

Metal cracks detection based on circular patch microstrip antenna

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Abstract. Cracks in metal can be produced by many factors, such as external loads, physical processes, and chemical processes, such as alkali and corrosion. Structure health monitoring (SHM) is very important in maintaining the reliability of a building. Considering that the ultimate goal of a building health monitoring system is to provide sensory information that can facilitate decision making regarding the feasibility of components. Microstrip antennas have been shown to be able to detect cracking in metals according to their characteristics. In this paper will discuss the capability of a microstrip antenna with a circular patch having dual frequency operation to detect crack in metal.

1 Introduction

Metal is widely used in the construction of infrastructure as a framework to withstand the load of a building. Its role is very important in maintaining the reliability of a building. Structure health monitoring (SHM) refers to the process of implementing damage detection and characterization strategies for engineering structures. Damage is defined as a change in the material or geometric properties of a structural system, including changes in system connectivity, that affect system performance [1].

SHM is needed to ensure the robustness of a building, its application is expected to reduce losses caused by the failure of a building either due to age or disasters that occur, especially for Indonesia, which is in a disaster-prone area. Cracks can be defined as unintentional discontinuities in a structural material. In general, cracks are the result of material failure. Cracks can be produced by many factors, such as external loads, physical processes, and chemical processes, such as alkali and corrosion [2-4].

Considering that the ultimate goal of a building health monitoring system is to provide sensory information that can facilitate decision making regarding the feasibility of components, it is necessary to develop new crack sensors that can not only detect cracks but also provide quantitative information about cracks. Microstrip antenna sensor that can detect crack length and propagation with its sub-millimetre resolution [5-6]. This sensor has many advantages such as high resolution, small size, light weight, low cost, and makes use of advanced microwave detection technology to facilitate wireless detection and signal processing.

Microstrip antennas have been widely developed as sensors to detect cracks in metal. Changes in the structure of the metal will correlate with the frequency shift in the antenna characteristics [7-9]. In this article, we will discuss a circular patch microstrip antenna with an inset feed for detecting cracks in metal. frequency shift and minimum return loss are the parameters to be analyzed.

2 Methods

Microstrip antennas can be used to detect cracks that occur in metal. The characteristics of the microstrip antenna are highly correlated with the shape of the conductors in the patch and ground plane. the metal crack detection system uses a microstrip antenna using a ground plane which will be replaced with the metal to be tested.

2.1 Antenna Microstrip

Microstrip antenna generally has three parts, namely, patch, substrate and ground plane. The patch and ground plane are located at the top and bottom of the antenna, between which there is a substrate. The type of microstrip antenna used in this study has a patch with a circular shape. The substrate uses FR4 composite materials. The patch and ground plane materials used are copper conductors.

The microstrip antenna that will be used to detect cracks in metal has a circular patch shape. The feeder used is an inset feed type with an impedance of 50 ohms [10]. In Figure 1 can be seen the dimensions of the antenna. The patch antenna has a radius of 42.3 mm and the feeder has a length of 36.7 mm and a width of 3.1 mm where the

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feeder length of 24.78 cuts the patch antenna with a width of 1 mm on each side.

The ground plane on the opposite side of the patch and separated from the substrate has a thickness of 1.6 mm. The ground plane has dimensions of length and width of 93.2 mm and 92.2 mm, respectively

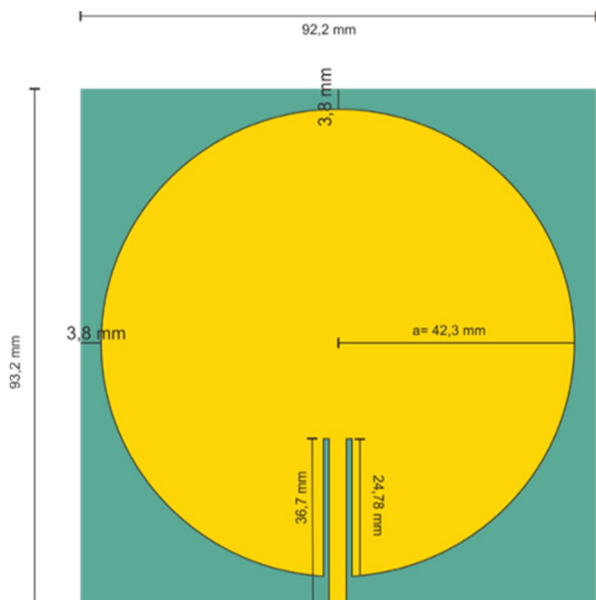


Fig. 1. Antenna Microstrip

The antenna has an operating frequency range according to its characteristics. The antenna that has been designed has two working frequency ranges. this value is obtained from the return loss. at low frequencies the antenna has a centre frequency of 1000 MHz and at high frequencies it has a value of 2803 MHz. Return loss simulation results can be seen in Fig. 2.

