



PROCEEDINGS

**ELECTRICAL ENGINEERING & INFORMATION
TECHNOLOGY RESEARCH TOWARD
ECO-FRIENDLY TECHNOLOGY
AND HUMANITY**

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Chair: Munawar A Riyadi

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Presenter bio: I am Lecturer at electrical engineering department unmer - malang
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Chair: Aghus Sofwan

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Presenter bio: I received my B.S degree from Diponegoro University, M.S. degrees from Universitas Indonesia, Indonesia, in 2005 and 2011, and Ph.D. degrees from Nagoya University in 2016. My research interests include molecular robotics, DNA computing, signal processing and machine learning.

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Presenter bio: My name is Syafi Muhammad T, I am a Master Student in Universitas Indonesia. Currently, I am at my second semester and this is my first paper submission!

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Presenter bio: I am a lecturer and researcher on Departement of Information Systems at Madura Islamic University. my research concern on fields e-government, smart city, technology acceptatance, technology adoption, human computer interaction/user experience

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Presenter bio: I am Emny, a lecturer at Universitas Bina Nusantara, School of Computer Science major in software engineering.

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Presenter bio: I work at Kariadi Hospital as an Electrical Planner. I studied at Diponegoro University in Semarang by majoring in Electrical Engineering.

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A New Experiment of the Capacitive Sensors for Identification of Signal Fluctuations

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Abstract— This study shows a new approach method of material identification system using a capacitive sensor called the multi-frequency capacitive sensor system. The material to be measured is a pure liquid of H₂O. This sensor system's workings are to use the principle of EIS (Electrical Impedance Spectroscopy), in which the measured material is non-invasive or not in direct contact with the sensor. The material is put in a vessel that has been wrapped with foil paper and coated by four electrodes sensor. The new approach method used is to obtain a signal response that is a pulse signal. It has the value of the difference in voltage reduction between the output voltage and the input voltage stored by DSO (Digital Storage Oscilloscope). This study aims to get the primary signal assumed to be noise, but the desired noise. Several frequencies inputs are low frequencies, where vary from 1 kHz - 1 MHz. Therefore, the results obtained clearly show that the multi-spectral capacitive sensor system can produce the main input. This main signal is assumed to have fluctuations values of the signal response of the measured material. Also, it will be advanced signal processing that is identified quite correctly.

Keywords—capacitive sensor, fluctuations, material identification

I. INTRODUCTION

A capacitive sensor is one types of sensor that is undergoing progressive development. Utilization has been applied in various studies, ranging from smartphones to biomedicine, including knowing the composition of a material. One method that utilizes the dielectric property of capacitors is Impedance Spectroscopy (IS).

Impedance spectroscopy is an observation field related to the electrochemical. It has three approaches that are often used until now: transient signals, single frequencies, and noise signals. Several researchers before [1-5] have researched water identification that applies single frequency impedance spectroscopy. It aims to take measurements and show the results of the impedance response.

Research on transient signals that predicts EIS spectra and provides the resulting responses have been carried out by several scholars [6-7]. Furthermore, an approach that uses white noise signals has been developed by reference [8-10], which analyzes some of the effects of chemicals using the EIS method. The study conducted by H. Ashassi investigated ZnO nanoparticles' effect at several different concentrations in the anti-corrosion activity of epoxy coatings in NaCl solution

using the EIS method [8]. Furthermore, A.M.Homborg had demonstrated a two-time – frequency technique that produced an effective solution for trend removal. All measurements were made with a Compactstat control computer from Ivium technology that works on zero resistance ammeter and potentiometer [9]. The results show a consistent value for the residual power of the (potential) signals. Furthermore, a study conducted by F. Mansfeld has monitored the performance of the layer by observing trends in various experimental parameters and conducting analysis in time and frequency domains [10].

We propose the study that creates a tool for data acquisition of a material that we call the Multi Frequency Capacitive Sensor (MFCS). The system has an approach that resembles the noise signal in the spectroscopy approach, and also they have been developed in the following studies [8-10]. MFCS is a tool that works based on observations on fluctuations. It is represented based on the average statistical magnitude and standard deviation of the spectral noise observed in many data sets. This research is a frontier project because of the new approach we use. Besides, this research can also determine the ability of the MFCS tool to identify molecules in certain materials, from pure water, mixtures of chemicals, oils, and so on. Lastly, this sensor system is expected to be a device that can detect or identify a substance's content without any direct contact between the sensor and the material tested, so it has no destructive properties.

