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Improvement of Isolation in Rotary Transformers for the Ultrasonic Testing System

超音波探傷装置向け回転トランスの高アイソレーション化

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1. Introduction

Steel material is used in various industries such as cars, ships, pumping oils and so on. An automated ultrasonic testing system is applied to the steel production line. In this system, rotary transformers with multiple ultrasonic probes, which rotate around the Steel Under Test to detect defects at the surface and transmit signals, are adopted. Fig.1 shows the outline of the ultrasonic testing system.

Fig.2 shows the conventional rotary transformer with signal lines, which consists of microstrip lines on PCB (Printed Circuit Board) and a steel plate with counterbone[1]. In the system, rotary transformers are arranged to face each other for transmitting or recieveing signals detected by each probe. In this configulation, however, high signal-to-noise ratio cannot be obtained because signal lines are close to each other and isolation is insufficient.

In this paper, we propose a novel rotary transformer with high isolation.

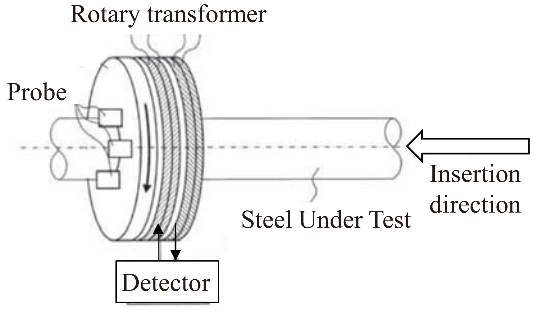

Fig. 1 The outline of the ultrasonic testing system

2. Design of the proposed rotary transformer

Fig.3 shows the proposed rotary transformer. Similar to the conventional structure, we adopted microstrip line on PCB (FR4;relative dielectric :4.1, tanδ:0.02) for signal lines and a steel plate with counterbone. In addition, the equivalent electrical walls are formed between adjacent signal lines in order to attain high isolation. The wall consists of the GND line on the front surface and multiple VIA holes. The VIA holes are connected with the backed ground plane as shown in Fig.3. In this case, the VIA holes are arranged concentrically on GND lines on the front surface at intervals of $\lambda/4$ or less, where λ is the wavelength at the center frequency. With this configuration, we can achieve high isolation since each signal line is electrically shielded from adjacent lines. Here, each signal line is designed, factoring the electrical walls of VIA holes, so that its characteristic impedance is 50 ohm. As a result, we obtained the design parameters as shown in Table.1, where Ws is width of signal line, w is width of GND line, g is gap between signal line and GND line, t is thickness of conductor and d is thickness of PCB.

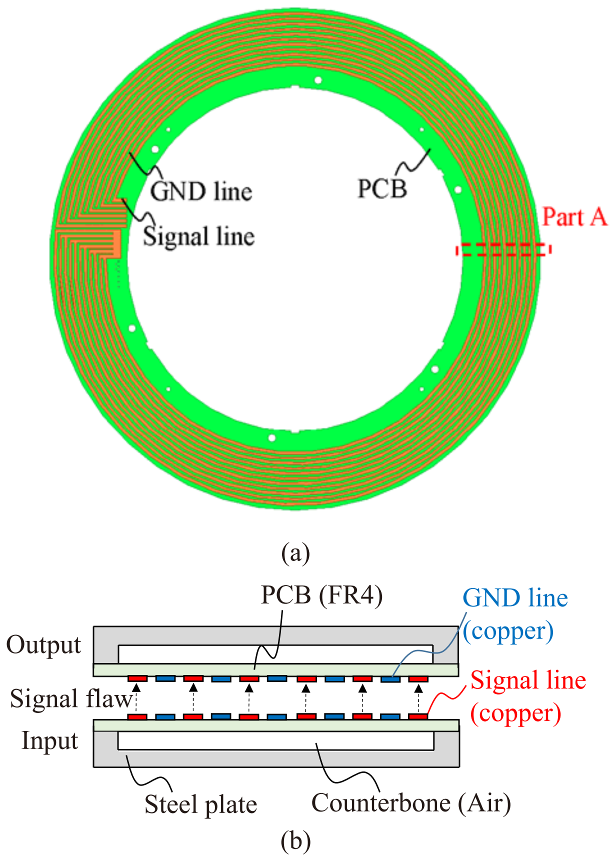

Fig. 2 Conventional rotary transformer with signal lines(a)Top view, (b)Outline of the cross section at Part A when two rotary transformers are faced each other.

