Low Cost PVDF Sensor Casing for Ultrasound Power Measurement

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Abstract: - Ultrasound machine is widely used in industrial and medical institutions as one of its capability to visualize the image inside the object non invasively. In the medical sector, any over access of ultrasound wave can cause heating which may be harmful to the human skin. In order to avoid the unwanted power exposed to human, ultrasound power meter is required. The existing ultrasound power meter, however is high cost, heavy and only for therapy machine. Since few years ago, polymer sensor (PVDF) has been explored to be a potential candidate for ultrasound sensor. This sensor has excellent bandwidth and acoustic coupling. In order to enable the PVDF sensor for low cost ultrasound power meter, a robust low cost casing has been developed in this project. The casing has been designed to enable the optimum capturing ultrasound power from therapeutic and diagnostic ultrasound machine, minimize interference effect and noise as well as stabilize mechanical construction of sensor. Test result shows acceptable correlation between ultrasound intensity and sensor’s generated voltage. Hence, this design can be calibrated and collaborated with processing devices in order to complete the low cost ultrasound power measurement system.

Key-Words: - PVDF, Ultrasound, Intensity, Power, Sensor, Receiver, Casing

1 Introduction
Ultrasound is one of the most popular and productive non-invasive therapeutic and diagnostic modality. The most frequencies used for the diagnostic and therapeutic purposes are about 1-10 MHz. Higher frequency of the ultrasound will give good resolution of image. However, high frequency and high power ultrasound may cause harmful to the human soft tissues but it is not as danger as magnetic resonance imaging (MRI) and Computed Tomography (CT) [1].

PVDF (polyvinylidene fluoride) is a thin film that is strong and tough as reflected by its tensile properties and impact strength. Some advantages of the PVDF are stable to UV and the effect of weather, low smoke generation, also excellent transmittance of solar energy, excellent dielectric strength, high heat resistance and excellent physical and mechanical properties for a fluoropolymer [2]. However, robust casing of PVDF sensor for well functioned ultrasound application is not yet well defined [3] [4]. In order to enable the utilization of PVDF sensor for ultrasound power measurement, a robust casing has been designed and implemented using low cost material.

The casing is built from plastic material. There are two PVDF film attached inside the tank-type casing. The size of the casing can be varied and depends on the size of therapeutic or diagnostic ultrasound probe. The work was also to investigate a low cost appropriate material that can absorb the ultrasound wave. This material or absorber is important to reduce the reflection of ultrasound wave inside the receiver. In order to reduce the current leakage and protect the signal from external noise, a special connector between sensor and electronic circuit also developed.

For testing purpose, 1 MHz frequency from ultrasound therapy machine was used in this project. The ultrasound probe area is 5 cm². De-gassed water was used as ultrasound wave propagation medium.

2 Development Method
The expected result is a designed casing for ultrasound power meter receiver. The casing should be able to protect the sensors from the water leakage.
that can cause short circuit to the electrical part. Besides that, the receiver should have a good absorber that can prevent the ultrasound wave from being reflected into the receiver and increase the chance for the sensor to capture good signal from the ultrasound transducer.

This project used ultrasound transducer to give ultrasound wave to the designed receiver. It also used oscilloscope to detect and measure the signal from the receiver. Meanwhile, data analysis was done with the help of computer software.

General setup for the system is described as in Fig.1.

![Fig.1 General view of system](image)

The system is being used to receive the signal from the ultrasound transducer/transmitter (therapeutic or diagnostic probe) and display it at the oscilloscope in terms of voltage by varying the intensity of the power emitted by the transmitter.

### 2.1 Fabrication of water-tank

The fabrication of the water-tank is based on the power meter available in the market. The difference is the sensor used to measures the ultrasound signal from the ultrasound transducer. For the available power meter in the market, they are using radiation force based position sensor as the main sensor to detect the ultrasound signal. This project uses PVDF sensor to detect the ultrasound signal. The actual illustration of this water-tank can be seen in Fig.2. Two holes at the bottom of the tank are for the PVDF sensors.

![Fig.2 Schematic of water-tank](image)

Outer casing is made of Polyvinyl Chloride (PVC). The height of the PVC pipe used is about 90 mm with 110 mm diameter and 2 mm thickness. There are some reason using this type of casing, i.e. because it light in weight, low-cost, easy to cut and can avoid from any current leakage to the user.

The cutting must be perfect to avoid any water leakage during the experiment. The bottom of this pipe is closed by hard plastic with two holes for the PVDF sensor. PVC glue is being used to glue those two parts together.

Rubber is a material that has a good attenuation characteristic which is used to absorb the access ultrasound wave inside the tank as shown in Fig.3. The blue material is rubber that already sticks inside the inner wall of the PVC pipe. The thickness of the rubber is 15 mm. At the bottom of this casing, there are 2 holes for the PVDF sensors.

