Development of Capacitive Sensor for Aerial Interface

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ABSTRACT

This paper introduces our development and application of a capacitive sensor to detect hand and finger gestures based on high-sensitivity and noise-robustness sensing technology. Application of the developed capacitive sensor includes a touchless aerial interface.

1 INTRODUCTION

In recent years, mobile devices such as smartphones, automotive navigation and industrial control panels have been thinner and lighter and touch panels have been used. In touch panels, the principle of capacitive sensing is mainly used, and in general, self-capacitance detection method is mainly used as an ON/OFF switch function, and mutual-capacitance detection method is mainly used for pointing, coordinates and touch gesture recognition. In addition, as one of the measures against covid-19, the needs for non-contact interface is also increasing.

To realize non-contact detection, it is necessary to understand the principle that the difference in the presence of the detection object more than a few cm away or the sensing value in the event to detect increases.

In general, self-capacitance detection method is more sensitive than mutual-capacitance detection method if the detection electrode area is the same. However, self-capacitance detection method tends to have a parasitic capacitance between detection and the surrounding ground potential. When parasitic capacitance is provided, the detection signal contains components and impairs the detection dynamic range, which is a suppressor of sensitivity improvement [1,2].

We have developed non-contact detection touch panel that overcomes these challenges using high-sensitivity, noise-robustness sensing and noise canceling technology.

In addition, we have combined these technologies with aerial display to develop applications for touchless aerial interface. the aerial display was made by the method of AIRR (Aerial imaging by retro-reflection) system which has been proposed as suitable for mass production and cost-effective [3,4].

2 TECHNOLOGIES

2.1 High sensitivity of self-capacitance

The method of Absolute self-capacitance sensing is shown in Fig.1. To reduce the influence of parasitic capacitance in self-capacitance detection method, a guard electrode is provided on the opposite side of detection zone against the detection electrode [5]. By controlling the guard electrode potential, the inflow of static charge between the detection electrode and the surrounding ground potential is suppressed, and a shielding effect from the ground potential can be obtained, thereby parasitic capacitance can be reduced.

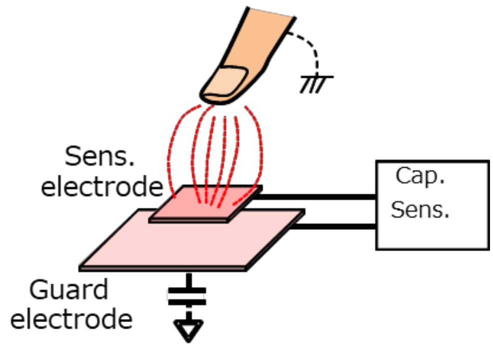

Fig.1 Absolute self-capacitance sensing

2.2. Both high sensitivity and noise immunity

Proximity operation is detected as a change in capacitance, because the detection uses the electric field, it is often affected by electromagnetic noise. Therefore, in non-contact detection, the balance between the increase of the detection signal and the noise immunity is the key point.

We used sine-wave to resolve these conflicting issues. Show in Fig.2. The driving waveform of a square wave contains the fundamental frequency and its odd-multiple harmonic components, while the sine wave has only a fundamental frequency component. This filters the frequency components of noise other than the drive frequency, improving noise immunity. And, this quiet drive is advantageous for electromagnetic interface from the viewpoint of radiation.

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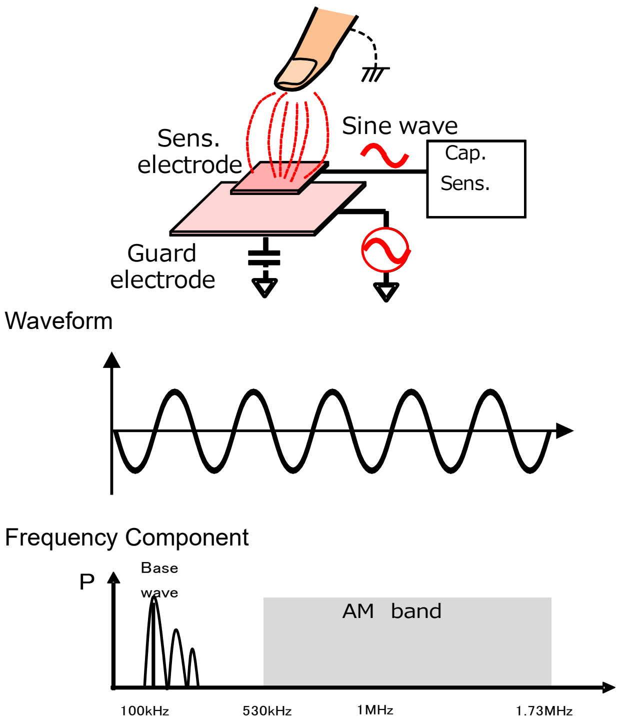


