Design of Voltage Measuring Circuits in Electrical Impedance Tomography Based on Dual Frequency Phase-Sensitive Demodulator

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Abstract: In this paper, a dual frequency phase sensitive demodulation (PSD) technique is suggested to measure electrode voltages in electrical impedance tomography. The simulation results obtained by the dual frequency PSD are compared with the single frequency PSD in terms of accuracy on a simple phantom.

1 Method

Electrical impedance tomography (EIT) is a noninvasive imaging modality based on the reconstruction of the conductivity profile inside a solution domain. In an EIT system, imaginary and real parts of observed voltages need to be measured accurately. In the past researches, the phase sensitive demodulation (PSD) technique has been used for extracting the amplitude and phase of the electrode voltages [1]. Figure 1 shows the block diagram of single frequency PSD in bioimpedance measurements. The output of the multiplier circuit consists of a dc component and an ac signal with double frequency. To separate out the dc component, a low-pass filter is needed to eliminate the ac signal. If the dc component is very lower than the amplitude of ac part, the dc component is not accurately measured. In bioimpedance measurements, the mismatch of the imaginary and real parts of electrode voltages can be effects on the measurement accuracy [2]. To resolve this mismatch, a dual-frequency PSD has been used to accurately measure the voltages in [2]. In the voltage measuring circuit with dual-frequency PSD, two signals with different frequencies can be used to excite the tissue and the real and imaginary parts of electrode voltages can be measured in two different low and high frequency, independently (Figure 2). In EIT measurements, when the imaginary part of electrode voltages is very low, an auxiliary higher frequency is used to increase the amplitude of imaginary part of electrode voltages; resulting the measurement accuracy of the imaginary part can be improved. Table 1 presents the simulation results obtained for voltage a port with single frequency PSD at f_0 =1 *kHz* on a simple phantom. The results obtained with dual frequency PSD technique at corresponding frequency f_0=1 *kHz* and auxiliary frequencies f_a=10 *kHz* and f_a=20 *kHz* are shown in Table 2.

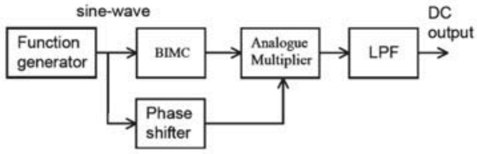

Figure 1: The block diagram of single frequency demodulator [2].

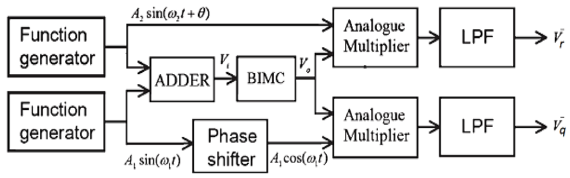

Figure 2: The block diagram of dual frequency demodulator [2].

Table 1: Simulation results with single frequency PSD at *f*=1 *kHz*.

Exact solution		Simulation results		Relative error rate	
Real part $V_r^E(V)$	Imaginary part $V_q^E(V)$	Real part $V_r^S(V)$	Imaginary part $V_q^S(V)$	Real part E_r (%)	Imaginary part E_q (%)
0.4995	0.00157	0.4985	0.00138	0.2	12.1

Table 2: Simulation results with dual frequency PSD at f_0=1 *kHz*.

Exact solution		Simulation results			Relative error rate	
Real part $V_r^E(V)$	Imaginary part $V_q^E(V)$	Auxiliary frequency f_a (*kHz*)	Real part $V_r^S(V)$	Imaginary part $V_q^E(V)$	Real part E_r (%)	Imaginary part E_q (%)
0.4995	0.00157	10	0.4988	0.00143	0.14	8.9
		20	0.4988	0.00153	0.14	2.5

2 Conclusions

The dual frequency analogue phase sensitive demodulator has been presented in EIT measurements for extracting the amplitude and phase of the electrode voltages accurately on the simple phantom. Simulations show the voltage measurement accuracy has been improved by using the dual frequency PSD technique.

References

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[2] D. Chen, W. Yang, and M. Pan, *IEEE Trans. Instrum. Meas.,* Vol. 60, pp. 1276–1282, 2011.