To distinguish the sensors used in this study with some sensors that have existed in several previous studies to identify the ingredients, especially the essential ingredients liquid or water and water mixed with several chemicals. Then, we will present several study results related to this study. Firstly, Min Seok reported on the design of a ring-type impedance sensor that can optimize water level measurements in the air. The approach used is a systematic numerical calculation that determines the electrode and the ring sensor[11]. Furthermore, Serge had made sensors using screen-printing methods at different temperatures, and he implemented the scanning electron microscopy (SEM), and Fourier transforms infrared spectroscopy (FTIR)[12].

Besides, B. O'Flynn demonstrated water quality with a monitoring station. Water quality parameters monitored are

pH, temperature, depth, conductivity, turbidity, and dissolved oxygen [13]. Then, Laurence Noirez had identified solid-like properties measured at room temperature in liquid water, and the method used consists of small shear stress to the fluid through contact to the surface [14]. Furthermore, Siu Chun Michael using a Bragg fiber grating sensor designed to detect the presence of a liquid aimed at giving an early warning signal for water ingress[15].

Furthermore, a study conducted by Q. Zilian showed a new non-contact method. It applied an Eddy current sensor to monitor flow in a pipeline based on the relationship between water-flow pieces and the inductance of the sensor [16]. The rearrangement of an ECT sensor and a model-based image reconstruction algorithm used for the thickness of the liquid layer has also been examined by Yi Li[17]. Then, Tinghu described a flow sensor based on an impedance polarization electrode to measure low water flow. Here, four electrodes are inserted into the pipe section via a mounting block[18]. H. Dibo detected contaminated water events tested with a water quality time series from an automatic water quality sensor [19]. Furthermore, Z. Serge designed a multi sensor to detect the main parameters of water quality [20]. Then, N. Amr had presented a non-destructive evaluation, a new technique for detecting water composite structures by evaluating the dielectric properties of different composite systems in their constituent materials [21].

In addition, capacitance sensors have been widely used to measure and monitor some of the activities and conditions of materials. However, material as an object is not liquid but oil. In [28], they evaluated the two-phase flow parameters in the tube bundle to analyze the vibration existence mechanism by separating the high sensor sensitivity with the optimal response. They use a simulation approach to improve measurement accuracy. Also, in [29], they had presented a new approach, so that capacitive sensors can effectively detect changes in the lubricating oil. Then, they display a qualitative relationship between the sensor and the lubricating oil with the compensation method. The results show that this sensor can be used for monitoring lubricating oil under certain conditions.

In this study, we use H₂O as an object placed in a pipe or vessel. The change in capacitance between electrodes caused by changes in the concentration or distribution of the dielectric material in the measured content. It represents the permittivity distribution in the pipe or vessel that has been reconstructed first. Furthermore, we do data processing automatically via a PC. We use frequencies in the low-frequency range ≤ 1 MHz. It is because low frequencies are easier to generate frequencies and also better at the noise. Whereas, low frequencies it can be predicted that the most dominant noise will occur. However, this noise is the desired noise that displays significant fluctuations or changes in the material being measured. In the end, the expected outcome of this study is a square signal. This is obtained by utilizing the low frequency as the signal input. The reason why the output is a box signal is because the value of the box signal has a lot of harmonic pattern so that it can generate the material identified.

This study is divided into several stages, starting from the background of the study conducted and some related references. Next, we will explain the research method that we implemented in this study and then show the results and analysis in the next section. Lastly, we provide some concluding points from the reviews we have done.

II. RESEARCH METHOD

The experiment in this study uses MFCS, which is a tool built by the research team to detect changes in the material on a molecular scale. This sensor works based on the principle of impedance spectroscopy, so it has the property not to damage the molecules/material being detected. The MFCS sensor is built into the shape of a measuring tube, which is surrounded by four electrodes separated as far as 90° with the grounding electrode in between. The four electrodes are divided into two pairs, namely the main pair and the disturbing pair. The first electrode in the first pair is connected to the primary input, and the second electrode of the main pair is connected with a predetermined impedance. The first electrode of the disturbing pair is connected to the disturbing input and the second electrode is connected with an impedance that has the same value as the electrode of the main pair.

