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Metamaterial Absorber Based Multifunctional Sensor Application

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Abstract. In this study metamaterial based (MA) absorber sensor, integrated with an X-band waveguide, is numerically and experimentally suggested for important application including pressure, density sensing and marble type detecting applications based on rectangular split ring resonator, sensor layer and absorber layer that measures of changing in the dielectric constant and/or the thickness of a sensor layer. Changing of physical, chemical or biological parameters in the sensor layer can be detected by measuring the resonant frequency shifting of metamaterial absorber based sensor. Suggested MA based absorber sensor can be used for medical, biological, agricultural and chemical detecting applications in microwave frequency band. We compare the simulation and experimentally obtained results from the fabricated sample which are good agreement. Simulation results show that the proposed structure can detect the changing of the refractive indexes of different materials via special resonance frequencies, thus it could be said that the MA-based sensors have high sensitivity. Additionally due to the simple and tiny structures it could be adapted to other electronic devices in different sizes.

Keywords: Metamaterial, Absorber sensor, X-band, Finite integration technique.

1. Introduction

Metamaterial absorbers are more susceptible and easily obtainable materials for applications [1-2]. These artificially structures capable of manipulating electromagnetic waves in a desired frequencies represent a promising approach to meet this need in wide range of application areas [3-7].

In this paper, we proposed to evaluate numerically and experimentally density, pressure and marble type sensing capable of the metamaterial absorber (MA). The most important feature of designed MA structure is the resonant frequency that changes due to environmental influences. The resonant frequency shift happens depending on the some physical parameters such as density, pressure and dielectric constant. This resonant frequency shift allowing us to precise detection of parameter change. We have designed the proposed structure and chosen the substrates as well as the working frequency range. Other expectation of the designed sensor can be listed as low engineering cost, low loss factor, resolution, sensitivity and durability that we have taken into account for the proposed design.

2. Numerical Design & Fabrication Techniques

Firstly, as seen in fig. 1a we designed MA-based absorber sensor by FIT based 3D EM solver and simulated the MA-based absorber sensor. We used high frequency RT/duroid® 5870 laminates as a



substrate which has 0.76 mm thickness and dielectric constant of 2.33. The MA-based sensor design consist of three layers which has copper plated split ring resonator (SRR) with RT5870 substrate, sensor layer and copper plated RT5870 substrate respectively as seen in Fig. 1. In numerical analysis, open boundary conditions applied in z direction and PEC boundary conditions applied in x-y plane for using this design to different sensing applications. The proposed design can be used in different applications at millimeter wave region in technology such as density, humidity, temperature and pressure. In this study we conducted and discussed density and pressure sensor applications as numerically and experimentally.

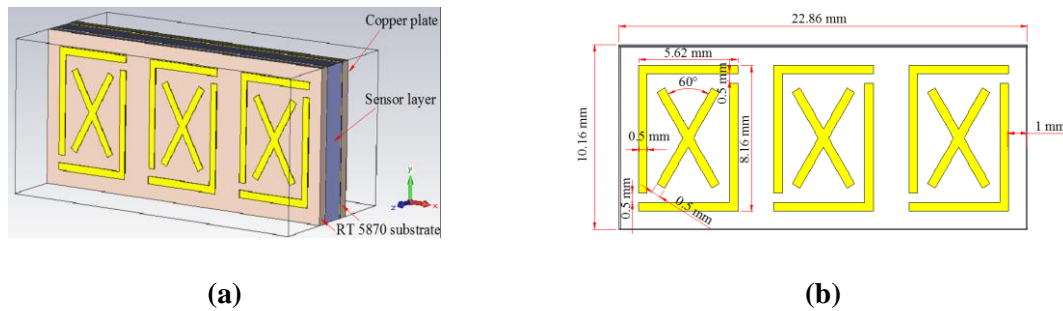


Figure 1. (a) The proposed MA based sensor design (b) sizes of the proposed MA based sensor design

Fig. 1 b shows the dimensions of suggested MA based sensor design. Resonator layer consist of three similar SRRs has cross patch inside. Dimensions of the unit cell are suitable for X-band waveguide; resonators have 1 mm space with the side wall and 0.5 mm patch width.

3. Metamaterial Absorber Based Sensor Applications

This section we provide details of density and pressure sensor application. In addition this design can be used in other sensor applications by the sensor layer is filled with different materials. According to sensing parameters, for example humidity or temperature, suitable material can be chosen when the environmental conditions affect the dielectric constant of the related material, this is going to change overall reflection constant which is required sensor applications.

3.1. MA Based Density Sensor

One of the distinguishing features of the materials which changes due to the used conditions are density and density sensing is one of the important applications in this study. For density sensing application, Arlon 300, Arlon 350 and Arlon 450 materials which have densities 2.07 g/cm^3 , 2.40 g/cm^3 and 2.45 g/cm^3 respectively are chosen in this part. Overall reflection coefficient of the unit cell changes by the inserted materials properties in the sensor layer.

Fig.2 shows numerically obtained absorptions values of the different materials calculated via $A(w) = 1 - S_{11}^2$. It's clear that resonance frequencies are linearly changed by inserted materials in sensor layer as 9.5, 9.42 and 9.3 GHz respectively. Fig.2. shows absorptions value is decreasing by the material density while there was a linear relation between the material density and resonance frequencies. The results show that the simulated values of the samples are good agreement of experimental obtained ones.

