A Composite Electromagnetic Absorber for Anechoic Chambers

Weijia Duan(1), Han Chen(1), Mingming Sun(1), Yi Ding(1), Xiaohan Sun(1)*, Chun Cai(2) and Xueming Sun(2)
(1) National Research Center for Optical Sensing/Communications Integrated Networking, Southeast University, Sipailou 2, Nanjing 210096, China
(2) Shenzhen Academy of Metrology & Quality Inspection, The Quality Inspection Building, Middle of Longzu Avenue, Shenzhen 518055, China
*Corresponding Author: xhsun@seu.edu.cn

***Abstract*- A composite electromagnetic absorber for anechoic chambers is proposed with the structure consisting of a pyramidal foam and a lossy frequency selective surface (FSS) structure. Simulation results show that the period of absorber array and the pyramid base impact directly on absorption nulls, and the effects of pattern size, surface impedance and substrate thickness of FSS are more complicated due to interactions between the pyramidal foam and FSS structure. Two examples are discussed and the results show that improved absorption below 3GHz can be achieved by properly selecting parameters.**

I. INTRODUCTION

Pyramidal foams are the most popular radar absorbing material used in electromagnetic anechoic chambers. They are not only cost-effective and lightweight, but also capable of providing good broadband microwave absorbing performance at wide incident angles[1]. Since the foams absorb wave energy by multiple reflections between the slopes of adjacent pyramids, the pyramids should be relatively large compared to wavelengths[2]. Their performance on long wavelengths will degrade if the thickness of pyramids is limited. The lossy frequency selective surface (FSS), on the other hand, has been used in designs of thin absorbers due to its ease of manufacturing and compact size of resonance cell[3]. Typically it is formed by periodic arrays of resistive elements patterned on a dielectric sheet. Although in theory its bandwidth position can be set at any frequency range, most researchers focus their work on bandwidth and absorption improvement at X band and Ku band for the applications in the field of radar[4, 5]. So far few reports have been found for absorption below 3GHz or applications in anechoic chambers.

In this paper, a thin composite foam-FSS absorber structure is proposed. The effects of absorber parameters including periods, thickness of base and substrate, pattern shape and size, are simulated and the results are discussed. It is shown that by carefully choosing parameters, the composite absorber can achieve better absorption performance than an ordinary foam or FSS absorber alone. Two examples of configurations with improved absorption at different frequency ranges below 3GHz are also presented. The design is suitable for anechoic chamber or environment of narrow band measurement.

II. STRUCTURE AND PARAMETERS

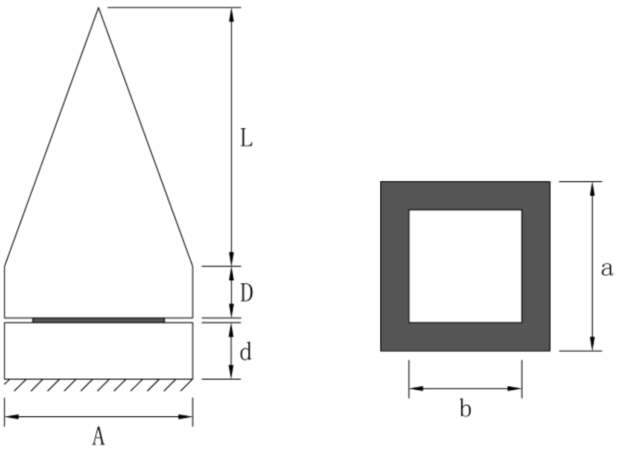
The composite absorber comprises two parts, as is illustrated in Fig. 1(a). The top part is a straight square pyramidal absorber with a taper height of *L* and a base thickness of *D*. The bottom part is an FSS structure composed of a resistive sheet with the shape of a square ring on a grounded square substrate of the thickness *d*. The square ring has an outer side length of *a* and inner side length of *b*, as is shown in Fig. 1(b). The surface impedance of the square ring is *Sr*. The square substrate has a side length of *A* as same as the side length of the pyramidal base.