The main input generates a voltage of 26 volts peak to peak, with a frequency that changes between the range of 1 kHz to 1 MHz. While disturbing input has not been used for a while. Then, this input produces an electric field, which then causes movement. This movement creates a voltage difference that is read by the system as an observed value fluctuation.

For a more precise way, the work of the MFCS proposed in this study, the MFCS system schematic, can be seen in Fig. 1 and the visualization shown in Fig. 2. The material measured and connected to the main input will be placed in a chamber. The chamber used is the Eyela SLI 220 incubator, with the temperature set between 340C-360C. Several considerations are using the chamber. First, the temperature at the time of data collection requires a long time. Then, it is more stable and is not affected by external temperatures that often change. Then, the Digital Storage Oscilloscope (DSO) is used as a feeder and reads the output and stores the output from the sensor. The reason for choosing DSO is because it is easy to manage its output via a PC and connect to a computer via Universal Serial Bus (USB). The DSO used in this experiment is the Picoscope 3000 series manufactured by the Pico Tech company.

Then, data processing is done automatically through a Personal Computer (PC) using Matlab software into 2D (dimensional) form graphics. From this 2D graph, we will obtain and study a change in the H₂O material. So this research can determine where the work point of the MFCS tool is. Fig. 1 shows the performance system of MFCS used in this study.

Therefore, in this study, we propose an approach method for processing signal fluctuations that are the output of MSCS data acquisition with more appropriate equations to be easier to handle. The following will explain some of the approach methods we use to obtain signal processing results.

First, the input voltage can be seen in (2), as follow:

$$V_{in}(t) = f_{in}(t) + N_{in}(t) \quad (2)$$

Where, $V_{in}(t)$ is an input signal in time domain, $f_{in}(t)$ is the perfect square wave and then $N_{in}(t)$ is the noise.

Next, we obtain the voltage value on channel C, which is the sum of the input frequencies with the input noise, noise from the material and noise from the equipment, which is shown in the following equation.:

$$V_c = f_{in}(t) + N_{in}(t) + N_{material}(t) + N_{equipment}(t) \quad (3)$$

Then by referring to (3), the results are still in the time domain, the output obtained on channel B is called V_{out} and the equation becomes:

$$V_{out}(t) = V_{in}(t) - V_c(t) \quad (4)$$

Based on (2) and (3), we will get the value of V_{out} with (5):

$$V_{out}(t) = (f_{in}(t) + N_{in}(t)) - (f_{in}(t) + N_{in}(t) + N_{material}(t) + N_{equipment}(t)) \quad (5)$$

When simplified, then (6) becomes:

$$V_{out}(t) = N_{material}(t) + N_{equipment}(t) \quad (6)$$

Equation (6) is converted into the frequency domain:

Where, $V_{in}(t)$ is the voltage on channel A in the time domain, then, $V_{out}(t)$ is the voltage on channel B in the time domain. $V_c(t)$ is voltage on channel C in the time domain, $V_{out}(f)$ is voltage on channel B in the frequency domain. $N_{in}(t)$ is noise at input in the time domain. $N_{material}(t)$ is noise from material objects in the time domain, $N_{material}(f)$ is noise from material objects in the frequency domain and $N_{equipment}(t)$ is noise from equipment in the time domain.

Finally, Fig. 5 shows the comparative value of the value obtained from the subtraction of the value on channel C with the input signal on channel A in absolute value based on (6). For more details, one of the initial results is read on DSO at a frequency of 10 kHz, where the signal is still in a time domain and then converted into the frequency domain by using Fourier transform.

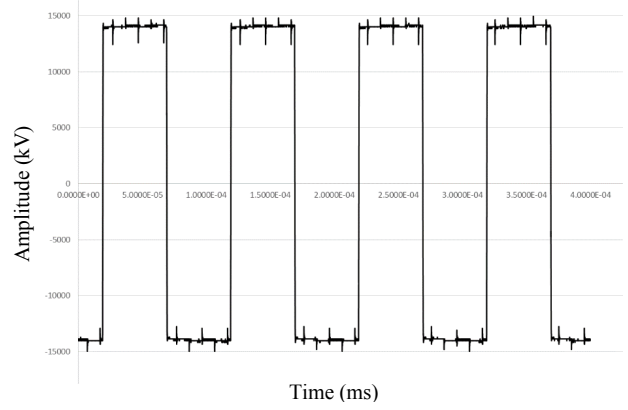


Fig. 3. The Results of MFCS Acquisition Data on Channel A (Y_A) DSO Output for 10 kHz Input Frequency.