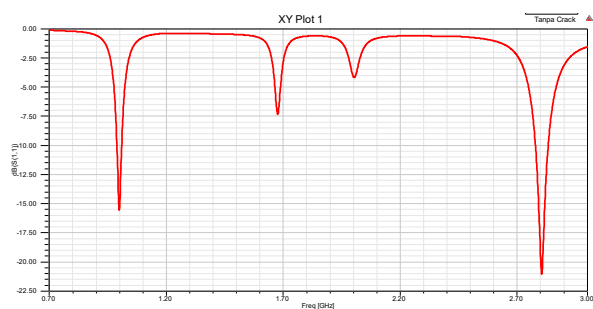


Fig. 2. Return Loss Antenna Simulation Result

2.2 Crack Detection

Cracks in metal were tested using a microstrip antenna by placing it on the ground plane. The metal tested has a width of 500 mm and a length of 93.2 mm according to the length of the antenna. Fig. 3 shows the configuration for detecting metal cracks using a microstrip antenna, where the crack position is located outside the patch.

In Fig. 4 you can see the configuration of metal crack detection, where the cracks are placed in the patch. the position of the crack at the centre of the circular patch. metal crack detection test using microstrip antenna based on simulation using the finite element method (FEM)

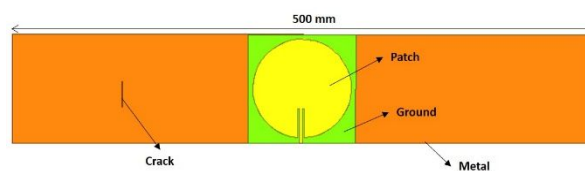


Fig. 3. Crack Detection Outside Patch

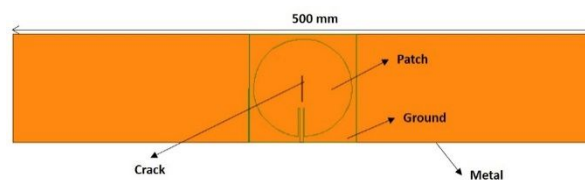


Fig. 4. Crack Detection Inside Patch

3 Results and Discussion

Cracks that occur in metal change the shape of the structure of the metal. in the test using a metal microstrip antenna placed on the ground plane of the antenna. Referring to the characteristics of the microstrip antenna, the change in structure will correlate with changes in the electrical property of the antenna.

3.1 Crack Detection Inside Patch

The test is carried out on metal cracks placed under the patch. Based on the simulation results, there is a shift in the centre frequency of the antenna operation to be greater than the operating centre frequency of the antenna without crack. in Fig. 5 can be seen the simulation results of the frequency shift caused by the crack that occurs in the patch.

The artificial crack in the test metal has a width of 1 mm with a length varying from 2 mm to 22 mm in increments of 4 mm. the results of the frequency shift of all cracks are positive from the centre frequency of the antenna without cracking for low and high frequencies. the frequency shift at high frequencies has a greater value than the frequency shift at low frequencies.

frequency shift at low frequencies based on the simulation results obtained insignificant changes in the value from 4 MHz to 6 MHz. The highest frequency shift was obtained for cracks with a length of 2 mm, 10 mm and 22 mm, while the lowest frequency shift occurred for cracks with a length of 14 mm. at high frequencies, the large frequency shift that occurs in the 2 mm crack length has the highest shift value of 19 MHz. and the lowest frequency shift is obtained at the crack length of 14 mm with a large shift of 6 MHz.

Centre frequency antenna value is obtained from the minimum return loss value. in Fig. 6 it can be seen the minimum return loss value for the antenna without cracks and the antenna on the crack test. Based on the simulation results, it is found that there is an increase in the minimum return loss value of the antenna when there is a crack in the test metal. The highest return loss value at low frequency occurs for cracks with a length of 14 mm with a return loss value of -13.4186 dB. at high frequency, the highest increase in return loss occurs in cracks with a length of 6 mm of -18.3199 dB.