Fig. 2 New sensing method

As these countermeasures effect, the comparison result of detection distance vs. (SNR) is shown in Fig. 3. The signal noise ratio (SNR) of the sensing signal can be represented as:

$$(\mathrm{SNR}) = 20 \log S/N, \quad (1)$$

where S denotes signal change in object present or not; and N denotes noise components in the detection signal.

We assume that (SNR) of 10 dB or more is necessary for determination of the presence, and detection has come possible near 50mm.

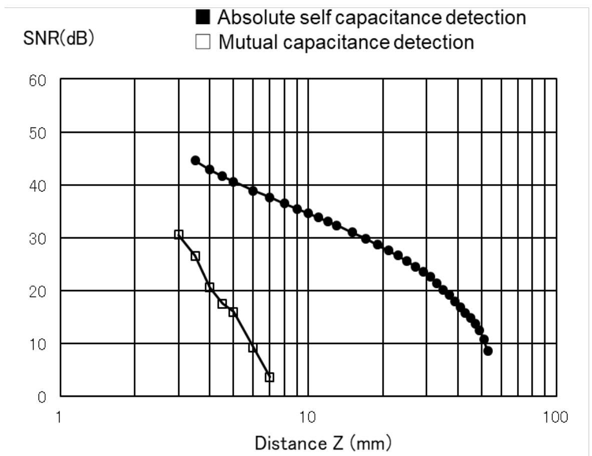


Fig. 3 Effect of countermeasures on the signal to noise ratio

2.3 Countermeasures for display noise

In general, it is necessary to transmit light and require a transparent electrode with high transmittance, but because of the high resistance, it is susceptible to noise generated when driving display pixels.

We used noise cancellation electrodes with the time constant equivalent to that of a sensor electrode, and used the difference in output values to reduce noise. The method and its results are shown in Fig. 4.

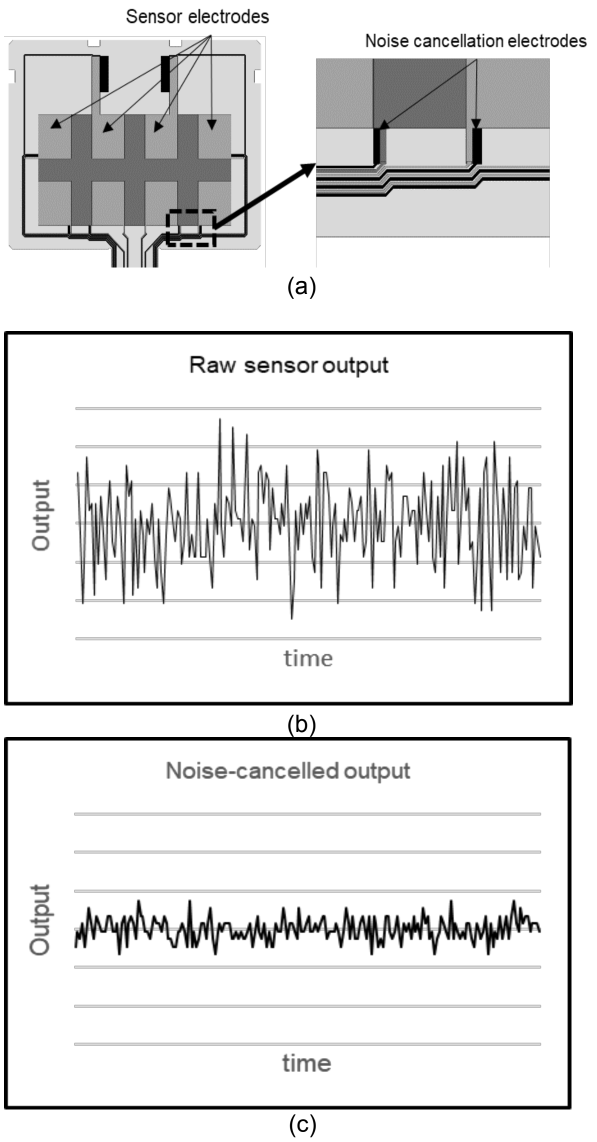
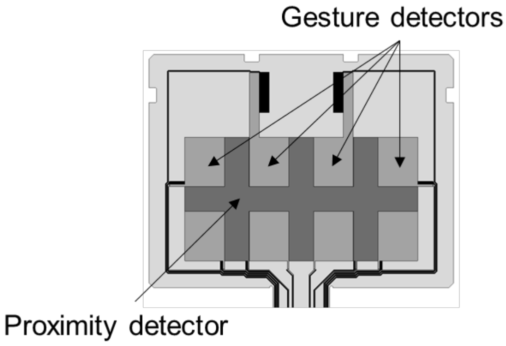


