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Ultrasonic exploration at extreme shallow underground in submerged soil

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Now a lot of land mines remain buried in the world, so that the clearance of them is required. As a tool of removing land mines, equipments using electromagnetic radiation are often employed. However, there is a problem that the land mines in the flooded soil such as in Southeast Asia cannot be detected in the rainy season. Therefore, the new way using sound waves will be profitable to detect the land mines in the flooded soil. In this research, the acoustic exploration at very shallow area in submerged sand is examined at a water tank in the lab. First we measure the propagation property of ultrasound of 120 kHz in the shallow submerged sand, and examine underground imaging. As a result, the acoustic velocity is measured at about 1500 m/s and the attenuation is measured at about -19 dB/m. And next, shallow underground exploring by using acoustic shielding boards is carried out. As a result, underground images in the water tank simulating the submerged soil are obtained. Then acoustic shielding boards can block wave which propagates specific route. This will make another exploration method possible.

1 Introduction

Now a lot of land mines remain buried in the world, so that the clearance of them is required. As a tool of removing those land mines, metallic detectors or Ground Penetrating Radar (GPR) are often used. However, they are not effective in Southeast Asia in the rainy season when most of the land is flooded and change into marshes, because electromagnetic waves are not transmitted well in water. Therefore, using sound waves will be profitable to detect the land mines in the flooded soil.

The acoustical propagation in the fluid-saturated porous has already revealed in the Biot–Stoll theory, and it can be calculated by the Biot-Stoll model[1-2]. While Prof. Kimura researches a sound wave propagation model and the propagation mechanism in marine sediment with this theory[3) , we research a propagation at very shallow area in submerged sand because our final purpose is to search land mines at submerged land. However, because Biot-Stoll model needs 13 parameters, this theory is difficult to apply in the very shallow submerged sand. Then we measure acoustical propagation in very submerged sand at the lab. In this research, for an acoustic exploration at very shallow submerged sand, we measure the propagation property of ultrasound at 120 kHz and we produce several images of underground.

2 Underground exploration using acoustic shielding board

Our final purpose is the underground exploring for detecting the landmines buried in submerged soil. Then the exploring method should be easy and safe. To scan the underground by a not buried transducer is suitable for such cases. Figure 1 shows our exploring method for detecting buried objects. It makes an easy exploring possible, because we do not have to bury transducers. At such cases, we usually record strong signal from ground surface. But an acoustic shielding board blocks these waves, and only signals from target would record. We tried some experiments for verifying this theory.

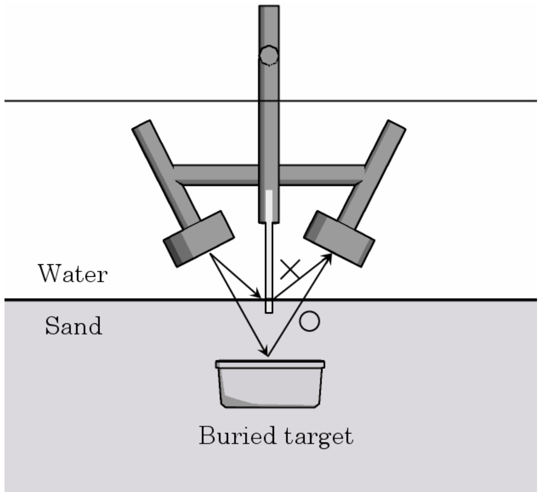

Fig. 1. Our exploring method with ultrasounds emitted from the water. The acoustic shielding board placed in the middle of the transducers block direct wave and reflected wave from the ground surface.

3 Experimental

3.1 Experimental environment

Experiments are carried out in a water tank of 500 liters in capacity (width 128 cm, height 96 cm, depth 48 cm). Sand particles of 200 to 300 micrometers in diameter taken from a shore are put in this water tank. Water is poured in around 5 cm in depth above the sand surface. As a transmitter and a receiver, we employ two transducers whose resonant frequencies are about 120 kHz (8 cm in diameter, 4cm in thickness, PZT element, 17 degrees of directivity). The transducers are fixed with pipes for focusing. Focal length can be adjusted for a target object. The appearance of the transducers fixed with the pipes is shown in Fig.2. The buried target for exploration is a hollow plastic container (width 12 cm, height 9 cm, depth 5 cm). As a transmitting signal, burst waves of 120 kHz at 7 cycles are generated by a function generator (Tektronix AFG 3022), and the electric power of about 300 W is put on the transducer through the amplifier (ENI 2100L). The received waves are recorded with the oscilloscope (Tektronix TDS2002). Furthermore, we employ acoustic shielding boards (width 13 cm, height 18 cm, depth 0.5 cm waterproofed styrofoam). Ultrasound which is propagated through the specific route is blocked by these shielding boards. We put them for blocking a direct wave.

