A Practical Microwave Absorber Design based on Salisbury Screens

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***Abstract*—This paper presented a practical electromagnetic absorber design with periodic cells based on the well-known Salisbury screens. The unit cell has a size of 20cm x 20cm (7λ at the resonance frequency, 11 GHz) and a thickness of 20μm conductive ink. The return loss at the resonance frequency is up to 34 dB, which has a 3.5 GHz in bandwidth at the threshold of 10 dB. The frequency bandwidth is achieved by using the conductive ink with high dielectric constant to result in the resonance frequency shifted from high to lower frequency while in the meantime retaining the low profile. The sensitivity to the angle of incidence can be greatly reduced. Numerical and experimental results will be presented.**

1. Introduction

The Salisbury screen is a passive microwave absorber which is constructed by placing a single thin resistive sheet at a distance $\lambda/4$ beyond a perfect electrically conducting (PEC) ground plane [1]. At resonance, the impedance of the conducting plate is transformed to an open circuit at the resistive sheet which is normally 377 Ω/square to match with the wave incident from free space, and thus totally absorb the reflected fields by the load sheet [2, 3]. This condition is satisfied at one frequency when the summation of the path length phase and the phase of the signal reflected from the ground plane is 360^0 [4]. The net field at the interface of the Salisbury screen will be cancelled, which is caused by the 180° of phase difference between these two field components.

As illustrated in Fig.1, the structure consists of three layers including an infinitely thin and flat resistive sheet, a lossless material and a PEC. In comparison to the conventional design of this absorber, which has a relatively narrow operational bandwidth because the performance of the resistive sheet is dependent on the operational frequency, this paper presents a method to fabricate the Salisbury screen. The high dielectric constant of conductive ink is used to result in the resonance frequency shifted from high to low frequency and reduce profile. As a result, the sensitivity to the angle of incidence can be greatly reduced at a slight reduction of bandwidth. The method is evaluated by using the commercial EM software to investigate the resistive sheet's characteristics.

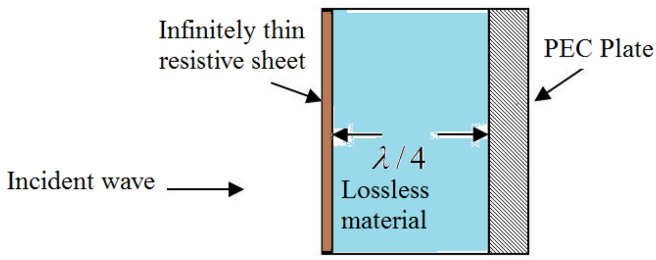

Fig.1: The schematic diagram of the Salisbury screen's structure for the design of absorber.

2. The Manufacture of Samples and Measurement

The unit-cell architecture of the absorber is formed based on the Salisbury screen theory as illustrated in Fig. 2. The conductive ink is coated on the surface of a plastic film (PET). The lossless material is made of PU foam while the conducting plate is made of carbon fiber in Fig. 2. In particular, the conductive ink was made by the mixture of graphene and its dielectric constant up to 350. The coating on the PET surface was made by blade coater. By putting the conductive ink into the scraper and the thickness of the ink can be controlled by the scraper. Afterward, a four-point probe is used to measure sheet resistance of the conductive ink on the PET. After repeatedly adjusting the mixing ratio of materials in the conductive ink, we can obtain the sheet resistance with a good absorption result.

The absorber is formed by the periodic arrangement of the unit cells. It is prototyped by stacking the multi-layer structures including a 2mm carbon fiber sheet, a 1.8mm PU foam and the resistive sheet in a sequential order as shown in Fig.2. Here the resistive sheet is implemented on the PET with a 0.1mm thickness and a 20 cm length by coating the conductive ink with a 0.02mm thickness. The inter-cell spacing is retained small. It is noted that the periodic design provides the advantage of easy implementation in the practical applications.

Numerical simulations are first conducted to design the structures at a proper resonant frequency. After the implementation of prototype, a measurement setup is established to investigate the performance, which may be used to compare with the simulation results. The setup is illustrated in Fig. 3, which is implemented in an arch chamber. The

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absorber is in the far-zone region of the feed antenna and receiving antennas to measure the reflection coefficients for the absorbing rate justification. In the examination, the illumination EM field is incident at 5°~45^{o} away from the normal direction with horizontal polarization and vertical polarization, respectively.