![Fig.3 Rubber inside the casing: top view (a), side view (b)](image)

### 2.2 PVDF sensor housing

SMA connector is a high frequency component that is used as the base of the PVDF sensor as shown in Fig.4. Top section of the SMA connector is connected with brass casing to hold the PVDF films. Conductive Epoxy is inserted inside the brass casing that act as backing material and as the adhesive between the PVDF and the conductive part. Top of the PVDF also have a layer of nonconductive epoxy that used to secure the PVDF from the water. This sensor is directly connected to the coaxial cable (RG-58). There are two sensors needed for the tank type and this is one of them [5]. This sensor then will be put at bottom of the tank.

![Fig.4 PVDF sensor with SMA connector](image)
Backing material is used to ensure the effective operation of the sensor as well as adjusting certain bandwidth. It must be sufficiently attenuating to absorb the ultrasound wave incident. For this sensor, EPO-TEK EE129-4 was used also as the material to make an electrical connection. It comes with part A and Part B, this part should be mixing together with ratio of weight is 1:1. It takes almost 8 hours to become hard and can conduct electricity.

The backing material used under the PVDF film for wave attenuation is mixing of aluminum powder with the epoxy resin. This material will reduce the signal by absorbing the ultrasound wave which may cause some echo and noise to the signal. Aluminum is being used because it is a soft metal so easier to make a smooth surface. It also has relatively low acoustic impedance among other metal [6].

This sensor is totally immerse in the water. Therefore, after it is plugged at the bottom of its casing, plastic glue was used to protect the sensor from water leakage. At top side of the PVDF sensor also must be protected by using epoxy resin hardener. This hardener should not have bubble inside it because it can disturb the ultrasound wave and it should be a very thin layer to avoid it becomes attenuation to the wave.

2.3 Integrated receiver casing
After the fabrication of PVDF sensor is completed, the last step is to insert the sensor at the bottom of the casing. Plastic glue is being used to stick the sensor and the base of the tank together. Fig.5 shows the complete design of the tank-type power meter. The gold color inside the tank is the PVDF layer that has already covered by the epoxy resin to prevent it from water leakage. This PVDF sensor is connected to the BNC cable that will connect this receiver to the oscilloscope.

3 Implementation and Testing
This receiver has been tested using the ultrasound transducer. For better visualization, we can see the diagram on the Fig.6. The transducer head is approximately 5cm from the sensor and the head surface is immersed inside water in tank. For this project, only one transducer head is used that is 5cm² with frequency 1 MHz (as capability of available ultrasound therapy machine).

![Fig.6 Implementation setup](image.png)

Water used inside the tank, as a measurement medium, is degassed water. That because ultrasound propagation in water closely approximates in the human tissues. The ultrasonic attenuation in the water can be taken as a lower limit on the attenuation which will be encountered in the human body. Large areas in the body can consist of low attenuating material such as urine and amniotic fluid. The use of water prevents measurements in a more highly attenuating material such as liver equivalent gels from representing the highest possible intensities which might be encountered in the body [7].

The procedure to make a degassed water is, boil distilled water one 20 minutes, then pour into a suitable container, seal tightly and place in the refrigerator. This process will give the required quality. The container should be heat resistance glass or thick plastic may be used after the water has been cooled. Before testing, pour water into tilted test tank to minimize the turbulence. The test tank water surface will absorb the oxygen and a change of degassed water is recommended before each experiment [7].

The experiment was conducted by varying the power emitted by the transducer head from 0.1W/cm² to 1.9W/cm². The output voltage peak-to-peak produced was recorded at the oscilloscope. The temperature level being used is at room temperature.
From the result as can be seen in Table 1, the output voltage shows some pattern while the intensities of the transducer head are higher. If the output voltages become increase as the intensities of the transducer head increase somehow we can say that the voltage output is proportional to the intensities of the transducer head.

Table 1 Voltage versus intensity

<table>
<thead>
<tr>
<th>Intensity (W/cm$^2$)</th>
<th>Voltage (V)</th>
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<tbody>
<tr>
<td>0.1</td>
<td>10.6</td>
</tr>
<tr>
<td>0.2</td>
<td>10.8</td>
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<tr>
<td>0.3</td>
<td>11.3</td>
</tr>
<tr>
<td>0.4</td>
<td>11.5</td>
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<tr>
<td>0.5</td>
<td>11.7</td>
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<tr>
<td>0.6</td>
<td>11.9</td>
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<tr>
<td>0.7</td>
<td>12</td>
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<tr>
<td>0.8</td>
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<td>0.9</td>
<td>12</td>
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<tr>
<td>1</td>
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The following Fig.7 shows graph of voltage versus intensity.

![Fig.7 Graph voltage versus intensity](image)

The non linear result is likely because of the noise from surrounding and also noise from the reflection of the ultrasound wave inside the tank itself. The noises cause the input signal become worst to be captured by the sensor. Still, linear correlation between voltage and non-zero intensity is approached in Equation 1.

$$V = 0.914I + 11.03$$

4 Conclusion

In this project, a low cost robust PVDF sensor casing has been successfully developed. Receiver housing is fabricated with inexpensive material and producing a good functionality. The unique design has been obtained while the test result shows a possibility to use it for ultrasound intensity measurement purpose. The derived formula can be further implemented along with data acquisition and signal processing platform for low-cost ultrasound power measurement system.

References:


