A Consideration on Chipless Displacement Sensor Using Inverted-F Antenna in High Temperature Environment

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***Abstract*— Eddy-current displacement sensors are used in a device for sensing the shaft vibration of turbines. However, they surfer from the high temperature environment. In this paper, the chipless displacement sensor system to measure the vibration was proposed based on the resonance of an antenna. From the numerical and experimental investigations, it was obvious that this system was able to measure the distance between the antenna and the turbine from 0mm to 8mm using the inverted-F antenna at 3GHz. And moreover, the resonant frequency of the inverted-F antenna affected by the temperature was considered, and it was confirmed that this system was hardly affected by the high temperature environment from 0 to 500 degrees.**

Keywords—Microwave; Inverted-F Antenna; and Displacement Sensors

I. INTRODUCTION

The eddy-current displacement sensor is usually used for monitoring the shaft vibration of turbines because the turbomachinery such as an electricity generator occurs breakdown by the shaft vibration of turbines. It consists of a sensor probe and an impedance/output voltage (Z/V) converter, and the distance between the sensor probe and the measured object can be recognized by occurring the eddy-current effects [1]-[3]. However this system is hard to use in the high temperature environment because the Z/V converter is subject to influence of the ambient temperature [4].

Having this fact in mind, the chipless displacement sensor which is able to measure the distance between the sensor and the measured object in high temperature environment has been proposed based on the resonance phenomenon of the antenna placed in front of the measured object.

In this paper, an inverted-F antenna was employed and the change of the resonant frequency by changing the distance between the antenna and the metal plate was evaluated from the numerical and experimental investigations. The details are shown as follows.

II. STRUCTURE OF INVERTED-F ANTENNA

Figure 1 shows the system configuration of the proposed displacement sensor for shaft vibration of turbines. An antenna type of chipless sensor is placed in front of the shaft. After receiving the chirp signal from the repeater, a signal with a resonant frequency of the antenna which is a function of the distance between the sensor and the measured object is reflected from the sensor. The repeater receives the signal and transmits the signal to the base station.

As the antenna for sensor, the well-known inverted-F antenna with the vertical polarization is selected as shown in Fig. 2, where the dielectric substrate consists of the Alumina substrate with a thickness of 0.4mm to be able to endure the high temperature environment, the relative permittivity and the dielectric loss tangent being 9.4 and 0.006, respectively. In this time, the structure of the inverted-F antenna was optimized and the change of the resonant frequency versus the distance between the antenna and the metal plate was evaluated.

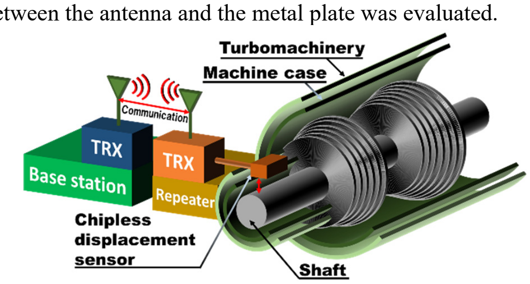

Fig. 1. System configuration of proposed displacement sensor for shaft vibration in turbine.

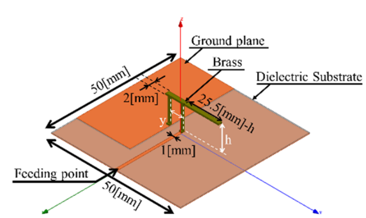

Fig. 2. Structure of inverted-F antenna.

III. NUMERICAL AND EXPERIMENTAL INVESTIGATIONS

A. Change of resonant frequency versus distance between inverted-F antenna and measured object

Figure 4 shows the structure of the inverted-F antenna faced on the metal plate assumed as the shaft. The reflection characteristics were calculated as a function of the distance d between the inverted-F antenna and the metal plate for the hights h of 5, 10, 20mm. The results are shown in Fig.4. It is obvious that the resonant frequency shifted by changing d. Figure 5 shows the calculated change ratio of the resonant frequency versus distance d. It is confirmed that the maximum change ratio was 224% when h was set at 20mm.

