Design of a Resonant Microwave Absorber

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1. Introduction

The microwave absorbers are extensively applied in many military and civilian applications for stealth, camouflage, radar cross section (RCS) reduction, and improvement purpose of the in-room EM wave environment in anechoic chambers and indoor wireless LAN area. Although the absorbers can be categorized to many types, it is well known that more useful device in those areas is the resonant type microwave absorber such as Salisbury screen [1]. Salisbury screen, which represents one of the simplest planar types of resonant absorbers, consists of a resistive screen located a quarter-wavelength above a conducting surface, separated by a dielectric spacer. Hence, it is thick. Several practical structures for enhancing the main disadvantage of Salisbury screen have been proposed [2]-[3]. The method is to utilize periodic structures such as Frequency Selective Surface (FSS) [4] or EBG (Electromagnetic Bandgap) [5]-[6]. In this paper, we propose new designs of broadband resonant microwave absorber using a periodic structure. The simulated and measured results for the absorber structure are presented to verify the function as a broadband absorber, and based on the examination, more improved absorber structure is also proposed below.

2. Design of the absorber

The overall structure of the proposed microwave absorber is shown in Figure 1. The structure is made up of a conducting plane, a dielectric spacer, and a thin resistive surface consisting of unit cells arranged periodically to form EBG surface. The resistive surface is spaced in front of a conducting plane by a dielectric spacer with a thickness of *d*, and this periodic structure can be analyzed as EBG one. From the recursion relation for the reflection coefficient of a single Salisbury screen [1], the reflectivity null condition is as follows.

$$h = (2n+1)\lambda_0 / 4, \qquad n = 0,1,2... . \tag{1}$$

Considering the characteristic of the conventional EBG structure, this equation means the maximum absorption of the proposed absorber can be occurred at the frequency in which the reflection phase of the pure EBG structure is zero.

The unit cell structure on a resistive sheet of the proposed absorber is shown in Figure 2. The design of this unit cell structure has been started from the basic square patch as an initiator, which is one of well-known patterns in periodic structure fields such as FSS, and the unit cell

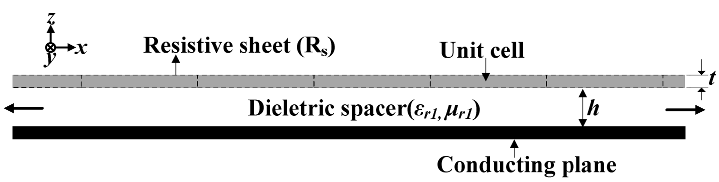

Figure 1: Cross section of the proposed absorber structure

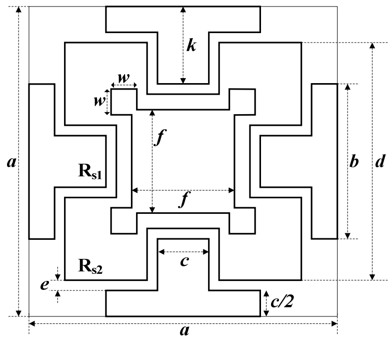

Figure 2: Unit cell geometry of a resonant microwave absorber

pattern consists of a center loop patch and four half cross dipole patches.

Through the reflectivity analysis as a function of frequency for various values of sheet resistance (R_s) on a modified square patch, the resistance value enabling the absorber to show a good absorption characteristic has been chosen. And by adding half cross dipoles around the center patch and by inserting slots to one, the unit cell geometry of Figure 2 has been obtained. The final parameter values of the structure have been optimized as shown in Table 1 through the parametric study for obtaining good absorption characteristic.

Table 1: Absorber parameters (unit: mm)

Parameter	Length	Parameter	Length	Parameter	Length
a	30	*e*	1	*t*	0.015
b	15	*f*	10	*w*	2.5
c	5	*h*	4.7		
d	23	*k*	7.5		

3. Computed and Experimental Results

The simulated result and measured one of the fabricated absorber under the condition of normal wave incidence when $\varepsilon_{r1}=\mu_{r1}=1$ and overall sheet resistance is 40 Ohm/sq are shown in Figure 3. All the computed results in this paper were numerically obtained from a finite element method (FEM-HFSS software), and the absorption bandwidth denotes the frequency bandwidth of reflectivity below -10 dB, which means high power absorption rate of 90%. The absorber sample for the measurement is fabricated by attaching the resistive sheet with a sheet resistance of 40 Ohm/sq on a Styrofoam spacer which back-plane is a metal, and overall dimension is 40 cm by 40 cm. Figure 3 indicates that the maximum absorption occurs at 7 GHz, the broadband characteristic of 76% fractional bandwidth (about 5.8~12.18 GHz) below -10 dB is obtained, and the simulated result and the measured one are in good agreement on the whole. Figure 4 shows the reflectivity