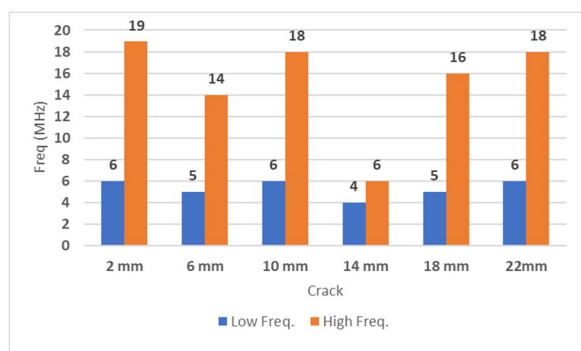


Fig. 5. Frequency Shifting Crack Detection Inside Patch

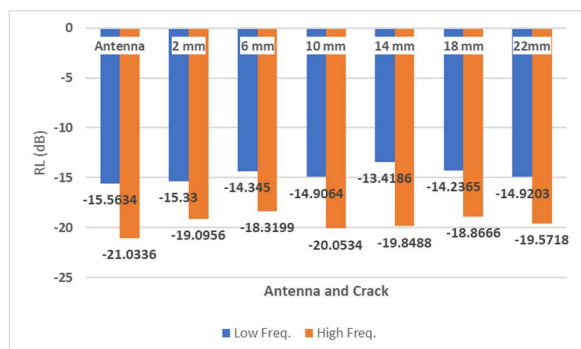


Fig.6. Minimum Return Loss Crack Detection Inside Patch

3.2 Crack Detection Outside Patch

Simulation results for metal cracks that are outside the antenna patch have a lower frequency shift than the cracks inside the patch. all crack test results for frequency shift are positive. The simulation results for the frequency shift for low and high frequencies can be seen in Fig. 7.

Frequency shifting at high frequencies has a greater value than at low frequencies. at high frequencies the frequency shift does not change much which has a value in the range of 8 MHz to 9 MHz. at low frequencies the highest shift value occurs in cracks with a length of 2 mm which have a frequency shift of 8 Mhz. The lowest frequency shift is obtained at the crack length of 10 mm with a shift value of 2 MHz.

The minimum return loss value obtained for the antenna used in the crack test on metal has a better value at low frequencies compared to the antenna without crack. The lowest minimum return loss value was obtained at the crack length of 10 mm with a value of -29,009 dB. this value is 86% lower when compared to the antenna without crack.

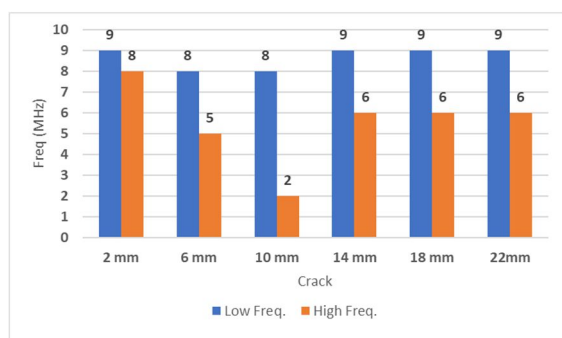


Fig. 7. Frequency Shifting Crack Detection Outside Patch

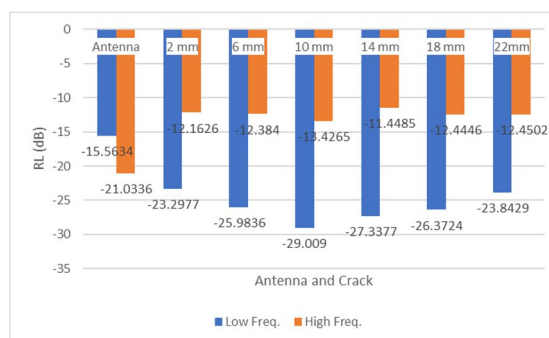


Fig. 8. Minimum Return Loss Crack Detection Outside Patch

4. Conclusions

Circular patch microstrip antenna with dual frequency at 1000 MHz and 2803 MHz has been simulated to detect cracks on metal. Based on simulation result crack position at patch antenna has better sensitivity than outside patch, especially on higher frequency. Crack with length 2 mm has maximum shifting frequency at higher frequency with value 19 MHz.

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