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Structural Optimization and Electrical Characterization of Microwave Absorbers

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***Abstract*— EM wave absorbing composites effective at microwave frequencies having crucial properties for their structural applicability will be designed and developed making use of a novel approach. The ability to understand and control the propagation of electromagnetic radiation underpins a vast array of modern technologies, including: communication, navigation and information technology. Therefore, there has been much work to understand the interaction between electromagnetic waves and metal surfaces, and in particular to design materials the characteristics of which can be tailored to produce a desired response to microwave radiation. The objective of this research work is to demonstrate that patterning metal surfaces with sub-wavelength apertures can afford hitherto unrealised control over the reflection and transmission characteristics of materials which are an order of magnitude thinner than those employed historically.**

***Index Terms*—Microwave absorber, structure, simulation, frequency domain.**

I. INTRODUCTION

The last two decades have witnessed a huge growth in the development of the electronic and electrical equipments which has given rise to a new problem of Electromagnetic Interference (EMI). Microwave Absorbers have been viewed as the most adequate solution to deal with the problem of EMI as they provide shielding and absorbing of the electromagnetic field. If the material used for microwave absorbers is of high conductivity and high dielectric constant, it can provide high EMI shielding efficiency [1-3]. In recent years there has been a growing interest in the area of conducting polymer as a suitable replacement for the conventional microwave absorbers which used carbon products, carbonyl iron and ferrites. Conducting polymers emerged as a new class of materials and offered a lot more applications than old materials [4-5]. Conducting polymers along with various materials have been reported for low infrared emissivity and high microwave absorption conductivity. Conducting polymers type microwave absorbers found applications in many fields one being military where it made targets less visible and even ideally invisible. This was done by using detection equipments and the technology was known as stealth technology [5-8]. Absorbers are also used for eliminating reflected signals. Absorbers can be used commonly in two categories in the electromagnetic range i.e. microwave range (1 GHz - 300 GHz) and lower frequency range (30 MHz – 1000 MHz). Absorber shape is the main parameter on which the performance of the microwave absorber depends. There are various shapes available for the absorber like layer type absorber, pyramid, wedge, walkway, convoluted and oblique absorber. Every absorber shape can be used for a particular range of frequencies like pyramidal shape absorbers are used for 1 GHz-40 GHz. For the best efficiency of the absorber the material chosen should be such that its dielectric constant and tangent loss doesn't affect the performance of the absorber. As this parameter can give a larger impact to the reflection loss parameter. Dielectric loss refers to the relative permittivity and tangent loss refers to the dissipation of power or energy from incident waves [9-10].

Microwave frequency corresponds to frequency range between 300 MHz and 300 GHz [8]. These frequencies are equal to wavelengths between 1 mm and 1 m. Nowadays, electronic devices operates with using microwave frequency, generally. Because of atmospheric opacity which is mentioned previously and required precision, microwave frequency is the best option for electronic devices to operate. In today's world, communication devices, satellites, aerospace applications, radars, wireless devices, mobile phones, military applications, medical applications etc. are being operated in microwave frequency [11-12]. All of these devices work in different frequency bands of microwave frequency. As number of electronic devices increase, interference of EM waves is inevitable. Absorbers having low reflectivity are preferable to trap most of the incident electromagnetic waves [13-15]. Thus, almost perfect free space conditions are obtained in a chamber. Various factors such as the electrical properties of the absorber material have an essential role in absorption performance of microwave absorbers [16-17]. The relative permittivity (dielectric constant) of the material used in an absorber is one of the most important factors [18]. It is a measure of the electrostatic energy stored in the material and affects the propagation speed of electromagnetic wave in the material. The shape of the absorber used in the chamber also has significant importance on absorption performance in addition to other factors. Interference of EM waves causes misinterpretations, miscommunications, wrong weather forecasts, wrong monitoring. There are many types of absorber having different shapes, such as pyramidal, wedge, convoluted, among many others. The wedgeshaped absorber is one of the most well-known type which is also commonly used for EMC/EMI measurements. Its wedge shape provides a suitable impedance match from free space to the base of the absorber. [19-20].

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In this research work microwave absorber structure is designed and simulated in frequency domain to analyze the frequency absorption spectra.

II. Simulation Process Flow

Microwave absorbers with radiation-absorbent material (RAM) are commonly used in anechoic chambers for electromagnetic wave measurements. Microwave absorption is modeled using a lossy material to imitate the electromagnetic properties of conductive carbon material. The infinite 2D array of rough structures is to be modeled using one unit cell with Floquet-periodic boundary conditions on four sides. The geometry of one unit cell consists of one inverted V-shape sitting on a block made of the same material. There are perfectly matched layers (PMLs) above the pyramid and the remaining space between the pyramid and the PMLs is filled with air. Figure 1 show the schematics of the methodology employed for simulation process. First step of the process is to designing the whole geometry in 3D domain. In the next step various structures are proposed for microwave absorbers.