As highlighted in Fig. 5, the resulting difference values look very volatile with marked up and down amplitude values for various times. Because the results is shown in Fig. 5 are still in the time domain, for further analysis purposes, it will be converted into the frequency domain. It is demonstrated by changing the frequency spectrum, as shown in Fig. 6. These results will be analyzed later, assuming that the spectral noise produced will show the distinctive characteristics of each material measured using MFCS.

From Fig. 6, it can be seen that the x-axis is spectral noise, and the y-axis is amplitude. For more details, the results of spectral noise that is already in the frequency domain, as shown in Fig. 6, the amplitude values range between the range -60 to 0 dB. Then it moves down and then looks more stable fluctuations starting from spectral noise 20 to 60 kHz.

Fig. 7 shows the Difference Between MFCS Acquisition Data Spectral Results on DSO Channels C (Y_C) and Channels A (Y_A) for the 100 kHz Input Frequency in the Frequency Domain. A different event is seen for the results shown in Fig. 7, the amplitude value slightly decreases at the beginning and then drops at 15 kHz spectral noise. Signal fluctuations are seen up and down which starts at 20 kHz up to 60 kHz.

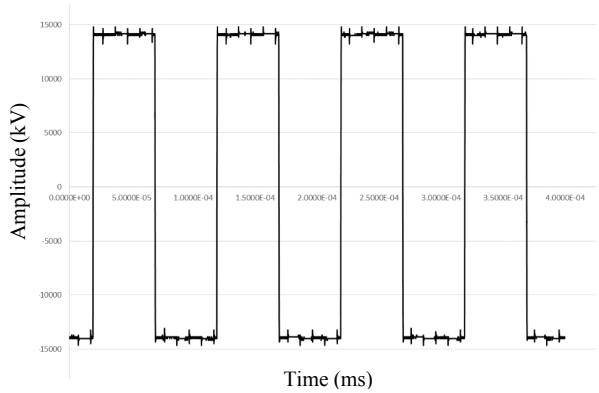


Fig. 4. The Results of MFCS Acquisition Data on DSO Output Channel C (Y_C) for 10 kHz Input Frequencies.

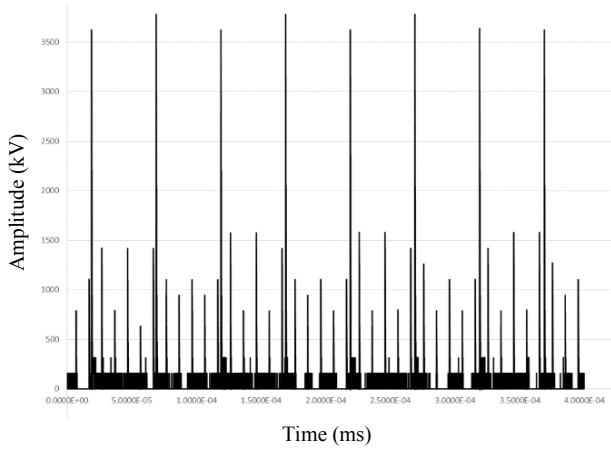


Fig. 5. The Result of MFCS Acquisition Data Difference on DSO Results of Channel C (Y_C) and A (Y_A) for the Input Frequency of 10 kHz in Time Domain.

A very different phenomenon is shown in Fig. 8, which uses a 1 MHz input signal. From the beginning, the value has been seen to be very volatile for high and low signals, where the amplitude values range from -80 dB to -10 dB.

Based on the results obtained, it can be noted some interesting points from this preliminary study. Fig. 7 shows the results are slightly more similar to the pattern of fluctuations with Fig. 6. However, the fluctuation trends look a bit rarer. Inversely proportional to the effects of the spectral noise in Fig. 8 which uses the highest frequency, which shows a pattern of sporadic fluctuations and not so noticeable fluctuations.

From the results of the difference in spectral noise for several different frequency inputs, it is pronounced that the fluctuation patterns are quite volatile. It will later help you in the further process to process the fluctuation patterns of the multi frequency capacitive sensor data acquisition.

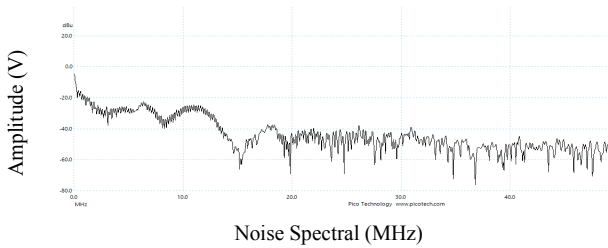


Fig. 6. Difference in the Results of Spectral Data Acquisition of MFCS on DSO Channels C (Y_C) and Channels A (Y_A) for the 10 kHz Input Frequency in the Frequency Domain.

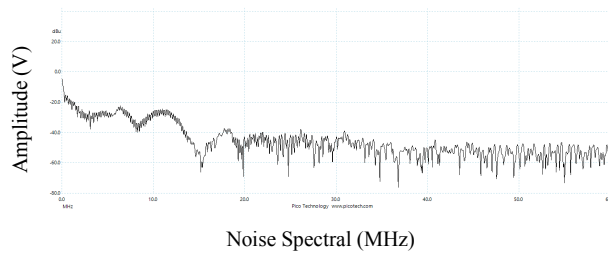


Fig. 7. Difference in the Results of Spectral Data Acquisition of MFCS on DSO Channels C (Y_C) and Channels A (Y_A) for the 100 KHz Input Frequency in the Frequency Domain.

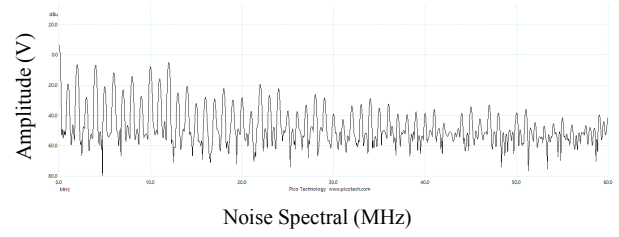


Fig. 8. Difference in the Results of Spectral Data Acquisition of MFCS on DSO Channels C (Y_C) and Channels A (Y_A) for the 1 MHz Input Frequency in the Frequency Domain.

Then, based on (1), we obtain the value of the fluctuation mean value (FMV) as shown in Fig. 9. The main purpose of the FMV will be to facilitate the computation and to process of quite large data sets from material identification. Based on Fig. 9, the x-axis is displayed in units of MHz, with a range of values ranging from 10^{-2} MHz to 102 MHz, which is spectral noise. Where, the y axis is a display of the input frequency, which is also displayed in units of MHz, with a range of values ranging from 10^{-3} MHz to 1 MHz. In this study, there are 31 input frequencies at low frequencies, as shown in Table 1. The scaling limit for the minimum amplitude value is 0, and the maximum amplitude value is 50.

In other words, Fig. 9 shows a fluctuation pattern of a material obtained from the data acquisition process by applying a capacitive sensor. In the end, the resulting fluctuation pattern can be used to identify the material and will be processed further.

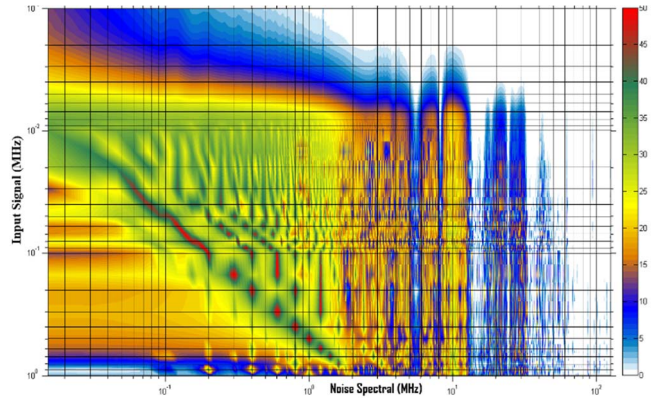


Fig. 9. MFP (Mean Fluctuation Pattern) of H2O

IV CONCLUSION

This research has obtained square waves by implementing multi frequency capacitive sensors with four electrodes. Whereas, the square wave is obtained from the reduction or the difference value between the input value and the output value that we store the value in the txt file. Based on these results, future work carried out is to analyze the mean fluctuation, so that it can be used for the development of a material identification system by utilizing the results of these sensors.

ACKNOWLEDGEMENTS

We are very grateful to those who have provided financial assistance, which is LPPM Unsyiah through Grant Lektor with Number: 118/UN11.2.1/PT.01.03/PNBP/2020.

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