To verify the calculated results, the inverted-F antenna was fabricated with h of 10mm as shown in Fig.6. Figure 7 shows the measured reflection characteristics and the change ratio of the resonant frequency. From the result, a reasonable agreement between the calculated and measured change ratios can be obtained although the change ratio was deteriorated to be 24.6% down than the calculated one.

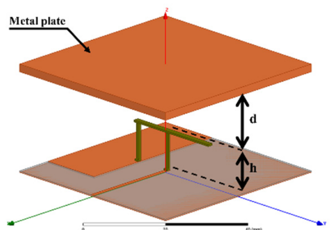

Fig. 3. Calculated model of inverted-F antenna faced on metal plate by distance of d.

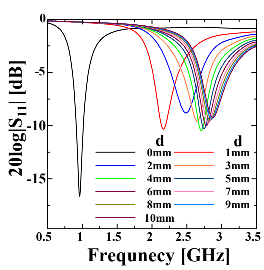

Fig. 4. Calculated reflection characteristics versus frequency with h at 10mm.

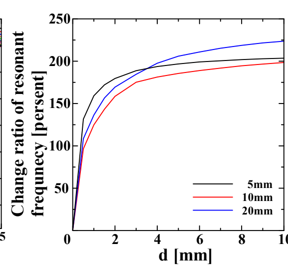

Fig. 5. Calculated change ratio of resonant frequency versus distance d.

Fig. 6. Photograph of fabricated inverted-F antenna.

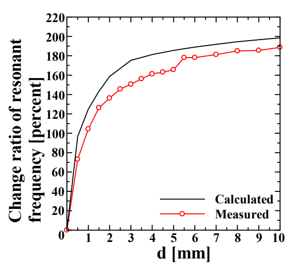

Fig. 7. Measured change ratio of resonant frequency versus distance d.

B. *Influence of resonant frequency in high temperature environment*

In a practical sense using in the turbomachinery such as an electricity generator, the displacement sensor is exposed to the high temperature environment of about 500 degrees. Therefore, the resonant frequency of the inverted-F antenna was calculated versus d by changing the temperature from 0 to 500 degrees. Figure 8 shows the calculated resonant frequency versus the distance d as a function of the temperature. Figure 9 shows the calculated change ratio of resonant frequency versus the distance d as a function of the temperature on the basis of the change ratio of the resonant frequency at 0degree. From these results, it was confirmed that the difference of the change ratio of the resonant frequency was less than 1.7%, and it was considered that this system was hardly affected by the high temperature environment from 0 degree to 500 degrees.

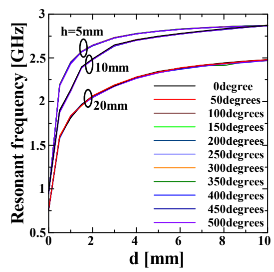

Fig. 8. Calculated resonant frequency versus distance d as function of temperature.

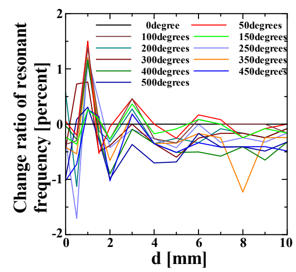

Fig. 9. Calculated change ratio of resonant frequency versus d as function of temperature with h at 20mm.

IV. Conclusion

In this paper, the chipless displacement sensor which was able to measure the distance between the sensor and the measured object in high temperature environment has been proposed based on the resonant frequency of the antenna, and it was confirmed that this system was able to measure the displacement using the inverted-F antenna from the numerical and experimental consideration.

In addition, the influence of the change of the resonant frequency in high temperature environment was considered, and it was confirmed that the resonant frequency of the inverted-F antenna was hardly shifted by the high temperature from 0 to 500degrees.

On the next step, sensing performance in high temperature environment will be also considered from the experimental investigation.

References

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