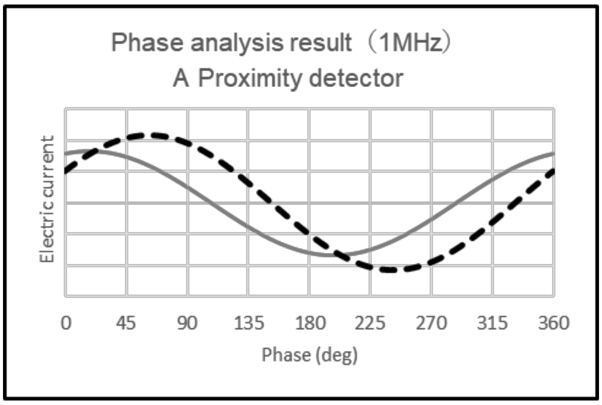
Fig. 4 Display noise cancelation method and the effect. (a) Noise-cancelation electrodes. (a)Raw sensor output. (b)Noise-canceled output.

Proximity detecting area was larger than the gesture detection electrode. Therefore, there was a problem that noises of different phases were stacked depending on the path of noise, and the effect of noise cancellation was reduced.

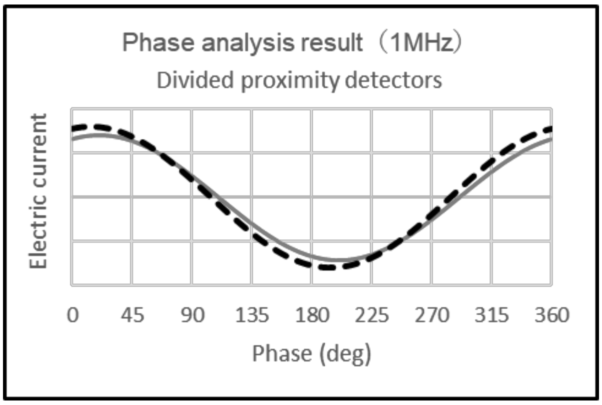
We divided the electrode to improve phase delay that is generated in an electrode for detecting proximity was also added. The effect is shown in Fig. 5.



(a)



(b)



(c)

Fig. 5 (a) Structure of a proximity detector. (b) phase differences by use of (b) single detector and (c) divided detectors

3 RESULTS

3.1 Development of non-contact detection touch panel

Self-capacitance detection method, the drive shield electrode system, and the sine wave drive are adopted as a method of both high sensitivity and robustness, and the scheme to the display noise has been described.

We applied these technologies to developed a proof of concept (PoC) model that can operate non-contact detection touches and demonstrated them in 2020, as shown in Fig. 6.

Fig. 6 Demonstration of PoC 2020

3.2 Apply of touchless aerial interface

We have developed a touchless aerial interface sample for PoC in 2021. As shown in Fig. 7, our developed capacitive sensor technologies are implemented in the aerial display system with AIRR. Specifications of PoC 2021 is shown in Table 1.

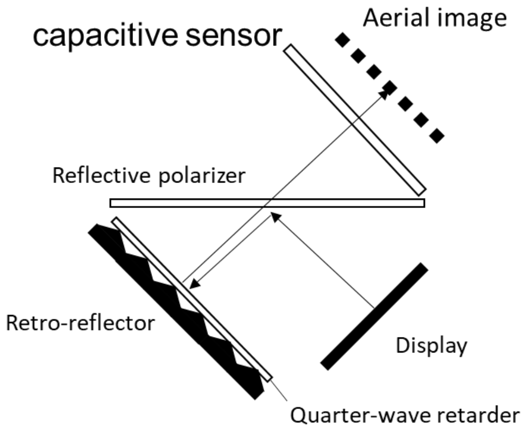
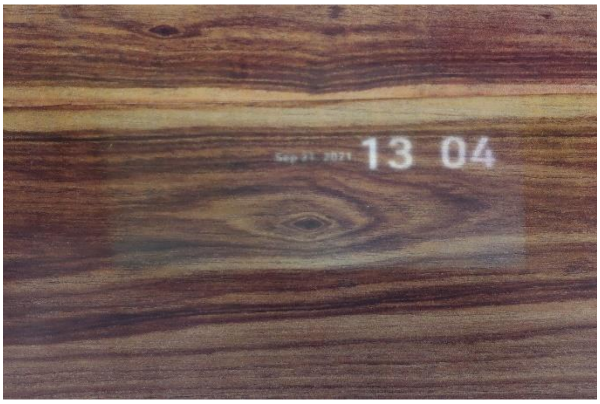


