Paper presented at SBMO/IEEE MTT-S International Conference on Microwave and optoelectronics, Brasilia, Brazil, 25 July.

[7] Knott E.F., Shaeffer J.F., Tuley M.T.,2004. Radar Cross Section, Raleigh, SciTech, NC, USA.

[8] Jiang, W., Hong, T., Liu, Y., Gong, S. X., Guan, Y., Chui S., 2010. A novel technique for radar cross section reduction of printed antennas. Journal of Electromagnetic Waves and Applications **24**, 1-60.

[9] Genovesi S., Costa F., Monorchi A., 2012. Low-profile arraywith reduced radar cross section by using hybrid frequency selective surfaces. IEEE Trans. Antennas Propag **60**, 2327-2335.

[10] Misran N., Cahill R., Fusco V.F., 2003. RCS reduction technique for reflectarray antennas. Electron. Letters **39**, 1630-1631.

[11] Li H., Wang B.-Z, Zheng G., Shao W., Guo L., 2010. A reflectarray antenna backed on FSS for low RCS and high radiation performances. Progress In Electromagnetics Research C **15**, 145-155.

[12] Ren, L.-S., Jiao, Y.-C., Zhao, J.-J., Li, F., 2011. RCS reduction for a FSS-backed reflectarray using a ring element. Progress In Electromagnetics Research Letters **26**, 115-123.

[13] Bodur H., Ünaldı S., Çimen S., Çakır G., 2017. A novel reflecarray antenna backed with double layer FSS for RCS reduction. Paper presented at International Applied Computational Electromagnetics Society (ACES) Symposium, Florence, Italy, 26-30 March.

[14] Kim S.H., Kim Y., Yoon Y.J., 2015. Reflectarray element combined a tripole with double rings and broadband RCS reduction. International Workshop on Antenna Technology (iWAT), Seoul, South Korea, 4-6 March.

[15] Bodur H., Ünaldı S., Çimen S., Çakır G., 2016. X-Bant uygulamalar için tek katmanlı geniş bant yansıtıcı dizi anten tasarımı. Paper presented at URSI-TÜRKİYE’2016 VIII. Bilimsel Kongresi, Ankara, Turkey, 1-3 September.