Development of a Trans-admittance Mammography (TAM) using 60×60 Electrode Array

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Abstract. We have developed a trans-admittance mammography (TAM) system as a supplementary or alternative method of the X-ray mammography to diagnose the breast cancer. Mechanical structure of the system is similar to the X-ray mammography with the breast placed between two plates. The pair of plates is movable to accommodate breasts with different sizes and rotatable to provide multiple images with different projection angles. Without using ionizing radiation, it acquires a projection image of tissue admittivity values. One plate is a flat solid electrode where we apply a constant sinusoidal voltage with a variable frequency. The other is equipped with 60×60 array of current-sensing electrodes, of which potentials are kept at the signal reference level. The electrode array is connected to six switching modules and each module routes current signals from 600 electrodes to two ammeter modules. Each ammeter module includes six channels of ammeters and each one of them comprises an independent current-to-voltage converter, voltage amplifier, ADC and digital phase-sensitive demodulator. Each ammeter sequentially measures exit currents from 50 electrodes chosen by the corresponding switching module. An FPGA controls six ammeters to collect real- and imaginary-parts of trans-admittance data from 300 electrodes. A separate FPGA arbitrates data and command exchanges between a DSP-based main controller and ammeter modules. It also generates a sinusoidal voltage signal to be applied to the breast. All the 3600 complex current data from 12 ammeter modules are transferred to the main controller, which is interfaced to a PC through an isolated USB. The system is provided with a program to display real- and imaginary-parts of measured trans-admittance maps. The measured maps at multiple frequencies are incorporated into a frequency-difference anomaly detection algorithm. In this paper, we describe the design and construction of the system.

Keywords: Trans-admittance, mammography, conductivity image

1. Introduction

X-ray mammography is the primary method to diagnose breast cancer. In order to detect the cancer at an early stage, it is recommended for women to take a scan regularly. X-ray mammography uses ionizing radiation with a dose of 1 to 2.5 mGy per view. This ionizing radiation could be hazardous and induce malignancy. The risk of malignancy increases with the number of scans. In using X-ray mammography, it is therefore necessary to find a balance between its benefit and the risk. For this reason, it would be beneficial to develop other method of detecting breast cancer without ionizing radiation.

There have been several efforts to develop new methods to detect breast and impedance imaging is
one of them [3]. However, impedance imaging methods still need to be improved to be used as a supplementary or alternative method to X-ray mammography. In this paper, we describe a new impedance imaging system for breast imaging, which we call the trans-admittance mammography (TAM).

2. System structure

The structure of the TAM system is similar to that of the X-ray mammography system as shown in figure 1(a). On the solid plate electrode, we apply a constant sinusoidal voltage with a variable frequency in the range of 1 to 500 kHz. We measure exit currents through the breast using 60×60 array of current-sensing electrodes. The TAM system comprises one voltage electrode, 3600 current-sensing electrodes, 6 switching modules, 12 ammeter modules and a main controller as shown in figure 1(b).

To measure an exit current on each current-sensing electrode, we need to connect the electrode to an ammeter. In order to measure exit currents from 3600 current-sensing electrodes, we implemented 72 ammeters so that each ammeter should be switched to one of 50 electrodes. Routing among 3600 electrodes, switching circuits and 72 ammeters is a technically challenging task and must be optimized for better performance. We came up with constructing 12 ammeter modules with each ammeter module containing 6 ammeters. Using 72 ammeters, this TAM system can measure 72 exit currents simultaneously. To handle switching among 72 ammeters and 3600 electrodes, we used 6 switching modules. A PC controls the TAM system through an isolated USB port. The DSP-based main controller inside the TAM system controls the constant voltage source and all ammeter modules.

3. Current-sensing electrode and switching module

The most distinct feature of the TAM system is the electrode plate with 60×60 current-sensing electrodes. Each current-sensing electrode is a gold-coated circle with 2 mm radius. The gap between adjacent electrodes in both x- and y-direction is 3 mm. On the back side of the electrode plate, we placed 18 BGA-type SMD connectors. Each connector has 200 pins and each pin is connected to one current-sensing electrode.

Figure 2 shows how switching modules work. Each switching module handles 600 current-sensing electrodes and 12 ammeters. One ammeter sequentially measures an exit current from 50 current-sensing electrodes. During switching and also current sensing, each current-sensing electrode must be at the ground voltage all the time. Since one switching module needs 600 switches, we chose ADG734BRU (Analog Devices, USA) because of its small size (4 switches in one chip) and low on resistance. An FPGA on each ammeter module includes a switch controller to manage 600 switches.
The sequence of operation is stored inside the FPGA and it is initiated by the start signal from the main controller.

![Figure 2. Switching module.](image)

### 4. Ammeter module

The TAM system includes 12 ammeter modules. In one ammeter module, there are 6 independent ammeters. Figure 3 shows the block diagram of the ammeter. The exit current passes through the current-to-voltage (I/V) converter, which produces a voltage signal proportional to the exit current. The rest of the ammeter is the same as the voltmeter use in the multi-frequency EIT system KHU Mark2 [5]. The voltage amplifier adjusts its gain so that its output signal spans 90% of the input range of a high speed ADC. Two phase-sensitive demodulators inside the FPGA calculate the real- and imaginary-part of the complex exit current, which is equivalent to the corresponding trans-admittance.

![Figure 3. Block diagram of ammeter channel](image)

### 5. Main controller

The main controller in figure 4 handles data communication among the PC and all ammeter modules. It also controls the constant voltage source for its amplitude and frequency. It comprises an FPGA (EP3C10F256C8N, Altera, USA), a DSP, a USB controller, a 16-bit DAC (AD9783, Analog Devices, USA) and several analog components for the voltage source. The output from the DAC is passed through a filter and amplifier to become a sinusoidal voltage signal applied on the breast. The DSP controls the entire system and the FPGA arbitrates data exchanges with 12 ammeter modules. The main controller is interfaced to a PC through the isolated USB controller.
Figure 4. Main controller.

(b) Figure 5. (a) Developed TAM system and its ammeter module.

6. Conclusion

Figure 5 shows the developed TAM system using 60×60 current-sensing electrode array. Its structure is similar to the X-ray mammography system. Using electrical current instead of ionizing radiation, the TAM system produces projection images of an admittivity distribution inside the breast. Since we can rotate the pair of electrode plates with the breast between them, it is possible to generate multiple projection images along multiple angles. In our future study, we plan to incorporate a frequency-difference anomaly detection algorithm into the TAM system and evaluate its performance.

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