Poster Abstract: Investigation of Distance Sensing Method Using Magnetic Resonant Coupled Coils for Deformable User Interfaces

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ABSTRACT

We investigated the possibility of using the output voltage of magnetic resonant coupled coils to realize a distance sensing method that can be applied even when the distance between coils is long. We changed the distance between PCB boards with 1 cm coils and measured the output voltage induced in one coil when an AC voltage of the resonant frequency is input to the other coil. As a result, a correlation was confirmed between the distance between the coils and the value of the output voltage. We found that the distance between the coils can be estimated from the output voltage even when that distance is more than five times the coil diameter. This method enables distance sensing between objects simply by placing a coil on the object. This allows for the sensing of positional relationships between components used in deformable user interfaces.

KEYWORDS

Displacement Sensor, Magnetic Resonance Communication

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1 INTRODUCTION

There has been much interest in deformable user interfaces. One idea for deformable user interfaces is to realize functions by emphasizing small components[3]. The position of components can be freely changed, so the interface is deformable. A deformable user interface changes its behavior by detecting changes in its shape. Therefore, the above-mentioned idea requires the detection of the distance between components to recognize the shape of the interface. Many of the proposed deformable user interfaces use cameras or connectors between components to detect their positional relationships. However, occlusion is a problem with the former, while wear and tear between connectors and limited component movement are problems with the latter. On the other hand, lasers and ultrasounds are generally used for distance sensing. However, these methods are unsuitable for small components because of their directivity and the device's size that emits lasers or ultrasounds.

Another distance sensing method is to check the characteristics between inductively coupled coils to detect the distance between coils [1]. This method does not use cameras or connectors and has no problems caused by these devices. This method is less directional than lasers or ultrasounds and can be applied to small components due to the flexibility in coil size. However, the conventional method [1] assumes that the receiver side is a passive device. Since the distance estimation was based only on the information on the transmitter side, and only the transmitter side was resonant, the distance that could be estimated was short in relation to the coil diameter.

In this paper, we realized efficient power transmission by using magnetic resonance, which resonates both the transmitter and receiver sides, and verified whether distance estimation over a long distance can be achieved for the coil diameter. Assuming application to a device in which both the transmitter and receiver sides are active, the receiver side voltage was used for estimation.

2 SENSING PRINCIPLE

When two coils exist and an alternating current flows in one coil, a voltage is induced in the other coil with a magnitude corresponding to the coupling coefficient between the coils (electromagnetic induction). The coupling coefficient is determined by the shape and position of the coils. If the shape of the coils is known, the coupling coefficient between the coils can be determined by measuring the induced voltage. If the positional relationship between coils changes in only one degree of freedom, the positional relationship can be detected from the coupling coefficient.

Among electromagnetic inductions, those that use capacitors and in which the transmitter and receiver operate at the same resonant frequency are called magnetic resonance. It can transmit large amounts of power with high efficiency even when the distance between coils is long[2]. We used magnetic resonance because we wanted to enable power transmission between components with coils located at a distance longer than the diameter of the coils.

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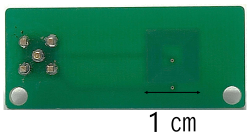
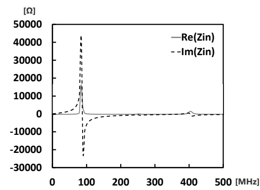


(a) Coil mounted on PCB board



(b) The simulated impedance characteristics of the coil

Figure 1: Implemented coil and the simulated impedance characteristics of a coil

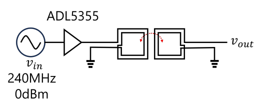


Figure 2: I/O circuits

In magnetic resonance, if the characteristics of the capacitor and coil on the transmitter and receiver sides do not match well, the resonant frequencies on each side will not match. This leads to a decrease in transmission efficiency. Therefore, we used self-resonance using a short-type coil's inductance and parasitic capacitance for highly efficient transmission without tuning capacitors.

3 EVALUATION

By using coil boards, we measured the output voltage when the distance between the boards was changed.

3.1 Experiment Design

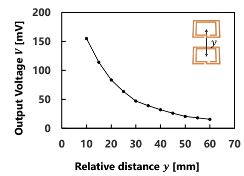
Considering its use as a component of deformable user interfaces, 1 cm square spiral coils were used in this experiment. The wiring width and space for each coil were 0.08 mm, and the number of windings was 20. The coil was formed by making a copper wiring pattern on a PCB board. Figure 1(a) shows the coil board and Figure 1(b) shows the simulated impedance characteristics of the coil (Z_{in}).

Since the wavelength of the signal is short compared to the length of the coil, there are self-resonant frequencies from the second order onward. We used 240 MHz, the second resonant frequency because the output voltage at this frequency was the highest.

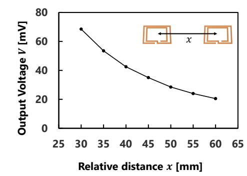
In this experiment, an AC voltage with 240 MHz and 0 dBm (v_{in}) was amplified by an amplifier and input to the coil on the transmitter side, and the output voltage of the coil on the receiver side (v_{out}) was measured with an oscilloscope (Figure 2).

3.2 Result

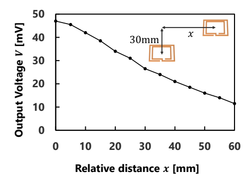
In this experiment, the output voltage was measured in four cases: (a) Coils were facing each other on the same axis, (b) Coils were placed in the same plane, (c) One coil was shifted in the x direction from the condition in (a), and (d) One coil was shifted in the y direction from the condition in (b). The results of each measurement are shown in Figure 3. Figure 3 shows the absolute value of the output voltage monotonically decreases as the value of x (or y) increases. In addition, the change in voltage can be confirmed even when x (or y) is more than five times the coil diameter. From these results, we found that x (or y) and voltage value correspond 1:1 in (a)-(d), and therefore, by formulating these relationships from the measured values, we can calculate x (or y) from the value of voltage and estimate the distance to more than 5 times the coil diameter.



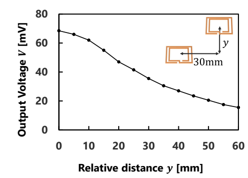
(a) Coils were facing each other on the same axis



(b) Coils were aligned in the same plane



(c) One coil was shifted in the x direction from (a)



(d) One coil was shifted in the y direction from (b)

Figure 3: Relationship between the positional relationship between coils and output voltage

4 CONCLUSION AND FUTURE WORK

We conducted an experiment to confirm the characteristics of the value of the output voltage in one of the coils when the distance between the magnetic resonant coupled coils was changed. As a result, a correlation between the distance and the output voltage was confirmed even when the coils were separated by more than five times the coil diameter. Therefore we found that the distance between the coils can be estimated from the output voltage even when that distance is long compared to the coil diameter.

We will implement the specific distance sensing method, including calibration, and investigate the characteristics of output voltage when the positional relationship between coils varies in 3-D space and when multiple coils are present to generalize the method.

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