Broadband FSS for Millimeter Radiometer

Xiaoming Liu[1], Fang Zhang[2], Lu Gan[1], Chijian Zhang[1]

[1]Laboratory of Millimeter wave and Terahertz Technology, College of Physics and Electronic Information
Anhui Normal University, Wuhu, Anhui Province, China
xiaoming.liu@ahnu.edu.cn

[2]School of Electronic Communication Engineering
Anhui Xinhua University, Hefei, China
salas0527@163.com

***Abstract*—Frequency Selective Surface (FSS) is one of the key components in a millimeter radiometer. Broadband FSS is in many cases required to monitor the species lines of many gas molecules. A broadband FSS is designed operating in the range of 40-60GHz. The bandwidth is more than 40%. A systematic parametric study is conducted to search for the most sensitive parameters.**

Keywords—FSS; radiometer; broadband; antenna

I. INTRODUCTION

Millimeter radiometers have been widely used in atmosphere remote sensing, such as AMSU-B[1], the Chinese FY-4 millimeter wave sounder[2]. These radiometers are usually deployed in a payload. A typical payload consists of a reflector antenna system, followed by a quasi-optical(QO) system, and a RF receiver chain. In the QO system, a series of engineered components are cascaded to separate the broadband electromagnetic radiation. One of the key components is frequency selective surface (FSS), which plays a role as spatial filter. The use of FSS makes it possible to divide the incoming signal into standard waveguide bands.

Generally speaking, a standard waveguide band has a relative bandwidth of 50%, say the V-band (40-75GHz). To cover the whole band as much as possible, a wideband FSS is required. Unfortunately, wideband FSS is a challenge work. The conventional FSS usually presents narrow bandwidth, in most cases, <20%. Although multi-layer structures are used to increase the bandwidth, the ratio of bandwidth enhancement is limited. In addition, increased insertion loss is also observed. Other techniques have also been used, such as introducing multi-resonating elements, adding coupling path, as so forth. However, the bandwidth is still difficult to be more than 30%, remains to be addressed.

This paper investigates the possible design using mesh grid structure to increase the bandwidth. Such a structure is in essence a complimentary structure, which by the antenna theory usually exhibits a nature of wideband. Also, such a structure can be using for low-pass or high-pass designs. A systematic parametric study is conducted to search for the most sensitive parameters.

The following parts are organized as follows: Section II describes the structure, Sections III is devoted to the parametric study with the conclusions given in Section IV.

II. THE STRUCTURE AND DESIGN

A. Structure of mesh-grid FSS

Mesh-grid structure can be evolved from mesh grid array and patch array, as shown in Fig.1. Mesh grid array acts as a high-pass filter, while patch array is a low-pass filter. The combined array is therefore a band-pass filter[3].

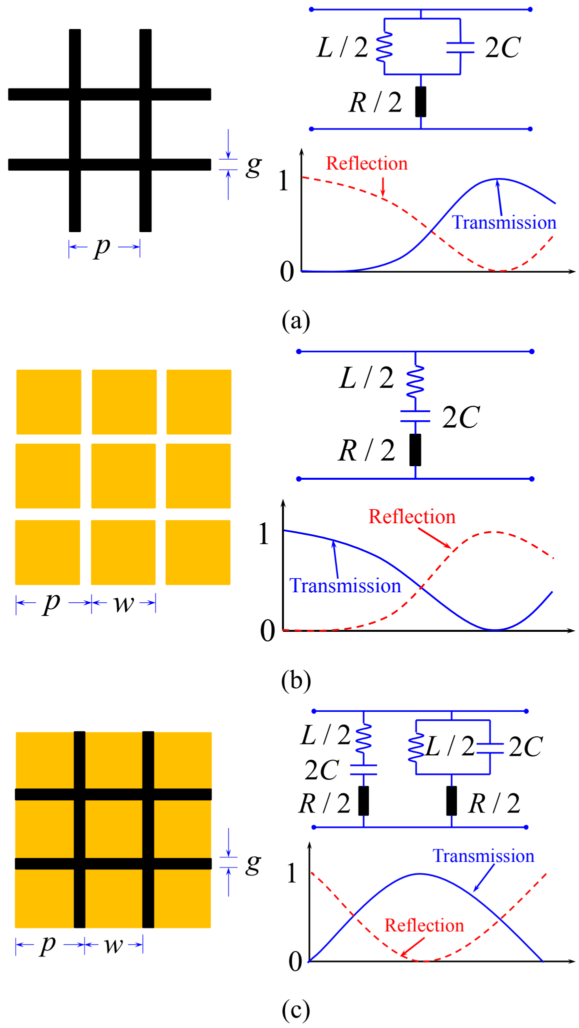


Fig. 1 Equivalent circuits of (a) mesh grid; (b) patch array; (c) combined array.

B. *Design of multi-layer FSS*

The design follows an antenna-coupling-antenna structure, being able to provide broad passband. As show in Fig. 2, the structure consists of two substrates and three metal array, the first and the third layers are patch array, and the second layer is an grid array. Such array was first proposed in Ref.[4].

Such a structure can also be considered as a complementary array. The middle grid array is fills the gaps of the first or the third layers, and forms a complete plane. By the Babinet principle, such structures can be broadband[5].

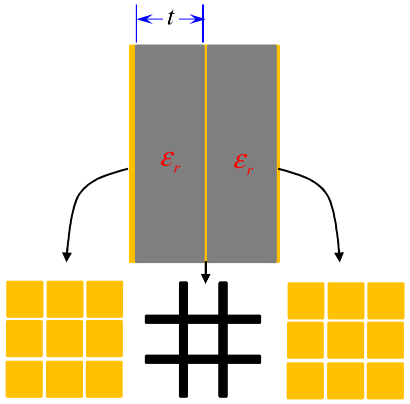
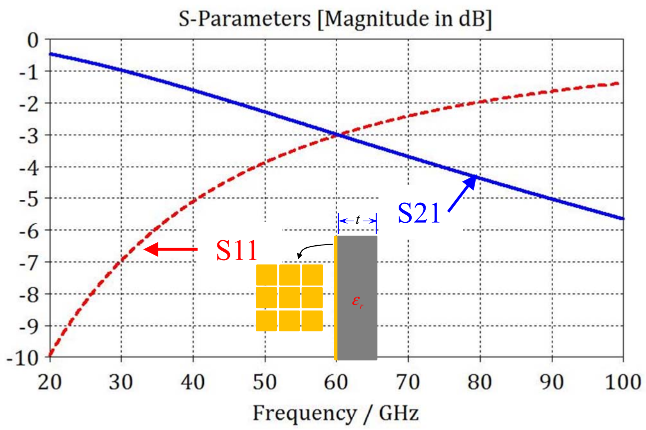
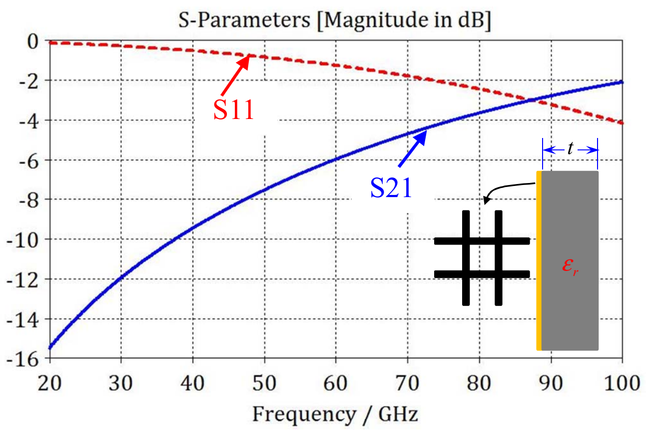


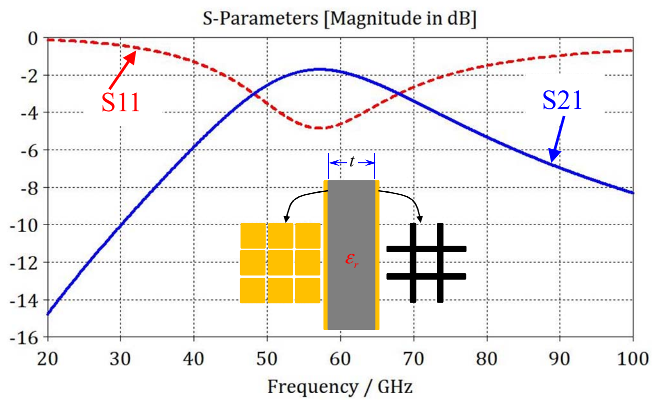
Fig. 2 the structure the multi-layer mesh-grid array.



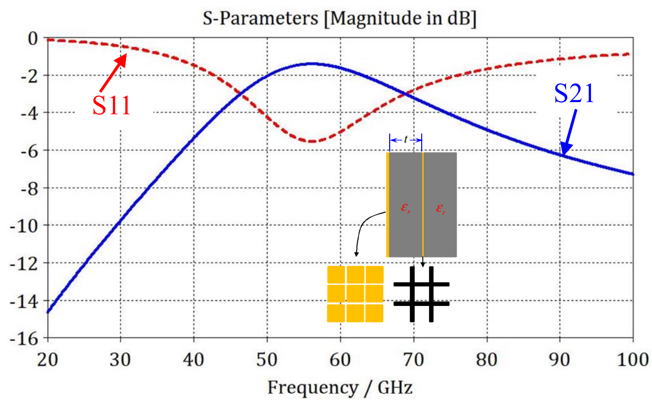
(a)



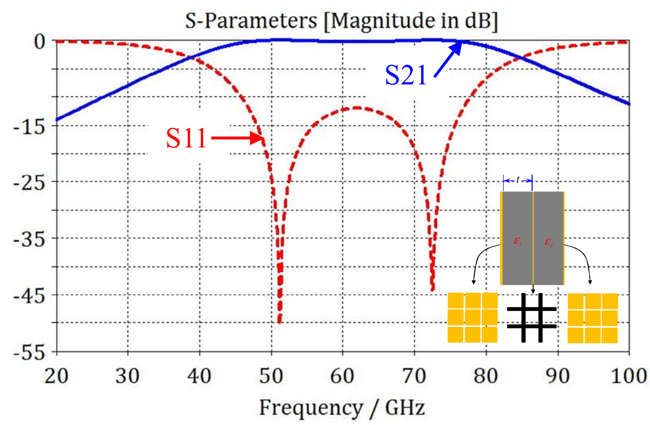
(b)



(c)



(d)



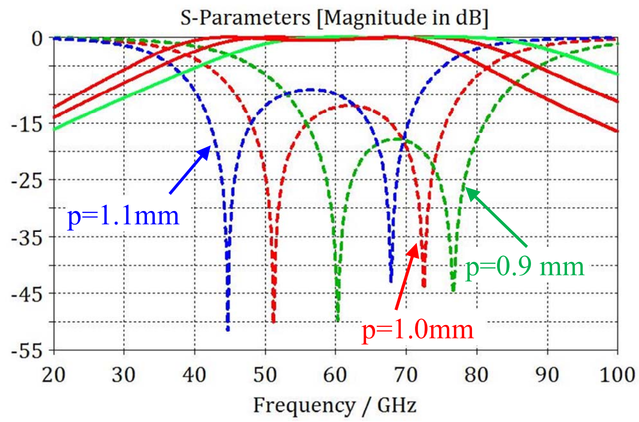
(e)

Fig. 3 the simulated results for the multi-layer mesh-grid structure. (a) single patch array on a substrate; (b) single mesh grid on a substrate; (c) patch-substrate-mesh structure; (d) patch-substrate-mesh-substrate array; (e) the complete structure.

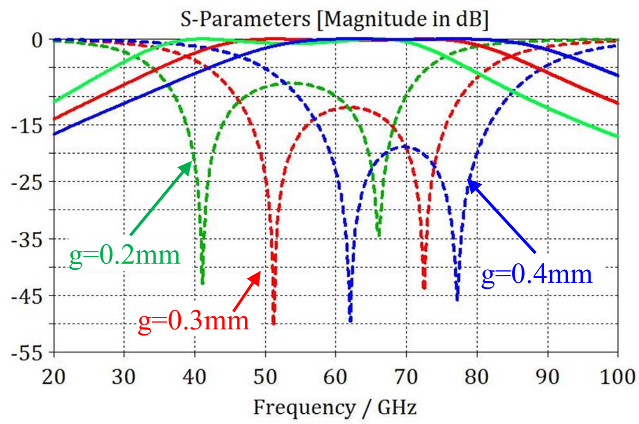
This design is intent to cover the V-band, 40-75 GHz. The parameters are p=1mm, g=0.3mm, t=0.2mm, and the permittivity of the substrate is chosen as 2.15. By putting these parameters into simulation, the results are shown in Fig.3. It is seen from Fig.3(a) that the patch array shows a nature of low pass. The plot of Fig.3(b) indicates that the mesh grid is a high-pass filter. The results of Fig.3(c) and Fig.3(d) demonstrates that patch-mesh structure exhibits a band-pass nature, though the insertion loss and bandwidth are not satisfactory. In addition, it is clearly shown that the results of the complete structure demonstrates a very broadband nature, almost more than 30GHz, showing a relative bandwidth of 50%.

III. PARAMETRIC STUDY

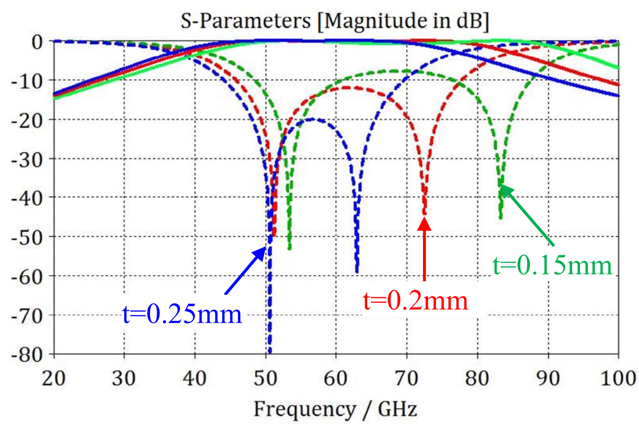
There are there key parameters for this complementary structure, the length of the unit cell p, the width of the mesh grid g, and the thickness of the substrate t.



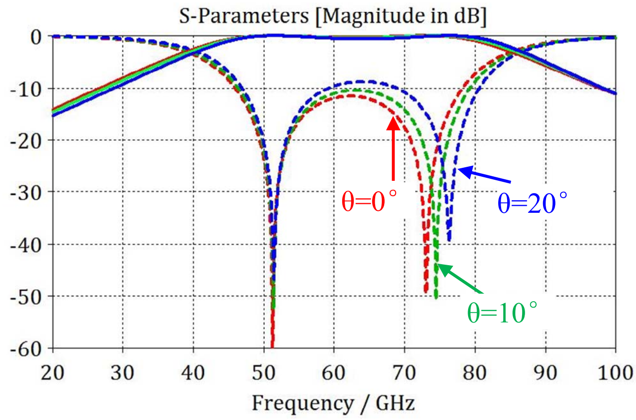
(a)



(b)



(c)



(d)

Fig. 4 Parametric study. (a) the influence of p; (b) the influence of g; (c) the influence of t; (d) angular dependent property

The influence of the unit cell length p is plotted in Fig.4(a), it is seen that the resonate frequencies changes noticeably with the change of p. In addition, the bandwidth decreases with the decreasing of p. Meanwhile, the S11 parameter in the passband decreases from -9.5 dB to -17.5 dB when p changes from 1.1 mm to 0.9 mm.

The size of the gap also produces considerable influence to the resonating frequencies, however, in an opposite way to that of p. The parameter g determines the size of the patch and the width of the mesh strip. Correspondingly, the equivalent capacitance and inductance are modified, leading to a frequency shift.

It is interesting to observe that the thickness of the substrate t only change the second resonating frequency noticeably. This phenomenon can be explained by that changing the thickness will modify the coupling between each layer. The second resonating frequency is related to the coupling effect between each layer, while the first resonating frequency is determined by the size of unit cell, and the size of the patch. In this connection, the second resonating frequency is more affected.

Angular stability is crucial to a FSS. We conducted a simulation by changing the incident angle from 0 to 20 degree, which is shown in Fig. 4(d). It can be concluded that the structure in this paper exhibits a satisfactory angular stability. A rule of thumb to realize angular stability is to decrease the unit cell. In this case, the circumference of the patch is nearly a wavelength, resulting in that the unit cell length p is less than a quarter of wavelength, smaller than that of a slot array.

SUMMARY

This paper presents a systematic parametric study on the antenna-mesh-antenna structure for the application of wideband FSS. It is shown that such a structure gives one a bandwidth of more than 50%. The most sensitive parameters are the length of unit cell p, the gap between the patch g, and the thickness of the substrate t. Moreover, this structure presents good angular stability. Fabrication and measurement will be conducted in the future.

ACKNOWLEDGMENT

This work is supported in part by the Natural Science Foundation of Anhui province under the contract number of 1708085QF133, Quality Control Project of Anhui province under the contract number of 2016jxtd055.

REFERENCES

[1] R.J. Martin and D.H. Martin, “Quasi-optical antennas for radiometric remote-sensing,” Electronics & Communication Engineering Journal, vol. 8, pp. 37-48, 1996.

[2] Y.-H. Dong, “FY-4 meteorological satellite and its application prospect,” Areospace Shanghai, Vo.32, No. 2, pp.1-8, 2016

[3] P. A.R. Ade, G. Pisano, C. Tucker, et al, “A Review of Metal Mesh Filters,” Proc. of SPIE, Vol. 6275, pp.6275U-1, 2006.

[4] R. Pous and D. M. Pozar, “A frequency-selective surface using aperture couples microstrip patches,” IEEE Trans. Antennas Propagat., vol. 39, pp. 1763–1769, Dec. 1991.

[5] Ben A. Munk, Frequency Selective Surfaces: Theory and Design. Wiley-Interscience, 2000.