Fig. 7 Proof of concept on a touchless aerial interface

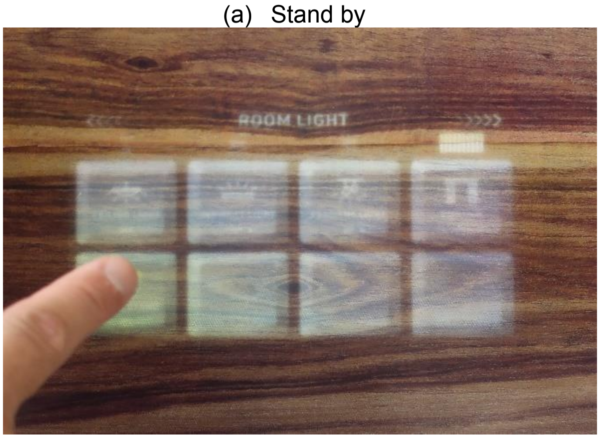
Table 1 Specifications of PoC 2021

Aerial display	7inch.
Viewing angle	30deg.
Luminance	300cd/m^2

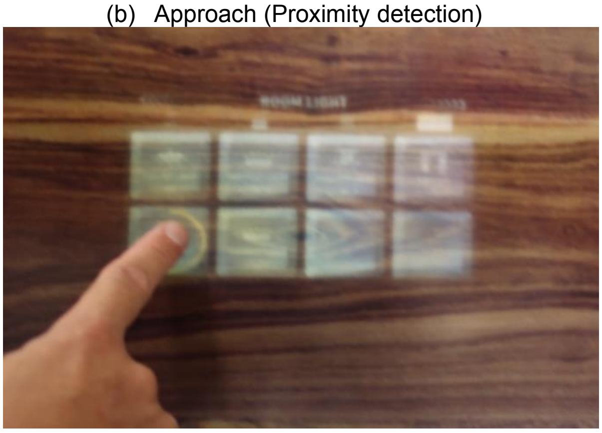
When a finger approaches to 50 mm, the proximity detectors detect the finger and the aerial image appears. By moving the finger closer, we can select a button with a gesture detection sensor. the aerial display and gesture detection area are adjusted to be exactly the same position, shown in Fig. 8.



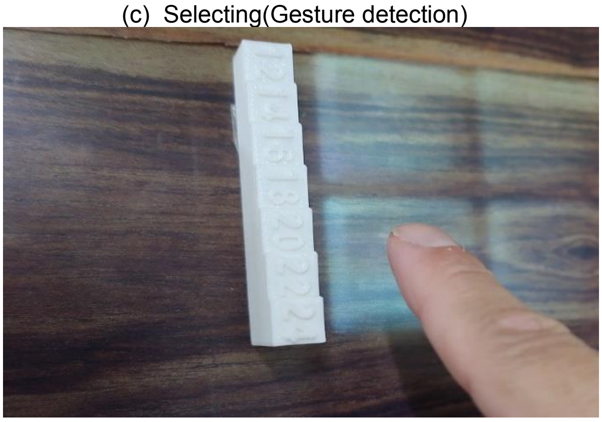
(a) Stand by



(b) Approach (Proximity detection)



(c) Selecting(Gesture detection)



(d) Selecting (Other angle)

Fig.8 Touchless aerial interface with PoC 2021

4 CONCLUSION

We explained touchless technologies using capacitive touch panel. The high sensitivity of the touch panel allows seamless human-machine interface (HMI) through conventional contact operation and non-contact HMI, improving hygiene and operability.

Furthermore, a touchless aerial interface developed by us is very simple system, which does not require image processing, cameras or external sensors. It suggests a world where a simple aerial interface is designed, integrated into the living space and life, and appears only when needed.

HMI devices is expected to evolve by working with aerial displays and various feedback functions.

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