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Analysis of a Micro-Strip Triangular Patch Antenna using DGS as a Strain Sensor

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Abstract
Microstrip patch antenna is a plane shape, light weight and low cost antenna that used to receive and transmit electromagnetic wave. This paper describes the design and simulation of a triangular microstrip patch antenna using DGS for strain measurement. The microstrip antenna was designed and simulated using Computer Simulation Technology (CST) Microwave Studio. When the antenna is under strain/crack, its resonance frequency varies accordingly. By using DGS in microstrip antenna the return loss and bandwidth has been increased. The resonant frequency of the microstrip patch antenna decreases linearly with the increase of applied strain. The microstrip patch antenna strain sensor can be integrated with other components easily and have a great potential applications in structural health monitoring.

Keywords: *Micro-Strip antenna, Strain sensor, Structural Health Monitoring.*

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INTRODUCTION

Structural health monitoring technology plays a significant role in the current civil engineering, aviation and spaceflight. In structural health monitoring systems, sensors are key devices that can sense physical information such as strain and temperature of the system. Optical fiber-based strain sensors have been applied in the structural health monitoring, however, this kind of sensors should be built in the structure beforehand. It usually requires digging holes and slots, which will impact on the mechanical property of the structure. Therefore, more investigations have been focused on new sensors that can conform to structures well without any damage[1-4]. One important part of any SHM system is the sensor which is used to detect the damage and is common in most of the techniques, where as the damage detection method is different from one system to another. Many of the sensors available for SHM are wired and therefore have practical limitations in order to be embedded into the structures, like strain gauges, piezoelectric transducers, fiber optic sensors, and micro-fiber composite actuators. These sensors have many disadvantages such as the need for installation during construction. Wires also limit the structures functionality, add more complexity to it and increase the weight of the structure.

Therefore, the number of sensors that could be applied is limited[5-7]. On the other hand, wireless sensors currently available in the market use batteries as an energy source which has a limited lifetime and increases the sensor size and weight; therefore, could not be used widely in the structure. In some cases where the sensor receives its energy through an antenna the sensory unit is too complicated[8].

In this paper, we demonstrated that a patch antenna itself can serve as the sensing unit for strain measurement. The relationship between the applied strain and resonant frequency of the patch antenna is first derived. The design and simulation of triangular patch antenna for strain measurement are then discussed.

ANTENNA DESIGN AND PRINCIPLE OF OPERATION

Side Length and Resonant Frequency

Figure 1 depicts the geometry of single element of triangular patch antenna. Based on the cavity model, length L of rectangular patch antenna it's the resonant frequency can be intended using the following formula

$$f_{10} = \frac{c}{2L\sqrt{\mathcal{E}r}}$$

where c is the speed of light in free space, and $\mathcal{E}_r$ is the dielectric constant of the substrate[5]. Therefore, when the dimension of antenna varies because of strain, the shift in resonant frequency is given as:

$$\frac{\Delta fr}{fr} = -\frac{\Delta L}{L} = -\mathcal{E}$$

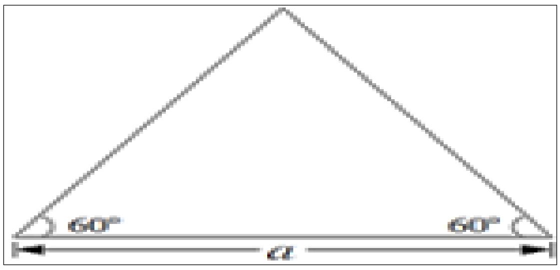

***Fig. 1**: Geometry of Triangular Patch Antenna.*

Design and Simulation

In this paper, a triangular micro-strip patch antenna is designed using CST Microwave Studio. The substrate of antenna is FR4 Lossy having permittivity 4.3 and height 1.6 mm. The simulation result of antenna is shown in Figure 2.

