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Study on Detection of Sediment in the Avalanche using the Microwave Doppler Sensor

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1. INTRODUCTION

In this study, to detect the sediment portion of the avalanche that contain sediment using the microwave Doppler sensor. The microwave Doppler sensor used in this study is 24 GHz band. Since microwaves in this frequency band are not easily affected by rain and snowfall, these are being developed for use in drive recorders and other applications. However, it is necessary to understand the attenuation of the microwave for the snow in order to apply this technology to detect the sediment in the avalanche. It is also necessary to know the rate of reflection of microwaves from the snow and sand. Therefore, it is necessary to verify whether the reflection of the microwave from the sediment is correctly measured or not.

In this report, we discuss the results of the verification to see if the distance between the sensor and the object, which is known in advance, can be detected correctly.

2. MICROWAVE DOPPLER SENSOR

In this study, the Microwave Doppler Sensor that can emit microwaves in the 24 GHz band was used (NJR-4262J: New Japan Radio). Figure 1 shows the Microwave Doppler Sensor used in this study. This sensor can detect the position of an object by using the fact that the frequencies of the transmitted and reflected waves are shifted by the Doppler effect when the radio wave is reflected from the object. In this case, the IQ signal, which is the phase of the transmitted wave and the received wave, can be obtained from the sensor. This signal is detected when the target object is approached, the I output is $+\pi/2$ greater than the Q output, and when the object is separated, the I output is detected $-\pi/2$ greater than the Q output. This effect can be used to monitor the movement detection of an object.

In this study, we used Arduino uno to realize a simple measurement system. Arduino uno is one of the general-purpose microcontroller boards. In addition, the microwave Doppler sensor used in this study is an analog output type. Therefore, we used an AD converter to get the digital data. An overall diagram of the measurement system is shown in Figure 2. The sampling rate of the measurement data was set to 50 Hz.

Figure 1. Microwave Doppler sensor

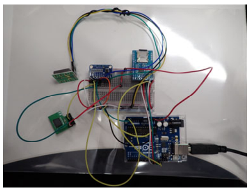

Figure 2. Measurement system

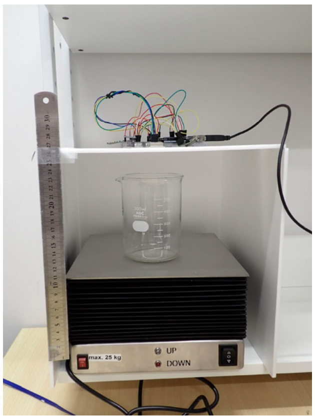

Figure 3. Overall view of the experimental system

3. EXPETIMENT CONDITIONS

In this experiment, sand and water were placed in a 500 ml glass beaker, and the beaker and the object were moved by means of the elevating machine that operated at a constant speed. The beaker was filled with four cases: empty, only water, only sand and water with sand. These objects were irradiated with microwaves from the top of the beaker to detect the signals. Figure 3 shows an overall view of the experimental system. The displacement speed of the elevating machine is 0.01 m/s. The object used in the experiments is shown in Figure 4. The object filled with sand in the beaker was prepared in two cases in amount of 150 ml and 300 ml of sand. The distance between the sensor and the top plate of the elevating machine is 16 cm, and the distance from the position where the content of the beaker is 500 ml to the sensor is 7 cm, and the distance from the position where the content of the beaker is 300 ml to the sensor is 10 cm. Each object was measured by repeating move up and down 3 times.