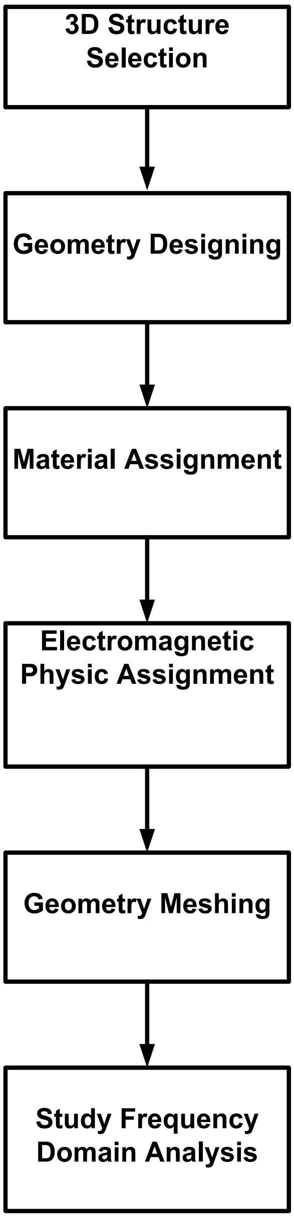

Fig. 1. Simulation process flow.

III. Results and Discussion

Simulation of microwave absorber in FEM (finite element method) based is carried out in following steps: creating single absorber geometry, then duplicating it to form 3x3 array of microwave absorbers, assigning material to the geometry, validating the simulation, and analyzing the structure in frequency domain.

Single pyramidal structure is designed in COMSOL in order to create an array of structure. Steps of geometry created for single pyramid is given below:
Creating a square base of dimensions 10.16 mm x 10.16 mm. Select the draw tab of the workspace of tool and click on the box button, click on the workspace and drag the cursor in x-axis, y-axis, and z-axis. After releasing the button a box will appear. Open the property setting and sign the exact dimensions to the box as per requirement.

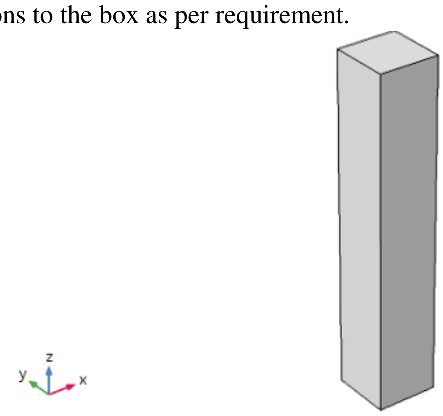

Fig. 2. Formation of square box.

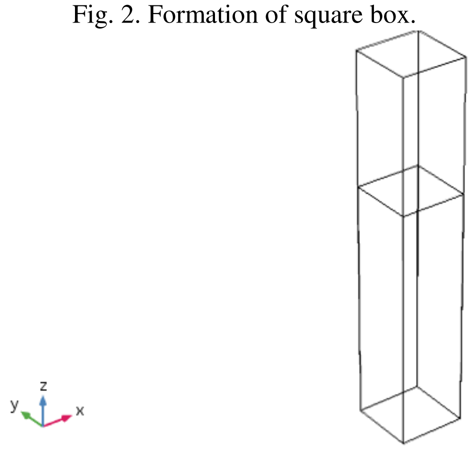

Fig. 3. Excitation port location of the structure.

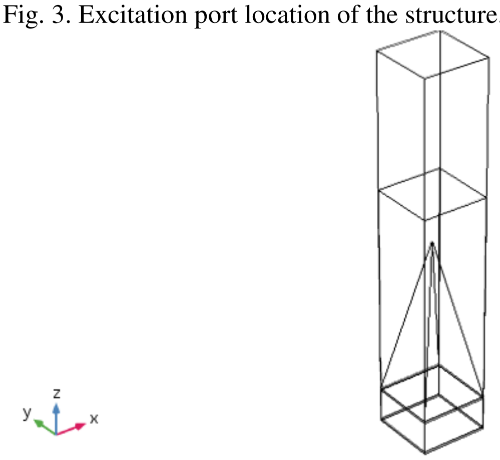

Fig. 4. Construction of the structure.

Creating the absorber structure: In order to create the structure another box is created with its base starting from 22.86 mm above the z-axis. The using the polyline geometry drawing option all the faces of the pyramid are created and the upper box was deleted as shown in Fig.4. The complete geometry of the microwave absorber constructed using blocks and pyramid is shown in Fig. 5.

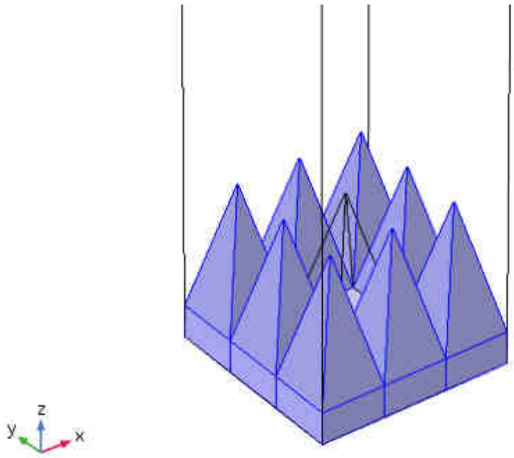

Fig. 5 Complete designed geometry.