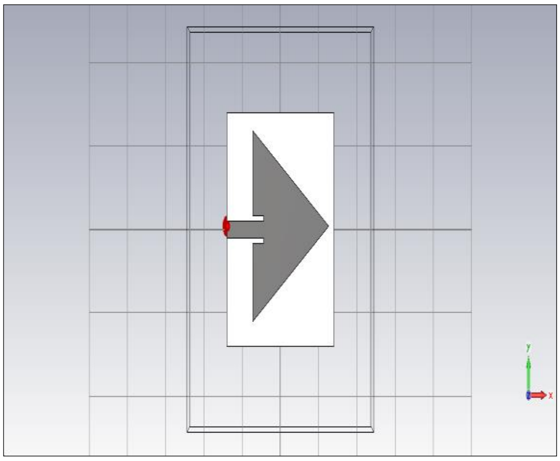

***Fig. 2:** Front View of Micro-strip Triangular Patch Antenna.*

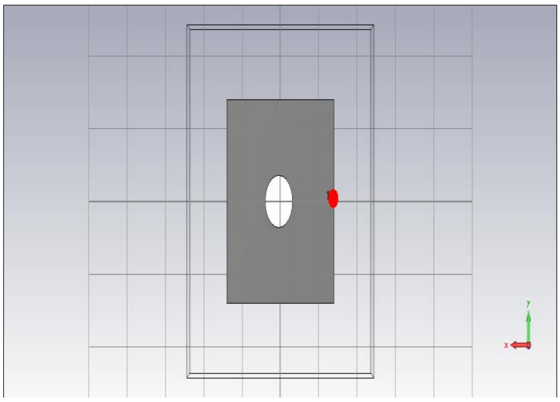

***Fig. 3:** Back View of Micro-strip Triangular Patch Antenna Using DGS.*

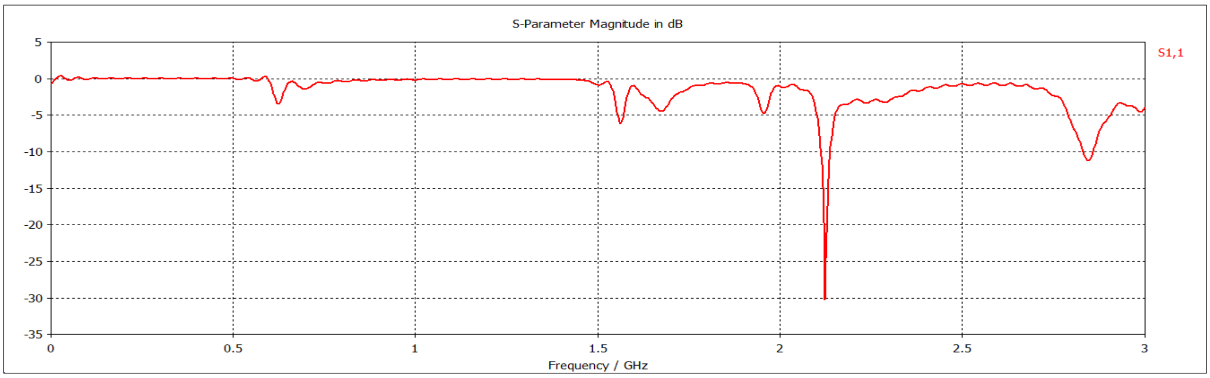

***Fig. 4:** Return Loss Vs Frequency Graph without Strain.*

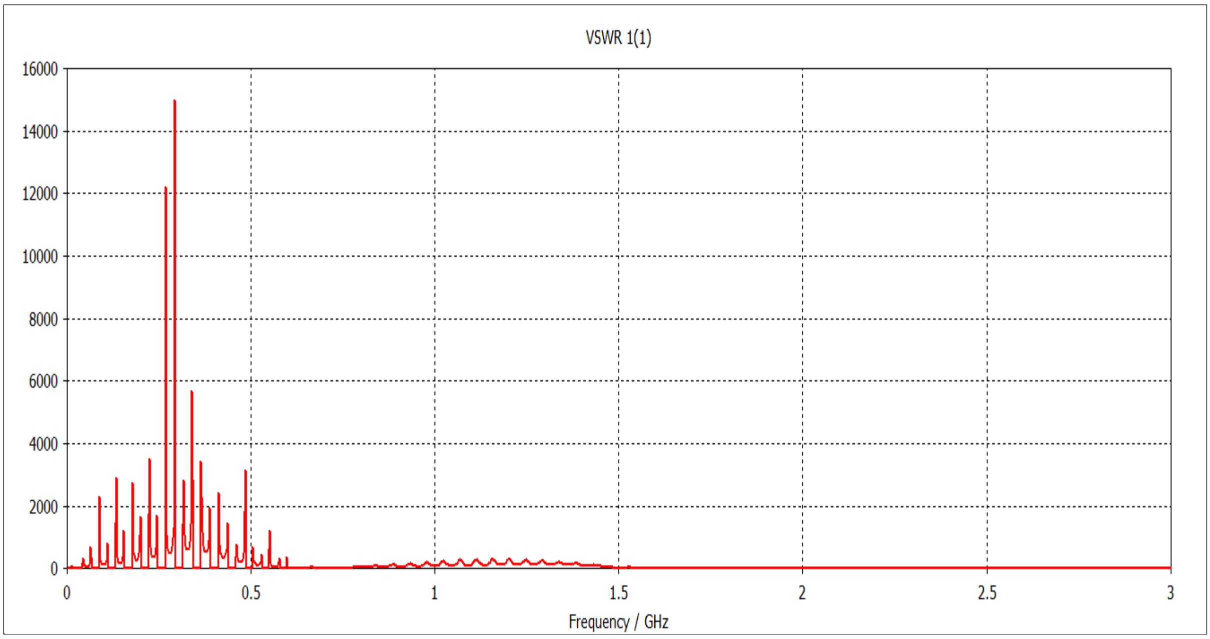

Fig. 5: *VSWR Graph.*

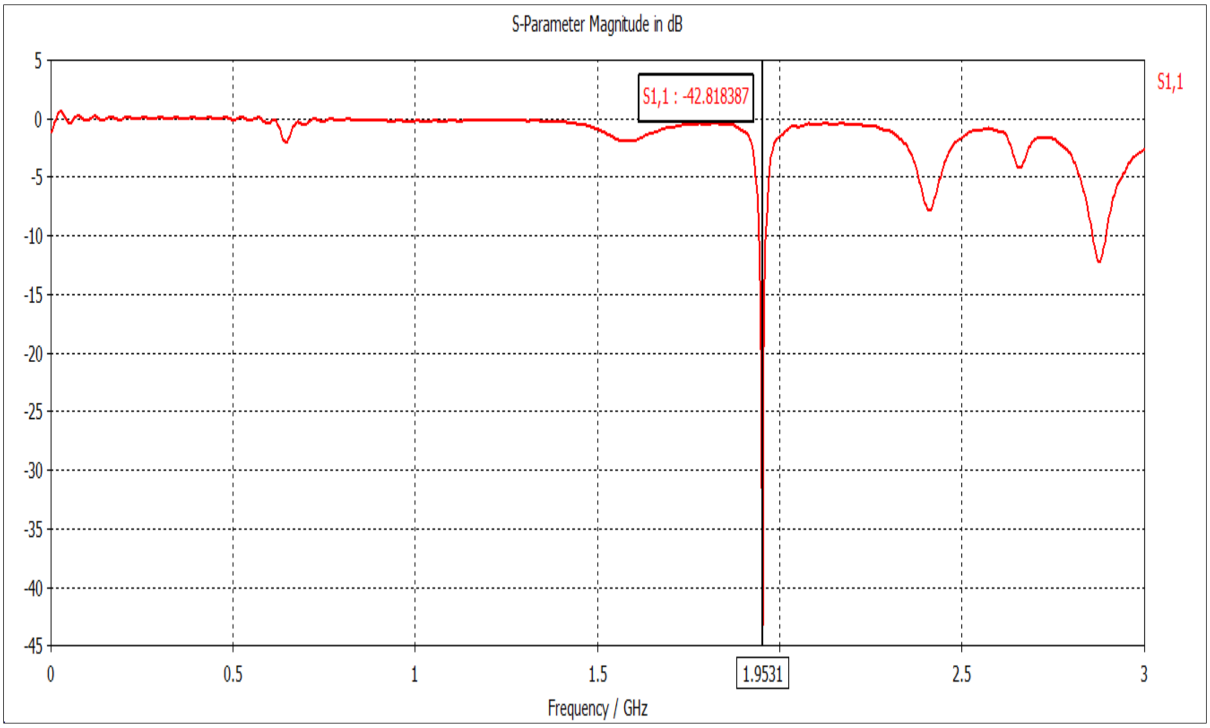

Fig. 6: *Return Loss vs Frequency Graph with Strain.*

When the tensile strain is applied on the patch antenna the radius of triangular patch antenna changes from all directions with same rate. The simulation curve of antenna with applied strain is shown in Figure 6.

A linear relationship is obtained between resonant frequencies and strains.

From Figure 4 and 6 it is clear that the resonant frequency is decreased with the applied strain.

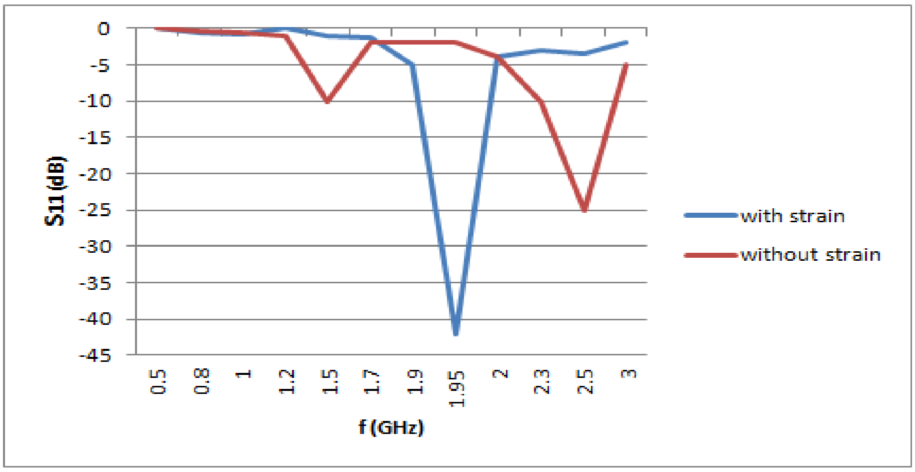

Fig. 7: *Measured S-Parameter of the Antenna Based Sensor.*

MATERIALS AND METHODS

Using the above analysis and conditions the parametric analysis and optimization in CST was used to find the dimensions to maximize factors such as return loss, VSWR pattern, far field pattern, antenna gain and bandwidth. FR4 lossy was used as a substrate having permittivity 4.3and height 1.6 mm and the port is feed to x-axis and y-axis having coordinate(-69,0).

CONCLUSION

The relationship between different types of damage and specific antenna types will be investigated. The challenge in this field is the determination of the smallest damage zone (relative to the size of the structure) that is detectable using this technique. Finally, depending on the results from this challenge to detect relatively small damage zones, the wireless aspect of this project will be investigated**.**

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