Fig. 2. The picture of transducers fixed with the pipes. The focal length is variable.

3.2 Measurement of propagation properties in very shallow submerged sand

Firstly, in order to confirm the propagation of ultrasound, we measure the velocity and the attenuation of ultrasound which is propagated through at very shallow submerged sand. Figure 3 shows outline of the measurement. A target object is buried at 3cm in depth. Transducers are buried at the same depth of the target. Two transducers are fixed for focusing about 30 cm. The acoustic shielding board is set in the middle of the two transducers. We move the target away from transducers at the intervals of 5 cm. The distance from the transducers to the target is change 20 cm to 55 cm. At each distance, reflected waves from the target are recorded. Figure 4 shows the received waves at each distance. Slope of an oblique line in Fig. 4 shows the propagating velocity of about 1500m/s. Figure 5 shows the attenuation of ultrasound. Slope of an oblique line in Fig. 5 shows the attenuation of about -19 dB/m. However the value of attenuation would change by situations, because we set the transducers for focusing about 30 cm. The value of velocity and attenuation are also change depending on density, specific gravity, pressure and particle size of sand, etc. Then an accurate measurement and comparing with the theory value are necessary. Another measuring method is also necessary for measurement of attenuation, because the focal length is fixed at this experiment. However, the propagation of ultrasound can be confirmed. From these reflected waves, it can be said that underground image of nearby area is obtained.

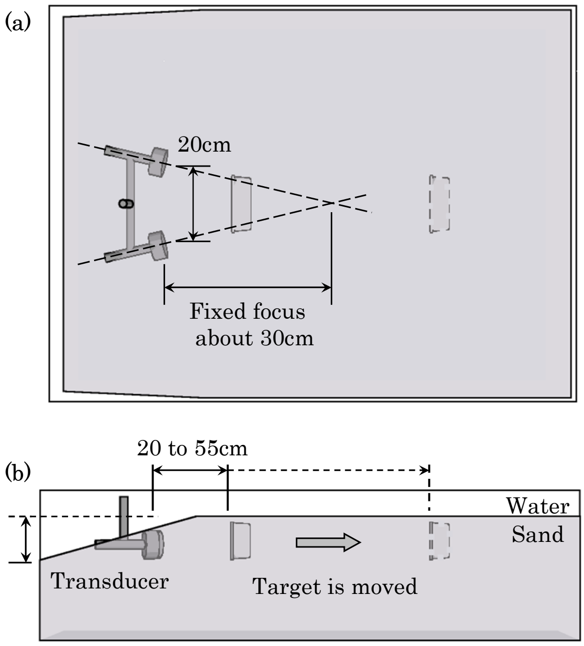

Fig. 3. Outline of the experiment for measurement of propagation property: (a) Top view, (b) Side view.

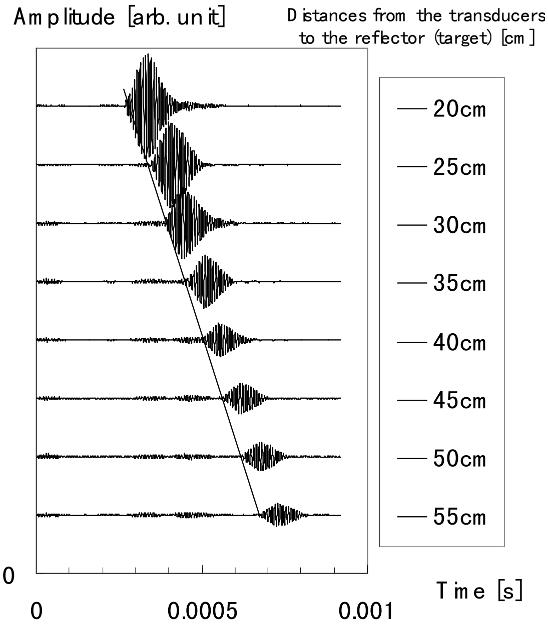

Fig. 4. Reflected waves at each distance. Slope of an oblique line shows the propagating velocity of about 1500m/s.

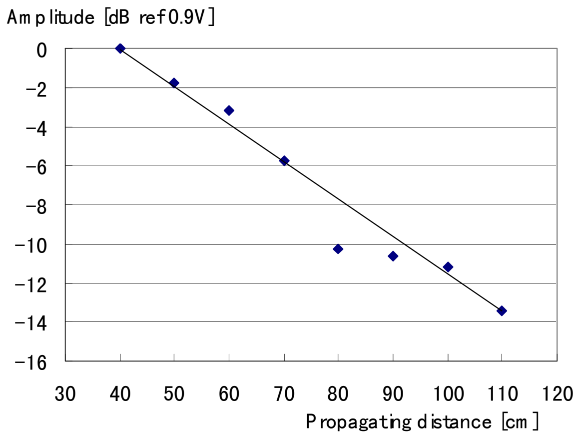

Fig. 5. The attenuation of ultrasound. Slope of an oblique line shows the attenuation of about -19 dB/m.