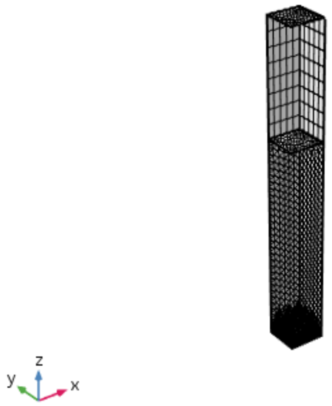

Fig. 6 Tetrahedral meshing of structure.

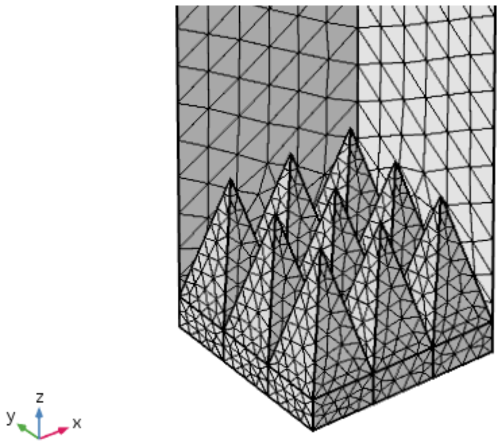

Fig. 7 Extended view of meshed geometry.

Mesh operations that were defined are used to refine the mesh of the geometry. If ports were defined, it iteratively refines the 2D mesh at the ports. Using the resulting mesh, tool computes the electromagnetic fields that exist inside the structure when it is excited at the solution frequency. If performing an adaptive analysis, it uses the current finite element solution to estimate the regions of the problem domain where the exact solution has strong error. Tetrahedra in these regions are refined. It generates another solution using the refined mesh. The iterative process (solve error analysis adaptive refinement) repeats until the convergence criteria are satisfied or the maximum number of adaptive passes is completed. The mesh structure and extended zoom mesh structure are shown in Fig. 6 and Fig.7.

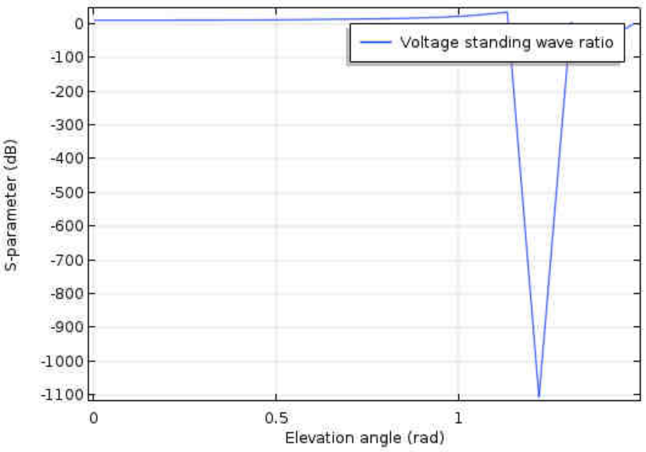

Fig. 8 VSWR plotted for the 5GHz frequency spectra.

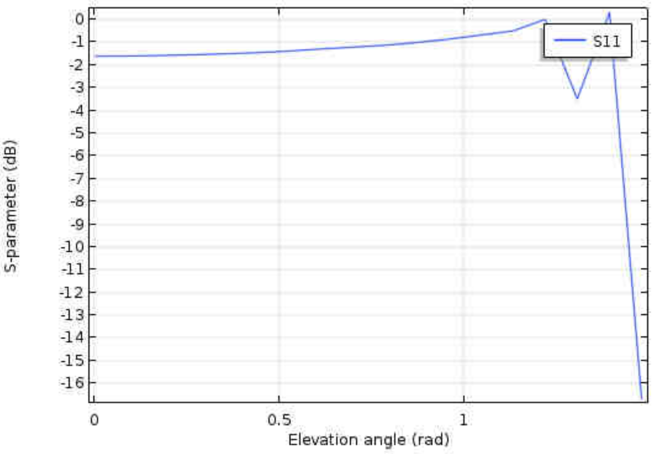

Fig. 9 S-parameter vs elevation angle plot for the 5GHz frequency spectra.

The designed pyramidal microwave absorber is simulated and frequency sweep was carried out from 0-5 GHz for geometry of dimensions in millimeters and also the same geometry was analyzed for dimensions in centimeters. Figure 8 and Figure 9 shows voltage standing wave ration (VSWR) and reflection losses (S11) for geometry in frequency domain.

IV. CONCLUSION

In this research work a microwave absorber is constructed from an infinite 2D array. Perfectly matched layers (PMLs) above the air at the top of the geometry cell absorb higher-order electromagnet wave modes generated by the periodic array, if there are any upward traveling excited mode from the source port. The VSWR and S-parameter for y-axis polarized incident waves is plotted and it shows quantitatively that the designed microwave absorber performs well for a range of incident elevation angles less than 40 degrees for 5GHz range of frequency spectrum.

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