III. SIMULATIONS AND DISCUSSIONS

To study the effects of absorber parameters on its reflectivity performance, simulations using finite element method are performed. We choose to set the taper length to a fixed value *L*=100mm. A commercial absorber material from Eccosorb is selected for both the pyramidal foam and the FSS substrate. Its relative permittivity and permeability around 3GHz is $\varepsilon_r = 6 - i$ and $\mu_r = 1.7 + 1.2i$ respectively.

In this section, the effects of parameters on the absorber's performance below 5GHz will be simulated and discussed. Results are shown from Fig. 2 to Fig. 7. Two examples of configuration are illustrated in Fig. 8 and Fig. 9.

Fig. 2 indicates the significant effects caused by side length



(a) (b)

Fig.1 Schematic diagram of the proposed absorber. (a) is the side view of the absorber. (b) is the top view of the FSS pattern.

This work is supported by the Special Fund for Quality Supervision, Inspection and Quarantine Research in the Public Interest (No.201110044).

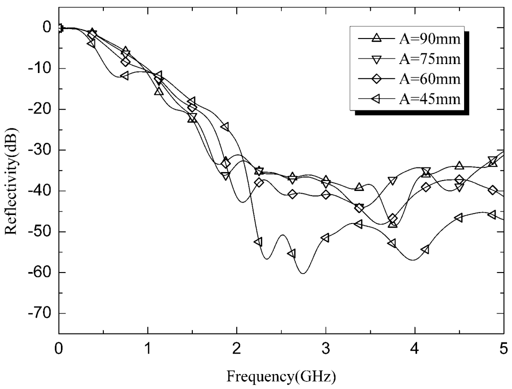


Fig. 2. Effects of period on reflectivity.

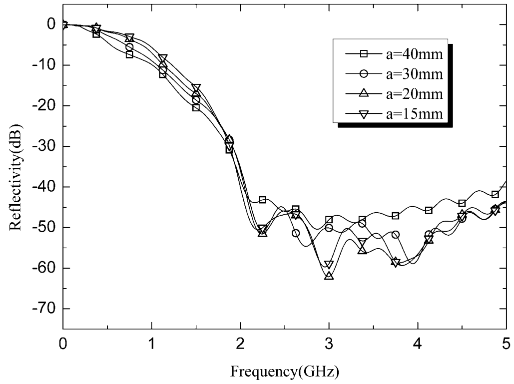


Fig. 4. Effects of side length of outer ring on reflectivity.

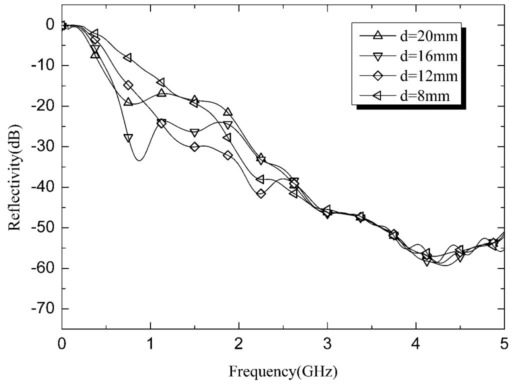


Fig. 6. Effects of substrate thickness on reflectivity.

A. For the pyramidal part, as the side length increases, the taper angle also increases. This will slightly degrade the performance because incident waves reflect less times between adjacent taper slopes, resulting in less absorption. Moreover, the side length *A* is also the period of the lattice and it affects the bandgap of periodic structures[6]. It can be seen from Fig. 5 that an apparent gap appears between 2GHz and 3GHz when the period *A* is set to 45mm.

Fig. 3 shows the effects of thickness of pyramid base. While a thicker base can improve absorption due to longer lossy path the waves travel, it also shifts the position of absorbing null towards longer wavelength. That is probably because the null is formed by cancelling of transmitted and reflected waves between surfaces[7].