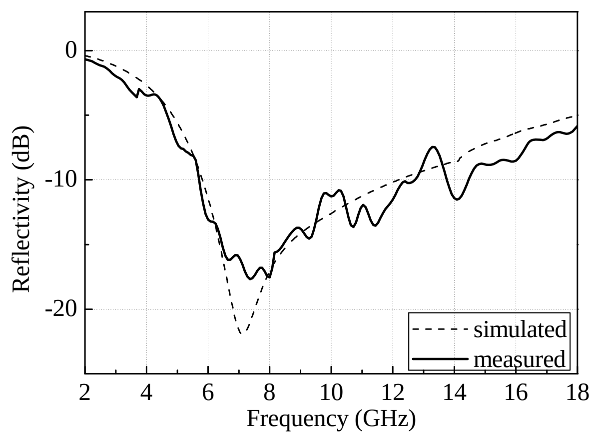

Figure 3: Reflectivity response of a resonant microwave absorber with
$\varepsilon_{r1}=\mu_{r1}=1$, $R_{s1}=R_{s2}=40$ Ohm/sq for normal plane wave incidence

characteristics as a function of frequency for the absorber including sheet resistances different each other. From the parametric analysis about sheet resistance, the optimized values have been selected, and it is seen that the absorption bandwidth can broaden due to different sheet resistances compared to results of Figure 3. For the design of a resonant absorber with lower maximum absorption frequency, unit cell pattern of Figure 2 and design parameters shown in Table 1 have been modified. Especially, the center slot making the center patch become the loop patch has been eliminated and overall sheet resistance also has been changed because size of the patch and sheet resistance have relatively significant influence on maximum absorption frequency shift. The calculated result for the modified absorber with lower maximum absorption frequency is presented in Figure 5. The result shows the absorption bandwidth from 1.4 GHz to 3.2 GHz, which is about 78% fractional bandwidth.

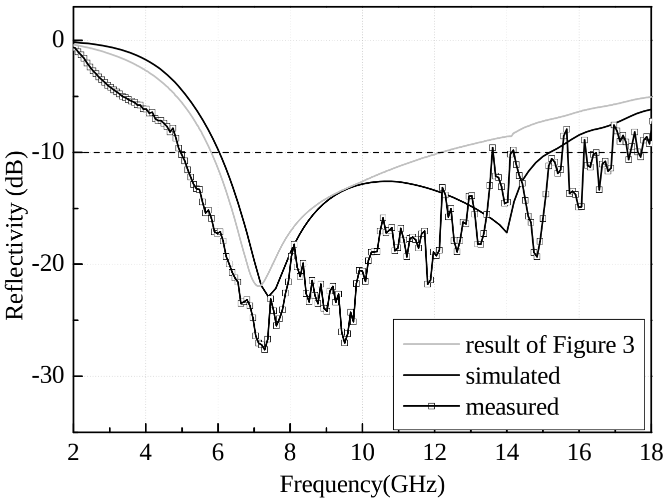

Figure 4: Reflectivity results of the absorber with $R_{s1}=40$ Ohm/sq and $R_{s2}=40$ Ohm/sq

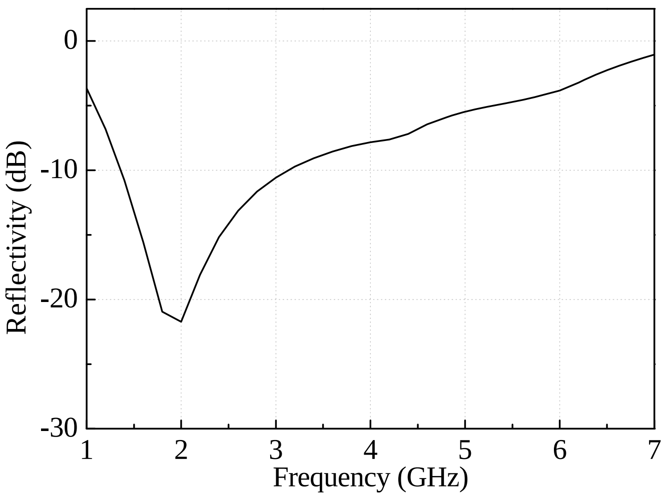

Figure 5: The calculated reflectivity of the modified absorber with
a= 70, b=35, c=11.7, d=53.7, e=2.3, h=20, k=17.5, and $R_s=80$ Ohm/sq

4. Conclusions

The resonant type microwave absorber using a periodic structure has been presented. Novel two absorber structures have been proposed, and the measured and simulated results of those have been presented, which show a good agreement with each other in terms of position of the absorption null points and whole tendency. The absorption characteristic of the absorber can be easily expected and controlled by regulating the physical parameters of the periodic surface. Future research will be directed towards developing more practical prototype which can be more easily applied to real situation.

Acknowledgments

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References

[1] Ronald L. Fante and T. Mccormack, "Reflection Properties of the Salisbury Screen", IEEE Trans. Antennas Propagat., vol. 36, no.10, pp. 1443-1454, October, 1988.

[2] A. Tennant and B Chambers, "A Single-Layer Tuneable Microwave Absorber Using an Active FSS", *IEEE Microwave and Wireless componets Letters*, vol. 14, no.1, pp. 46-47, January, 2004.

[3] Ghaffer I. Kiani, Kenneth L. Ford, Karu P. Esselle, Andrew R. Weily, and Chinthana J. Panagamuwa, "Obique Incidence Performance of a Novel Frequency Selective Surface Absorber", *IEEE Trans. Antennas Propagat.*, vol. 55, no. 10, October 2007.

[4] B. A. Munk, *Frequency selective Surfaces: Theory and Design*, John Wiley & Sons, 1999.

[5] D. Sievenpiper, L. Zhang, R. F. J. Broas, N. G. Alexopolus, and E. Yablomovitch, "High-impedance elecromagnetic surfaces with a forbidden frequency band", *IEEE Trans. Microeave Theory Tech.*. vol. 47, pp. 2059-2074, Nov. 1999.

[6] Jong-Hwa Kwon, Sang-Il Kwak, and Dong-Uk Sim, "Partial EBG structure with decap for ultra-wideband suppression of simultaneous switching noise in a high-speed system," ETRI Journal, vol. 32, no. 2, pp. 265-272, Apr. 2010.