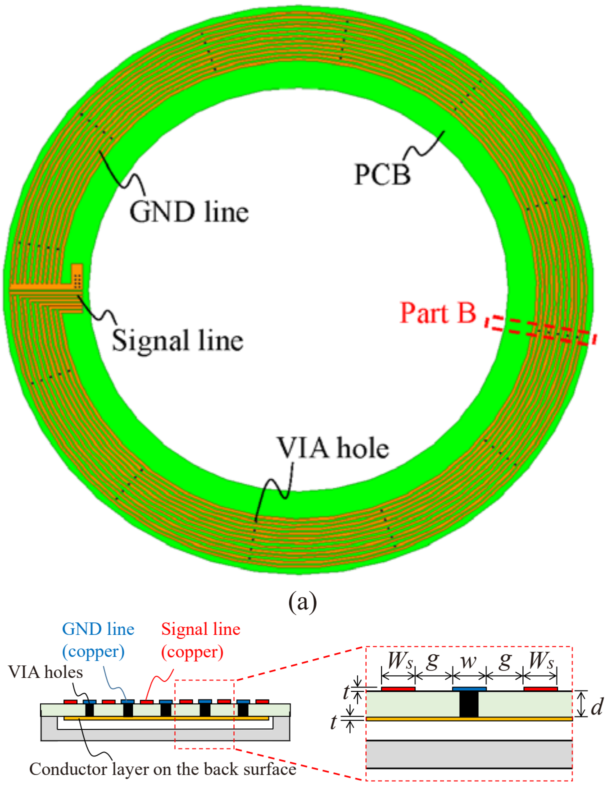

Fig.3 Proposed rotary transformer (a)Top view, (b) Outline of the cross section at Part B.

Table1. Design parameters

Ws [mm]	*w* [mm]	*g* [mm]	*t* [mm]	*d* [mm]
4	3.5	3.5	0.1	3

3. Simulation results

The proposed rotary transformer is designed using HFSS 2018.2 (ANSYS) which is based on Finite Element Method (FEM). Here, we evaluated S-parameters in three paths as shown in Fig.4. Path 1(S_{21}) means transmission characteristic from input line to output line. Path 2(S_{31}) means isolation characteristic between adjacent signal lines on the same rotary transformer. Path 3(S_{41}) is isolation characteristic between adjacent signal lines on the opposite rotary transformers.

Fig.5 shows that the simulated transmission and isolation characteristics, where the vertical axis is the amplitude of S-parameters [dB], and the horizontal axis is the frequency normalized by the center frequency *f0*. As a result, we confirmed that the isolation characteristics (Path 2 and 3) are improved by 18 dB or more while the transmission characteristic (Path 1) is approximately equal to the conventional one. The characteristics at the center frequency are summarized in Table.2.

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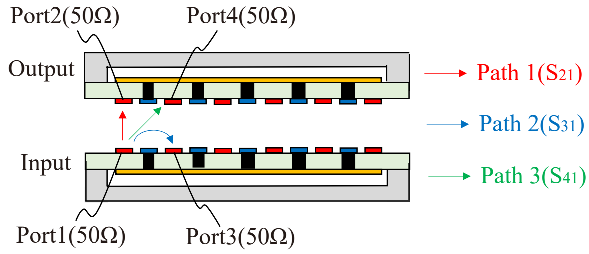

Fig.4 The image of signal transmission and isolation

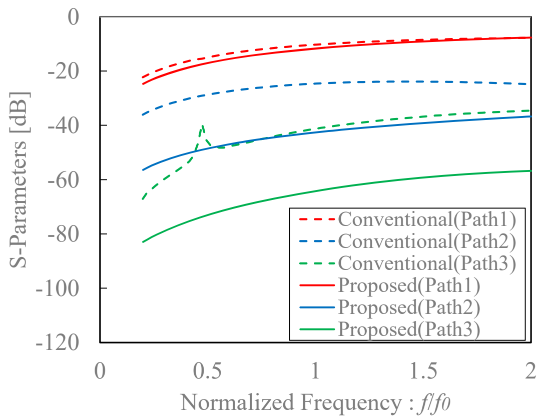

Fig.5 Simulation results.

Table2. Simulation results at the center frequency

Ref.	S21(Path 1) [dB]	S31(Path 2) [dB]	S41(Path 3) [dB]
Conventional	10.2	24.5	41.1
Proposed	11.6	42.6	64.2

4. Conclusion

In this paper, we proposed a new rotary transformer for the ultrasonic testing system. The proposed transformer consists of a steel plate with counterbone and PCB, which includes a conductor layer on the back surface and VIA holes for forming the electrical walls between adjacent signal lines. By FEM simulation, we confirmed that the rotary transformer attain better isolation than conventional one. In the future, we will carry out demonstration.

References

1. S. Shibata, Y. Fujikake, K. Hatabara, M. Ishihara and S. Mitsui: WO/2012/141279.