Evaluation of the Integrated In-cell Electromagnetic Resonance Sensor and Capacitive Touch Sensor

Yuji Suzuki[1], Satoshi uchino[1], Kohei Azumi[1], Tadayoshi Katsuta[2], Daichi Suzuki[1], Hiroyuki Wakana[3], Kaoru Ito[1]

[1]R&D Division System Development Department, Japan Display Inc., Kanagawa, Japan
[2]Display Solutions Company, Japan Display Inc., Aichi, Japan
[3] R&D Division Solution Development Department, Japan Display Inc., Kanagawa, Japan
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Abstract

We developed in-cell EMR reflective LCD panel, which shares the sensor pattern with capacitive touch sensor, without additional sensor layer. This technology contributes many benefits for thin design and less weight of the panel compared with conventional EMR products. This paper shows our in-cell EMR and capacitive touch sensing performance.

1 INTRODUCTION

1.1 Recent trend of pen technologies

Since smart phones and PC tablets have come into wide use since the 2000s, touch operation has been selected for the standard user interface. Products which can be operated by pen input are also increasing. Recently, pen-writing and pen- drawing attract attention in educational and industrial tablet markets as well as conventional PC tablets.[1]

In this paper, we classify the commercial pen technologies into three groups: passive pens, capacitive active pens and electromagnetic resonance (EMR) pens.[2,3] Passive pens have only conductive material, so it is the simplest configuration. We can use the passive pen to draw on general capacitive sensors. Capacitive active pens are used on many kinds of PC tablets and can support pen tilt and pen pressure. The pens need to be compatible with the capacitive touch sensors, therefore, they require a battery and specific IC to detect the pen tilt and pressure.

In contrast, EMR pen is different from the capacitive types. The structure of EMR pen is a simple LC circuit. That makes it possible to detect pen tilt and pressure by using EMR sensing without battery. However, another sensor is required on the panel for the detection.[2,4] The capacitive active pens have become mainstream in pen products since they can reduce the complexity and additional cost of panel. Table 1 shows classification and feature of pen technologies.

About the pen usability or maintainability without battery, we think EMR pen has advantages and potential can be used on various scenes than capacitive active pens. So, we have been developing in-cell EMR using our LTPS, in-cell touch technology to solve some conventional EMR panel problems.

Table 1. The classification and feature of pen technologies

Classification	Drawing Performance	Tilt/Pressure	Battery	Additional sensor
Passive Pen	Fair	Not Supported	Not Required	Not Required
Capacitive active pen	Good	Supported	Required	Not Required
EMR pen (Conventional Panel)	Good	Supported	Not Required	Required
EMR pen (In-cell EMR Panel *)	Good	Supported	Not Required	Not Required

1.2 The principle of EMR pen detection

The EMR pen detection is based on the principle of electromagnetic induction. Fig.1 shows the diagram of the signal path from TX to RX, through the pen coil. First, modulated current flows through the TX coil which generates a magnetic field. Then the pen coil detects the modulated magnetic field and charges the capacitor by its LC resonance. At this time, TX coil shifts to the receiving state and the pen coil generates a magnetic field which in turn induces an electromotive voltage onto the RX coil. The EMR sensor has multiple aligned RX coils, thus the coil closest to the pen detects a higher voltage than the other coils. By using this method, the EMR sensor can identify the pen position on the RX coils.[2,5]