3.2. MA Based Pressure Sensor

Another sensor application is pressure sensor that we investigate the MA based sensor parameters for pressure sensor application. We assumed that the sensor layer filled with air and thickness of the sensor layer varies with the different pressure values. It's clear from the Fig. 3. the sensors resonant frequency shifts when the different pressure values acting on the sensor by changing layer thickness where changing the capacitance of structure.

Furthermore, marble type sensor application is realized and discussed. This kind of application could be popular in future especially in agricultural product sensor area. This study can be the basis for

the development of multi-functional devices by adding extra feature. This structure can be developed for different potential applications such as portable detector devices.

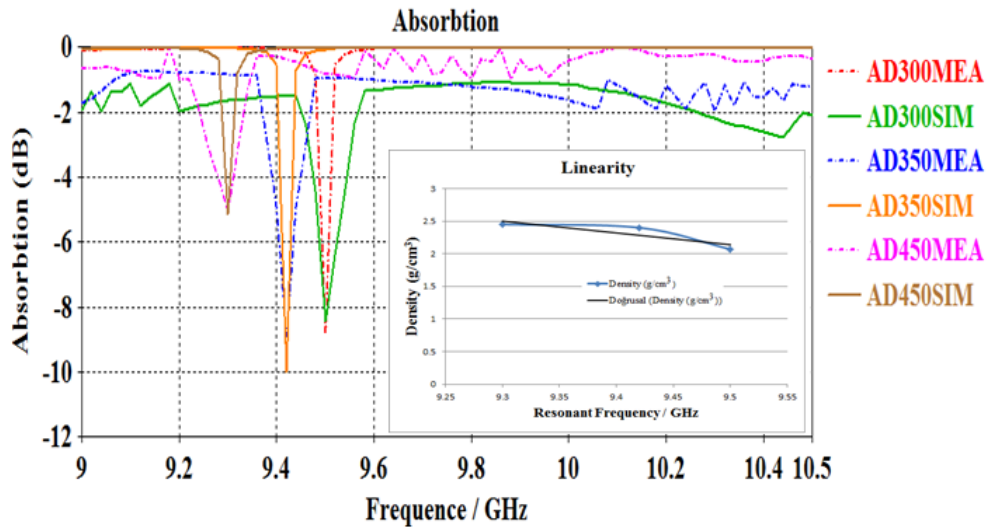


Figure 2. Numerical and experimental absorption values for density sensor application based on MA design

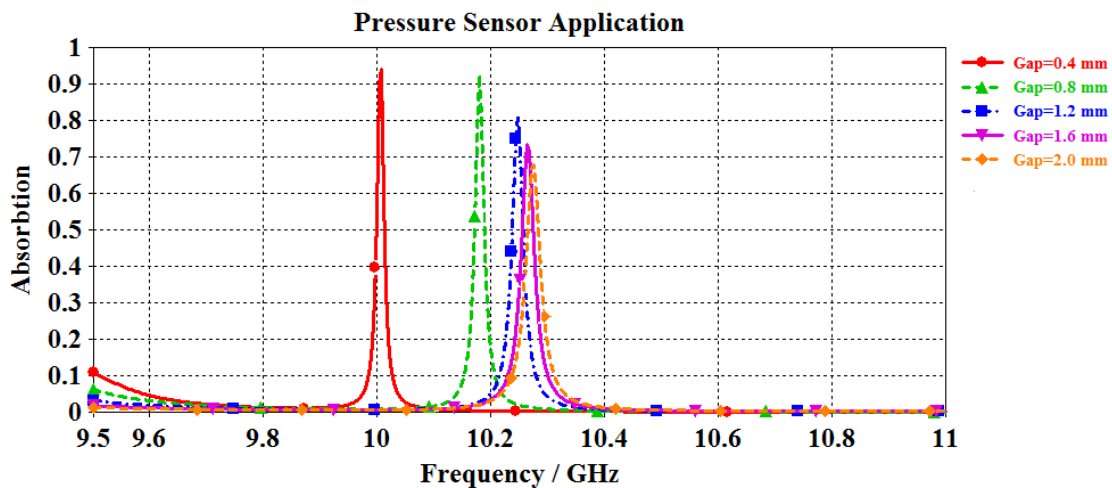


Figure 3. Pressure sensor application of MA based density sensor

4. Conclusion

In this study we investigate the different MA based sensor applications as density, pressure and marble type detection applications conducted for analyzing sensing capabilities of the suggested design. In order to show the sensing capabilities of the proposed design, density sensor application has been tested experimentally. It can be seen that experimental results are well consistent with the numerical results. The linearly shifting of the resonant frequency depends on the absorption level. . Simulation results show that proposed sensor can be used for different sensing applications when different kind of materials placed in the sensor layer. These materials that can be selected from linearly changes the results of a sensor design depending on the detection parameters such as humidity, temperature, etc. As an application addition to pressure and density sensor applications, marble type sensor application is performed and analyzed in detail. The result showed that MA based sensor can be used as marble type sensor.

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