Both the simulated and measured results are shown in Figure 4(a) and (b), respectively. It is observed that at the angles near the normal incidence, the reflection coefficients have high degrees of consistence. At wide angles, the resonant frequency will be shifted to higher frequencies. It is shown in Fig.4 that an absorbing resonance frequency at 11GHz is achieved with a return loss by 35dB, where a bandwidth of 10 dB by 3.5GHz has been achieved. Also the simulation results are consistent to the measured data for most curves except that at wide angles of incidence, the simulation may cause higher deviation of resonant frequencies.

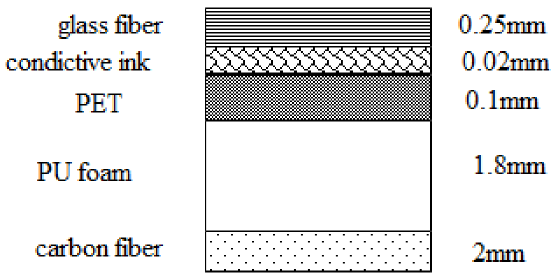


Fig.2. Schematic diagram of Salisbury screen sample.

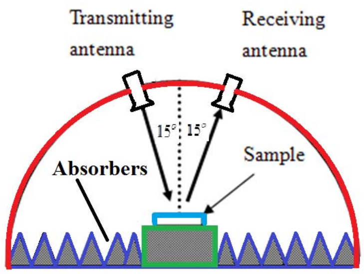
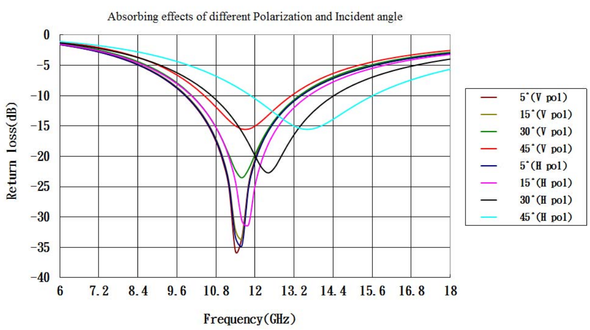
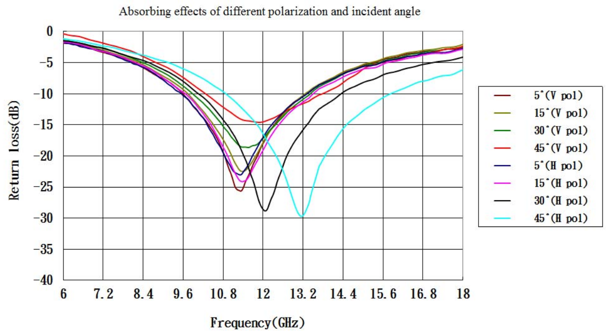


Fig.3. Schematic diagram of Arch chamber



(a)simulation data



(b)measurement data

Fig.4. Simulation and Measurement result of periodic-arranging Salisbury screen.

3. Conclusions and Discussion

The results obtained by using the commercial EM code, HFSS, have demonstrated that the resonant frequency of this absorber design is related to the dielectric constant and lossless materials of PU foam thickness, which are 350 and 1.8 mm, respectively. In this design, the predicted resonant frequency is at 11GHz, and is consistent to the measured result. However, the finite thickness of the actual resistive sheet has caused slight deviation of resonant frequencies, whose phenomena are consistent to the investigation in [6]. Thus if one considers the actual thickness by 20μm, the dielectric constant is 350 from the simulation result in Fig. 4. In this case, it shows that the resonance frequency is roughly 11GHz, and the bandwidth of 10dB is 3.5GHz. We will make it through the high dielectric constant of conductive ink result in the resonance frequency from high to low frequency shift and reduced profile, the sensitivity of the angle of incidence can be greatly reduced, but the return loss of 10dB absorbing bandwidth will be significantly reduced. A tradeoff between the performance and dielectric constant should be made.

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