The Influence of Multi-Frequency Current Injection in Image Reconstruction for Two-Dimensional High-Speed Electrical Impedance Tomography (EIT)

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***Abstract*—The image reconstruction for two-dimensional high-speed Electrical Impedance Tomography (EIT) has been successfully studied with multi-frequency current injection. The aim of this study is to get the best image reconstruction under the influence of multi-frequency current injection of this EIT system. In this method, we used current injection at 1 mA with varies of frequency in the range 10 to 50 kHz injected at the practical phantoms with 16 electrodes. Polyvinyl chloride (PVC) cylinder was put in the practical phantom as the anomaly. Then, The boundary voltage of the practical phantom was measured by the voltage measurement circuit. After that, it processed in the computer with Gauss-Newton Algorithm to got image reconstruction. The result showed that the best image reconstruction was achieved at 10 kHz of frequency current injection. The best image reconstruction had more accuracy of shape, position and electrical properties of an anomaly in boundary phantom than another image reconstruction result.**

***Keywords*— High-Speed, Electrical Impedance Tomography (EIT), Multi-Frequency, Image Reconstruction, Phantom**

I. Introduction

Electrical Impedance Tomography is an imaging technique using an electrical signal that injected in a medium such as human body and industrial part to get the image inside of the boundary medium by mapping conductivity distribution [1]. It has been used in Industrial, Geophysical and Medical Application. In The medical application such as for monitoring respiration system, preliminary cancer detection or another medical imaging purpose [2]. The advantages of EIT device are not harmful because it doesn't use radioactive material like CT scan, not expensive, portable and easy to build for DIY practice [3].

EIT uses constant current 1mA with a frequency between 10 kHz to 1MHz and it is injected into boundary medium by Electrode Pairs [1]. The output result is voltage feedback from boundary measurement using electrode pairs too that show conductivity response of the boundary medium [4]. The Conductivity is reconstructed using some algorithm to obtain a conductivity distribution image. In a recent study, many improvements of EIT has applied to get better performance such speed for monitoring purpose and resolution for the anatomical purpose [5]. The influence of current frequency tends to affect the capability of current can pass through the medium. In study of cola cole load, it said that low frequency had a lower capability to pass the medium than high frequency [6].

So, in this research, we studied about the influence of current frequency in image reconstruction for two-dimensional high-speed Electrical Impedance Tomography (EIT) to get the appropriate frequency of the current source and improve the result of reconstruction image.

II. Method

In this Research, the multi-frequency constant current 1mA signal that varied between 10 to 50 kHz had injected by High-speed EIT to boundary circle phantom that contained an anomaly as shown in Figure 1. The anomaly was a cylinder Pipe of Polyvinyl Chloride (PVC) and it was placed inside the phantom. The boundary phantom was using 16 of electrode pairs as the path of the current to pass into medium and measure voltage feedback. The practical phantom size had 9 mm diameter and it used 0.5 × 0.5 cm 2 copper (Cu) electrode. This measurement method used neighboring method for current injection process and it's speed was 1ms/data. The total data of neighboring method was 256 for one measurement process to get an image result. Then, measurement voltage had acquired automatically by DAQ device as part of this EIT [7].In this research, we used embedded system EIT, it means that unit control was using microcontroller and Single Board Computer (SBC).The multiplexer became a switch and it transmitted the current to the phantom and also as reciever that it collectted the boundary voltage's data.

Each variation of frequency gave one set of boundary voltage measured data and it shown as measurement point vs voltage graph as a forward problem then reconstructed by Electrical Impedance Tomography and Diffuse Optical Tomography Reconstruction Software (EIDORS) using

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Gauss -newton algorithm to reconstruct image [8], [9]. The final step was comparing each reconstructed image from all frequency variation to see the effect of frequency on quality of the reconstructed image and real image were included.

III. Results and Discussion

After measuring the boundary voltage of practical phantom. The boundary voltage was processed by unit control. Each voltage of number measurement was presented by boundary voltage distribution graph. The complete boundary voltage data was contained homogenous and inhomogenous voltage data. Homogenous condition was happened when the phantom was empty. If the phantom was contained an anomaly like PVC, it would happen an inhomogenous condition. The result of homogenous and inhomogenous voltage condition would show a difference between them and it can be seen as shown in Figure 2.