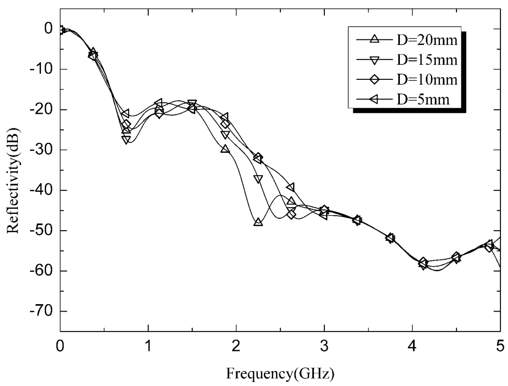


Fig. 3. Effects of base thickness on reflectivity.

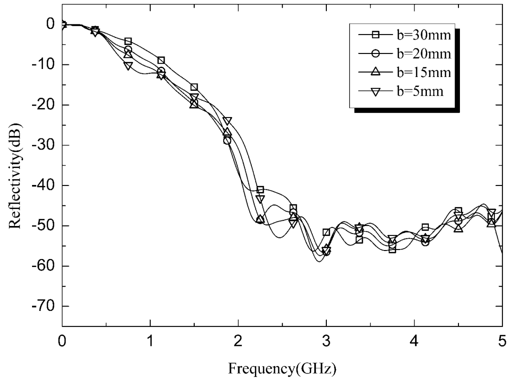


Fig. 5. Effects of side length of inner ring on reflectivity.

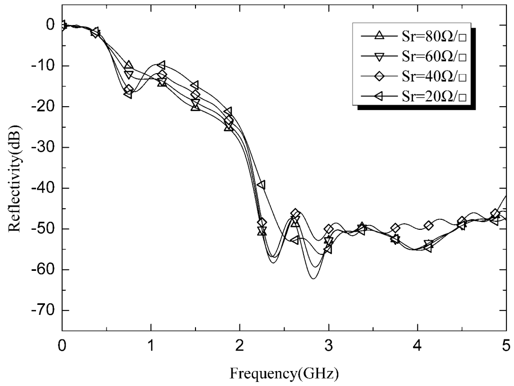


Fig. 7. Effects of surface impedance of FSS on reflectivity.

Fig. 4 and Fig. 5 show the influence of square ring on reflectivity. It appears that a larger ring leads to slightly less reflection. This might be explained as that large area of resistive patch could cause more wave loss under some circumstances. However, it is quite difficult to find more significant changes, because the size and shape of the square ring affects the FSS structure in many respects, such as the capacitance between adjacent rings, the inductance of the ring, the surface impedance of the FSS[5]. In fact, the design and analysis of FSS structure alone is very complicated. With the pyramidal foam combined to it, the whole absorber is added with more complication. In Fig. 6 we can see how the thickness of substrate affects the null. It should be noted that the shift of null position is not as regular as in Fig. 3. This might be explained as the result of multi-layer interactions

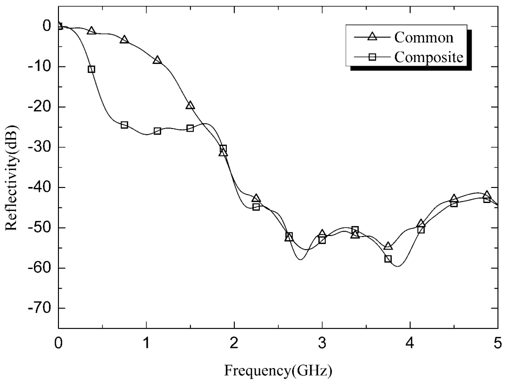


Fig. 8. Comparison between a common pyramidal foam and a composite absorber. (*L*=100mm, *A*=46mm, *a*=38mm, *b*=23mm, *D*=5mm, *d*=19mm, *Sr*=60Ω/□)