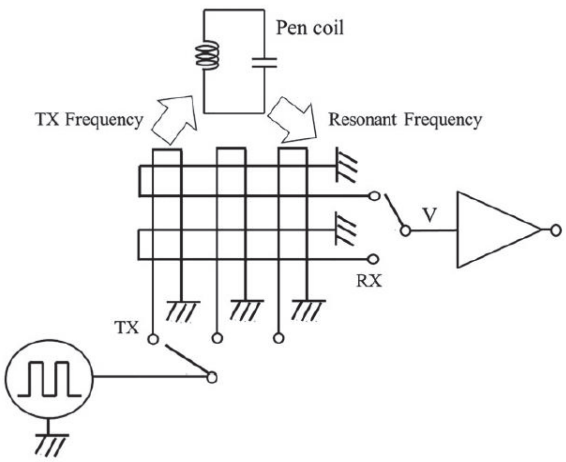

Figure 1. The diagram of TX and RX signal path and pen coil

2. The principle and Background of In-cell EMR Technology

2.1In-cell capacitive touch sensing

Fig.2 shows the in-cell capacitive touch sensor layer structure. The In-cell EMR sensor also has the same configuration. In-cell capacitive touch is based on our hybrid-in-cell and RX low resistance technology.[6-9] Typically, a larger size and higher resolution in-cell LCD has higher resistance on the RX receiver. However, we have researched a low resistance material that is confirmed to have over 80% lower resistance on a mobile sized panel compared with conventional ITO.

Using this material, we integrate the touch capacitive sensor inside the panel with the RX sensor placed on top of color filter glass and the TX sensor on the TFT(ITO) layer. This enables us to make a thin design and a light weight panel with improved transmittance properties compared with the on-cell and out-cell type of touch sensors.

During mutual-capacitance touch sensing, the TX-scan shifts from the top to the bottom of the panel with the RX nodes simultaneously sensing each scan. This allows us to detect the finger touch position. Our in-cell capacitive touch can also support self-capacitance sensing to detect specific objects like water.

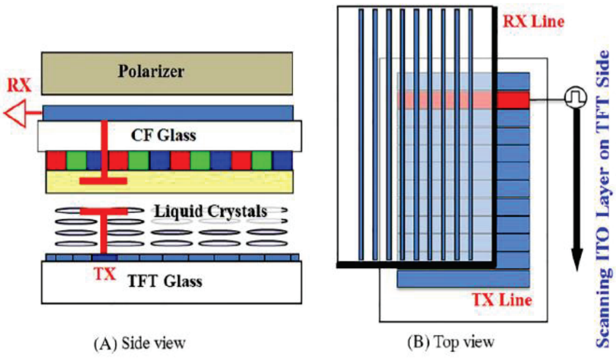

Figure 2. The in-cell capacitive touch sensor layer structure

2.2 In-cell EMR pen sensing

The In-cell EMR has the same basic structure as the capacitive in-cell touch sensor: TX electrode on top of the TFT glass and RX electrode on top of the color filter glass are shared by capacitive touch sensor and EMR sensor. The only difference is that the EMR sensor requires a loop-coil shaped RX and partially modified TX scanner circuit to generate the loop current. Fig.3 shows the diagram of TX hybrid driving for EMR and capacitive sensing. TX scanner circuit can be switched between EMR and capacitive sensing.

For EMR sensing, the TX generates a magnetic field on the panel. The direction of current flowing on the TX coil is modulated by the frequencies closest to the resonant frequency of EMR pen coil. Fig.4 shows the diagram of in-cell EMR TX driving and RX sensing.

We have published papers about the in-cell EMR. In this paper, we will discuss EMR and capacitive sensing performance in relation to in-cell panel structure.[10]

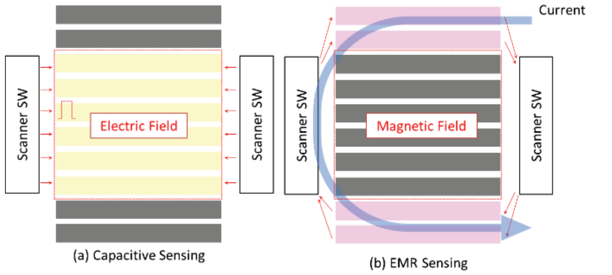

Figure 3. The diagram of TX hybrid driving for electromagnetic resonance (EMR) and capacitive sensing

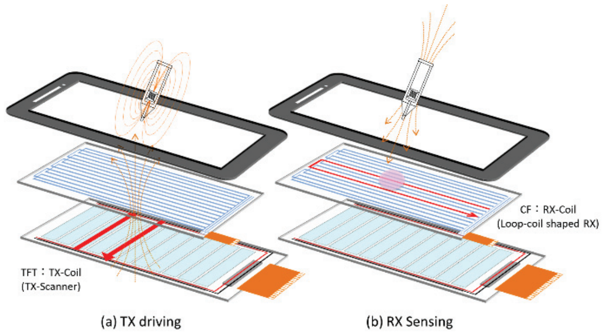

Figure 4. The diagram of in-cell electromagnetic resonance (EMR) TX driving and RX sensing

3. Structural Comparison Conventional EMR sensor with In-cell EMR sensor

The conventional EMR sensor is located under the display device as shown in Fig.5. Because they require a low resistance, its electrodes are not transparent. In contrast, our in-cell EMR sensor can be integrated inside the LCD panel. Therefore the distance between EMR sensor and the surface of the display device is closer than conventional EMR sensor. In the case of in-cell EMR, the noise influence from outside of panel is concerning. We evaluate that at the later chapter.

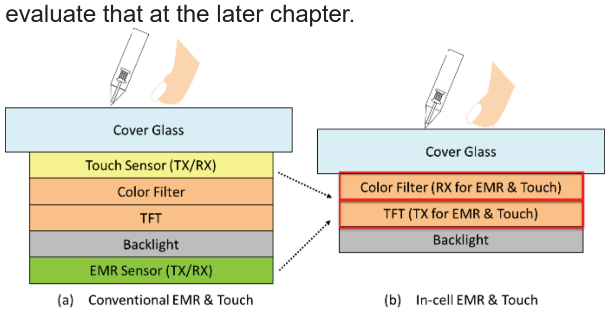

Figure 5. The stack comparison between conventional electromagnetic resonance (EMR) and this development

Considering conventional EMR sensor, if it is not synchronized with display driving, it is inferred that display noise affect EMR sensing on the out-cell EMR. However, our in-cell EMR has time sharing method, which is divided into display time, touch sensing time and EMR sensing time as shown in Fig.6. Fig. 7 shows the diagram of in-cell EMR and touch scan. First, the in-cell sensor searches for the EMR pen. Then depending on if the pen signal is detected or not, it shifts to the EMR or capacitive full scan.

The in-cell sensor continuously alternates EMR/capacitive touch scanning and display driving. In this way, our in-cell sensor saves the scan time to realize the 120Hz sensing.

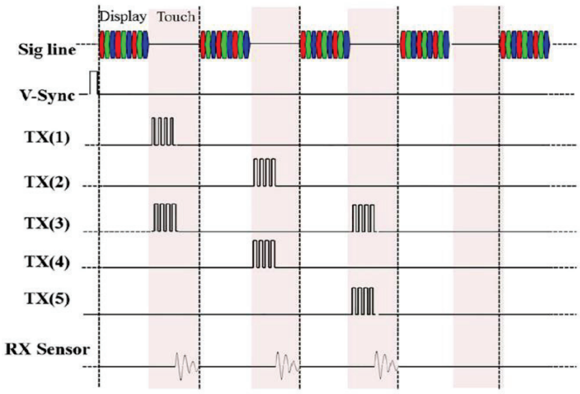

Figure 6. The timing diagram of our in-cell electromagnetic resonance (EMR) sensing

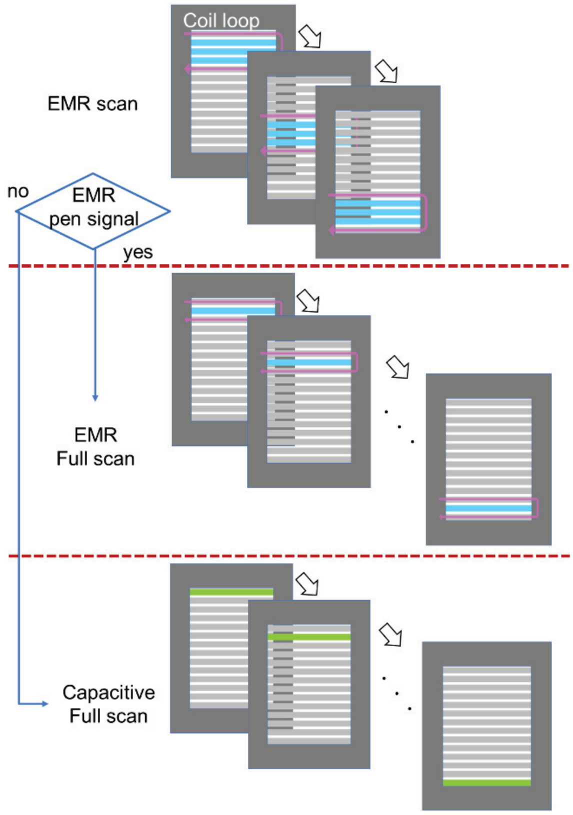

Figure 7. The scan diagram of our in-cell sensor

4. The prototype of In-cell EMR, 9.7inch reflective LCD

This is our second prototype, in-cell EMR panel. Table 2 is the panel specification. We developed this panel as a concept model based on reflective LCD technology to make full use of the characteristics gentle to the eyes and combine with EMR pen, particularly for the educational market. In this paper, we use this panel to evaluate the influence of EMR sensor integration to the LCD, SNR measurement related to the display images and measurement with palm on the LCD.

Table 2. In-cell reflective LCD panel specification

Display	In-cell Reflective LCD
Active area size	9.7 -in
Layout	Portrait
Aspect	3:4
TX, RX channels	50 × 34
Resolution	1536 × RGB × 2048 (QXGA)
Pixel density	264 ppi
Backplane	Low-temperature poly-silicon TFT
Thickness	0.97 mm (w/o cover glass)
Frame rate	Typ. 60 Hz
Reflectance	13.5%
NTSC	20.0%
Contrast ratio	18.5
Touch panel	Yes (capacitive)
Stylus	Yes (EMR pen)

Abbreviation: EMR, electromagnetic resonance; TFT, thin film transistor.

5.RESULTS

5.1 SNR related to the display images

One of the in-cell touch features is its immunity to the display noise. In comparison, the SNR of conventional out-cell touch sensor sometimes decreases to about 1/5 depending on the image pattern. Our in-cell EMR also has noise immunity since we allocate display and sensing time separately. Fig.8 shows the SNR of our in-cell EMR, the SNR does not change dramatically in each image.

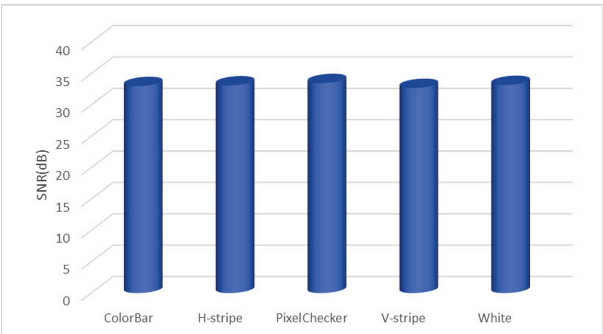

Figure 8. The results of SNR measurement

5.2 SNR evaluation with palm on the LCD surface

In capacitive touch sensing with passive pen, sometimes placing a palm on the screen disturbs the pen detection. This is because the capacitive sensor cannot easily distinguish between passive pen and palm. Also since the palm signal is bigger than small tip pen, it is difficult to detect the pen signal properly. Our in-cell sensor, on the other hand, can switch between the EMR sensing and capacitive sensing, prioritizing EMR sensing if the pen is detected. This means that when EMR scanning is active, touch, like palm signals, is not active, and thus cannot be detected. Fig.9 shows EMR and capacitive data with palm. On the EMR image to the left, palm does not appear because capacitive sensing is not active when the EMR pen is detected. When the pen is not detected then the capacitive scan kicks in and you can see the palm image.

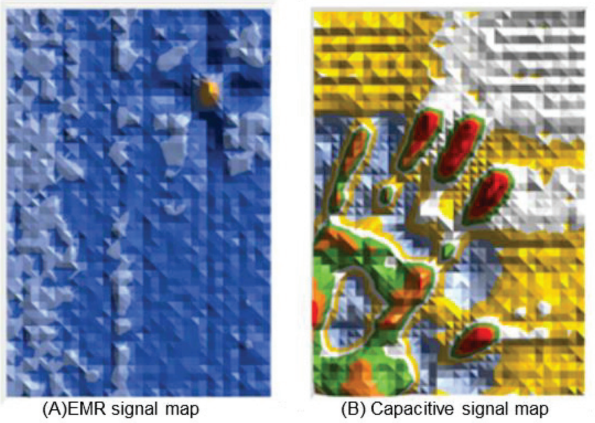

Figure 9. The diagram of the electromagnetic resonance (EMR) pen and palm detected on the sensor by each sensing mode

We were initially concerned about the influence of an approaching or touching hand/palm on the in-cell EMR sensor output due to the sensor-LCD integration. However, the results show that the SNR of in-cell EMR does not change much with or without a palm on the surface of LCD, as shown in Fig.10. This is presumed that the EMR signal is sufficiently greater than the noise from the human body and this noise can be ignored in the detection system. In addition, our 9.7-in EMR panel for demo has a 0.6mm cover glass, which also prevents noise coupling through the palm.

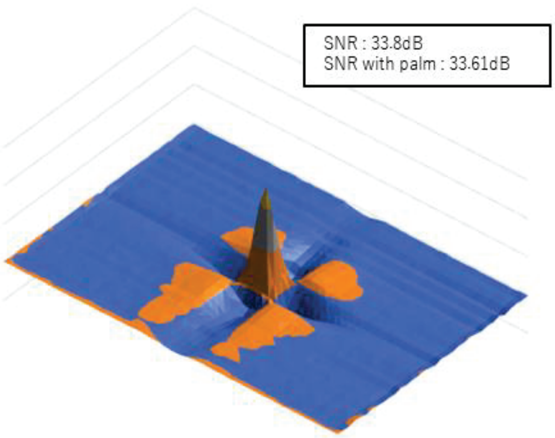

Figure 10. The diagram of electromagnetic resonance (EMR) pen signal with palm

Fig.11 shows capacitive data with 7mm slug and palm. In the case of capacitive sensing, palm signal is equal to or greater than passive pen (slug) signal, so the pen and palm cannot be easily distinguished. Capacitive SNR with palm is affected by human body noise and it becomes low.

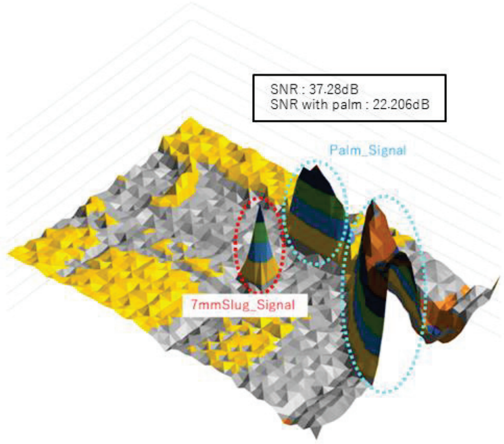

Figure 11. The diagram of capacitive signal map with 7mm slug and palm

6. CONCLUSION

Using a 9.7-inch reflective in-cell EMR panel, we have shown that our sensor is less affected by display noise because we use effective time sharing method between the display and EMR scan. Independent EMR and capacitive scan also allows palm rejection and the noise rejection when EMR pen is detected. In addition, we have confirmed that the in-cell EMR sensor has sufficient performance at 120Hz scan rate.

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