The form of boundary voltage distribution graph has special behavior. When the voltage measurement point is near current injection point, it has high voltage and it is decreasing if measurement point moves away from current injection point. From figure 1 shows the voltage shifting at peak point 4th and 5th, it happens because there is an anomaly on the phantom near electrodes 4th and 5th. the shifting voltage goes to upward. It means as the Kirchhoff's law on electricity said voltage is linear to resistance if current is kept constant. From correlation above, it can be analyzed when the PVC's anomaly was located inside of phantom and it was high resistivity. The voltage was increasing. So, the inhomogeneous line in that peak point is going upward shifting but this was the preliminary detection of anomaly's position and it doesn't show the distribution of conductivity. So, the next step is image reconstruction to see the anomaly's conductivity distribution inside the practical phantom.

The voltage shifting also happen in variation of current frequency but it describes another physical phenomena in EIT like Cola-cole does. In Cola-cole load analysis, it was said that when frequency of current is high. The current can pass through the medium with high resistivity. From this research, that cola-cole load principle will be proved with real application on practical phantom and also the influence of frequency to the image reconstruction result will be analyzed too. As mention on method, the frequency of current was 1mA, 10kHz to 50kHz and it was injected to the practical phantom. It gaves the result voltage distribution graph. But now it only show on specific peak point with all frequency variation result data as shown in Figure 3.

From Figure 3, the shifting voltage for each frequency is appeared. Higher frequency makes the the boundary voltage is decreasing. It happened because the current can easily pass through an anomaly for higher frequency. When current can easly pass, it can be easily said that the resistance is decreasing. But it is not completely true. It happen because the principle of Impedance. In impedance theory, when Alternating Current (AC) pass through circuit or medium that the medium has resistance, capacitance and inductance characteristic. The impedance will be appeared as the result of those characteristic. The capacitance characteristic has more sensistivity with frequency changing because of the reactance principle. When high frequency of current pass through capacitor. The current will be passed easily and the impedance result from capacitor is decreasing.

So, the impedance can't impede the current so the voltage is decreasing as the frequency increment. Form Figure 3 proofs the theory about the influence of current frequency. But it needs more evidence that shows the influence of frequency. So the next step is comparing the image reconstruction result of each frequency to add more evidence that the influence of frequency really does. After all boundary voltage of each frequency variation was measured. Then, it would be compared with each other to see the best result of image reconstruction. The comparison of each reconstructed image from each frequency variation shows in color distribution that blue color as a more resistive medium. In this case, the anomaly is a cylinder pipe (PVC) that located in the specified location to see the accuracy of EIT and identify the electrical properties of materials as shown in Figure 4.

At 10 kHz frequency, it gives better-reconstructed image than another does. Higher frequency gives lower intensity and size of conductivity distribution from image reconstruction. It happens because of the characteristic of frequency effect when passes through the medium as theory above. When higher frequency, current can easily pass through an anomaly and at the location of anomaly has increased the conductivity, so the blue color will decrease the intensity and shift to the positive value of color bar. However, the ability of EIT to detect PVC as resistive materials has accomplished as shown in Figure 4.

From Figure 4, the noise is shown by another color that opposite the anomaly. In this case is red color. It happened because there is corrosion at the electrode 1st and 2nd and also noise can happen if the contacting area of medium doesn't set perfectly and current signal has noise too. So, in this research, every measurement step is checked and set perfectly to minimize that noise.

IV. Conclusion

In this research, we studied the influence of frequency in image reconstruction result of high-speed Electrical Impedance Tomography (EIT).The result of this research is The use of 1 mA, 10 kHz sinusoidal constant current for image reconstruction in the two-dimensional high-speed Electrical Impedance Tomography demonstrated the best performance compared to others because the image reconstruction itensity color matches with the real image coverage area.The EIT system can recognise the anomaly object placed inside in the system. For future work, it is planned to find the best result imgae reconstruction of this current frequency variation when it is injected to human tissue.

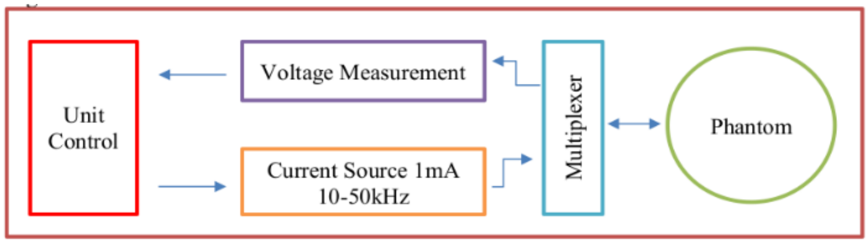

Figure 1. EIT device diagram with high-speed measurement process.