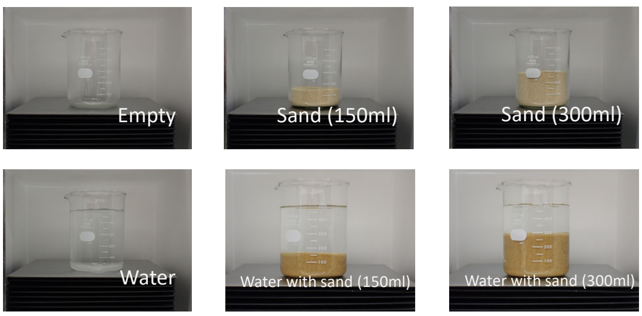

Figure 4. The object used in the experiments

4. EXPERIMENTAL RESULT AND DISCCATION

Figure 5 shows the output results of the I and Q signals and the resultant value of the I and Q signals obtained in the experiment. In figure 5, red shows the I signal, blue shows the Q signal, and green shows the resultant value of the I signal and the Q signal. The resultant value of the IQ signal is defined by the following equation

$$V_{IQ} = \sqrt{{V_I}^2 + {V_Q}^2}.$$

It is known that the amplitude of the signal obtained from the microwave Doppler sensor varies with the presence of the object. In the result of the measurement, we found three points where the amplitude oscillated greatly. In addition, each point was symmetrical and the time of the large amplitude oscillation was about 3 seconds. In this experiment, the raising and lowering of the elevating machine was done in 3 seconds each in all the experiments. It can be seen that the three points where the waveform changed greatly in all the measurements responded to the movement of the elevating machine. In other words, we can see that this measurement system is able to detect the movement of the object.

In the next section, we analyze the results of the measurement with the object containing sand only in the beaker. It can be seen that there is a difference in the amplitude of the waveform obtained by the movement of the elevating machine between the case with and without the sand. The difference in amplitude is smaller when the sand is as little as 150ml than when the sand is empty, and larger when the sand is 300ml. Accordingly, it can be seen that the difference in amplitude is dependent on the type of moving object and also on the distance to the sensor. However, the voltage obtained from the first step-up cycle to the second and third cycle was different from the initial value.

Next, the object filled with water up to 500 ml scale is analyzed. The first thing that can be confirmed from these results is that the voltages obtained by all the I and Q signals returned around the initial values after three cycles. This indicates that the signals obtained tend to be stabilized when water is included in the object. In addition, the amplitude that responds to the movement of the elevating machine is larger in the case of water only than in the case of an empty object. This indicates that the sensor used in this experiment is affected by water. On the other hand, in the case of the object containing sand and water, the difference in amplitude of the waveform obtained is different as in the case of the object containing sand only. These results suggest the possibility of using the microwave Doppler sensor to distinguish between water and sand for object detection.

In the future, we plan to conduct frequency analysis and noise signal processing to enable more detailed classification.

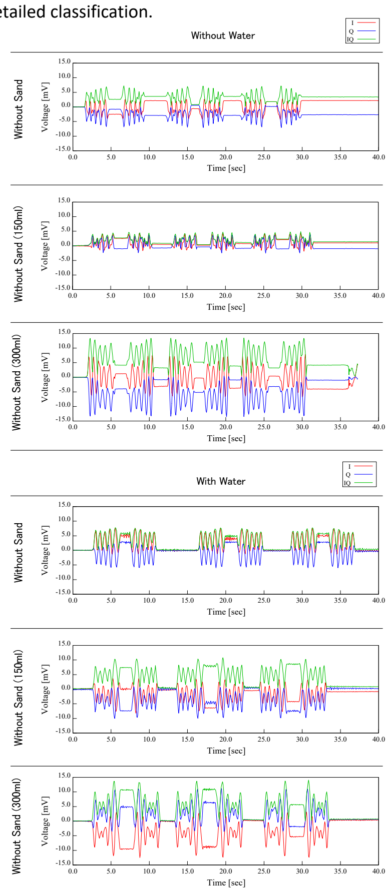

Figure 5. Experimental results

References:

[1] Nguyen Thi Phuoc Van, Liqiong Tang, Veysel Demir, Syed Faraz Hasan, Nguyen Duc Minh, and Subhas Mukhopadhyay: Review-Microwave Radar Sensing Systems for Search and Rescue Purposes, Sensors (Basel), 10.3390/s19132879, 2019.