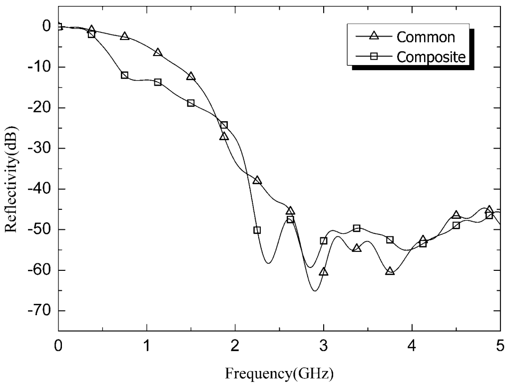


Fig. 9. Comparison between a common pyramidal foam and a composite absorber. (*L*=100mm, *A*=44mm, *a*=34mm, *b*=8mm, *D*=1mm, *d*=9mm, *Sr*=60Ω/□)

between the substrate and the pyramid. Also in Fig. 7, the surface impedance has a different effect with what has been reported in [8]. It is not obvious from the figure that maximum bandwidth is achieved when surface impedance is around 50 Ω/□.

Although the design and analysis of the proposed composite absorber is quite complicated, it provides possibilities to absorbers with improve performance. Here are two examples. In Fig. 8 we present a design with 25dB reflectivity from 500MHz to 1.5GHz. As a comparison, a common pyramidal absorber of the same material and total height is also presented. In the design of Fig. 9 we manage to introduce a null around 2.4GHz while keeping an average reflectivity at other frequencies.

IV. CONCLUSION

In this paper a composite electromagnetic absorber is proposed and analyzed. The absorber comprises a pyramidal foam and a lossy FSS structure. Simulation results show that while the period of absorber array and the base of the pyramidal foam have direct effects on absorption nulls, the influence of surface impedance and substrate thickness could be far more complicated due to interactions between the pyramidal foam and FSS structure. It can achieve improved absorption performance at low frequencies by proper selection of absorber parameters. Two examples of configurations are also presented, showing different absorption improvement below 3GHz compared with common foam of the same height. The proposed composite absorber might find applications in compact anechoic rooms or narrow band measurement. Further work can be focused on simplification of design procedure and manufacturing process.

REFERENCES

[1] L. H. Hemming, *Electromagnetic Anechoic Chambers: A Fundamental Design and Specification Guide*: Wiley-IEEE Press, 2002.

[2] Y. B. Feng, T. Qiu, C. Y. Shen, and X. Y. Li, "Electromagnetic and Absorption Properties of Carbonyl Iron/Rubber Radar Absorbing Materials," *IEEE Transactions on Magnetics,* vol. 42, pp. 363-368, Mar 2006.

[3] D. J. Kern and D. H. Werner, "A Genetic Algorithm Approach to The Design of Ultra-Thin Electromagnetic Bandgap Absorbers," *Microwave and Optical Technology Letters,* vol. 38, pp. 61-64, Jul 2003.

[4] H.-T. Liu, H.-F. Cheng, Z.-Y. Chu, and D.-Y. Zhang, "Absorbing Properties of Frequency Selective Surface Absorbers with Cross-Shaped Resistive Patches," *Materials & Design,* vol. 28, pp. 2166-2171, 2007.

[5] F. Costa, S. Genovesi, and A. Monorchio, "On The Bandwidth of High-Impedance Frequency Selective Surfaces," *IEEE Antennas and Wireless Propagation Letters,* vol. 8, pp. 1341-1344, 2009.

[6] S. R. A. Dods, "Bragg Reflection Waveguide," *J. Opt. Soc. Am. A,* vol. 6, pp. 1465-1476, Sept 1989.

[7] E. F. Kuester and C. L. Holloway, "A Low-Frequency Model For Wedge or Pyramid Absorber Array. 1. Theory," *IEEE Transactions on Electromagnetic Compatibility,* vol. 36, pp. 300-306, Nov 1994.

[8] F. Costa, A. Monorchio, and G. Manara, "Analysis and Design of Ultra Thin Electromagnetic Absorbers Comprising Resistively Loaded High Impedance Surfaces," *IEEE Transactions on Antennas and Propagation,* vol. 58, pp. 1551-1558, May 2010.