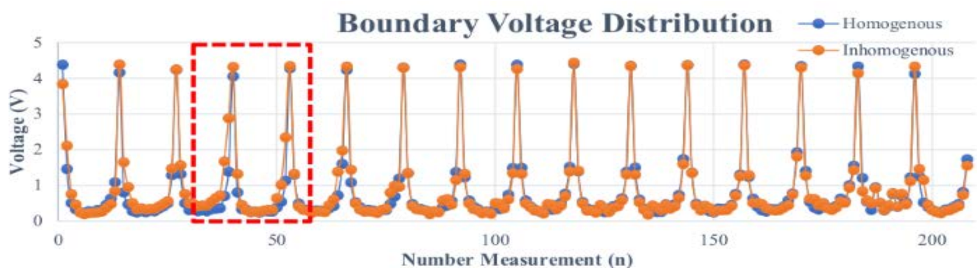

Figure 2. Boundary Voltage distribution at 10kHz.

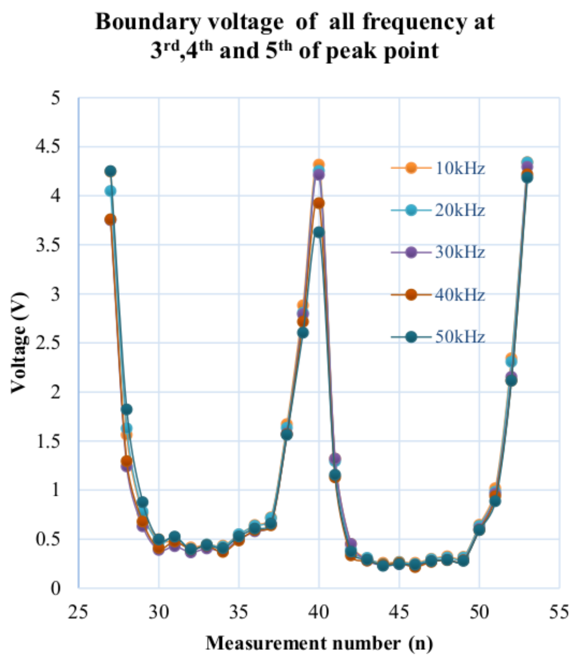

Figure 3. Boundary voltage for all frequency at specified peak.

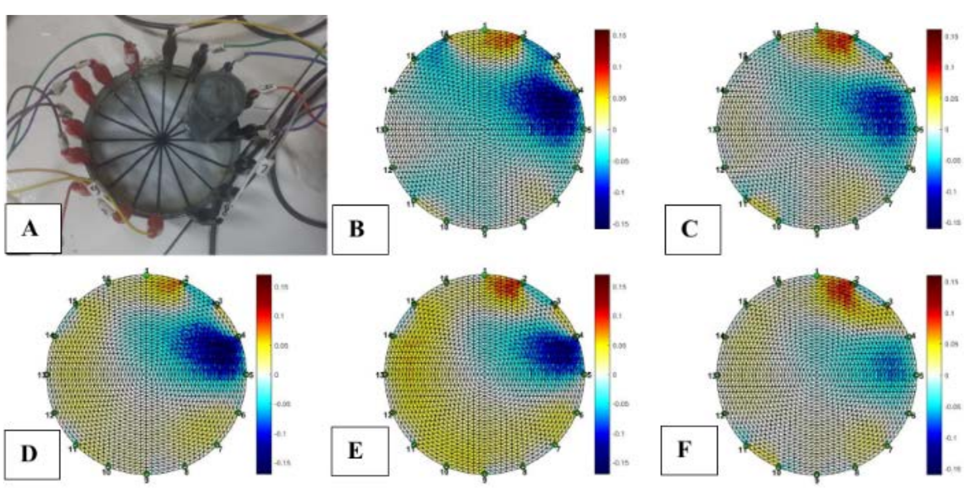

Figure 4. Comparison between(A) real image, reconstructed image at(B)10kHz, (C)20kHz, (D)30kHz, (E) 40kHz and (F) 50kHz constant current 1mA injection.

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