3.3 B mode image of shallow underground

Ultrasounds are thought to propagate in the above velocity and attenuation. By using this wave, we obtain an image of very shallow underground by scanning the transducers. Figure 6 shows a top view of the experiment. The transducers and two targets are buried at 3 cm in depth. The transducers are fixed for focusing about 30 cm. The distance from scanning line to targets are 25 cm and 35cm. The transducers are scanned by 2 cm. At each point, reflected waves from the targets are recorded.
We calculate an underground image shown in Fig. 7. The velocity is assumed to be 1500 m/s. In Fig. 7, rectangle lines show sizes and points of the buried targets. The buried points and responses of signals are almost corresponding. In Fig. 7, reflected signals from longer distance of 35 cm have stronger amplitude than distance of 25 cm. This would be caused by gap of focal length. To explore specific area, we can adjust focal length. As a result, B mode image of very shallow underground can be obtained by ultrasound wave at 120 kHz.

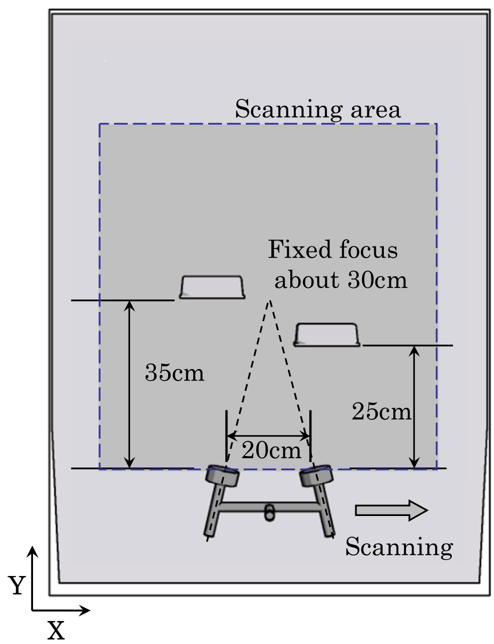

Fig. 6. Top view of the experiment for the B mode imaging. Square written in broken line shows scanning area.

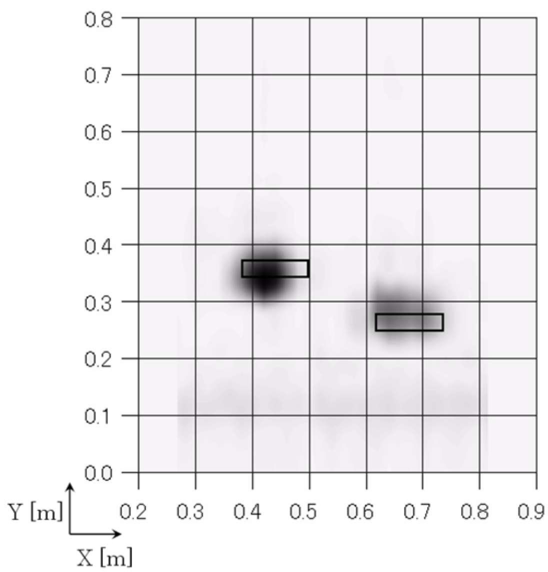

Fig. 7. Under ground image at the depth of 3 cm in water tank.

3.4 Three dimensional image of shallow underground

In order to easier exploring, we set the transducers to emit ultrasound downward. The ultrasounds are emitted in the water and propagate into underground. An advantage of this method is that the transducers do not have to be buried. An image of shallow underground is obtained by this method. At this experiment, we set transducer on the ground because the surface of the water is shallow. Figure 8 shows positions of the transducers and the buried target. Small circles in Fig. 8 (a) show measurement points. The transducers are scanned by 2 cm in two dimensions. The focal length is fixed about 10 cm. The oscillating surfaces of the transducers are set on the ground surface.

Figure 9 shows calculated image of underground. And a cross section where x is 56 cm is shown in Fig. 10. a rectangle line shows the size and the buried point of the target. The buried point and responses of signals are almost corresponding. As a result, we confirm the reflected waves from the buried target by using ultrasounds emitted downward. And shallow underground images can be obtained by this method. However, the transducers are set on the ground surface at this experiment. An exploration by using ultrasound emitted from water with transducers not contacted the ground should be carried out. This is a future task.

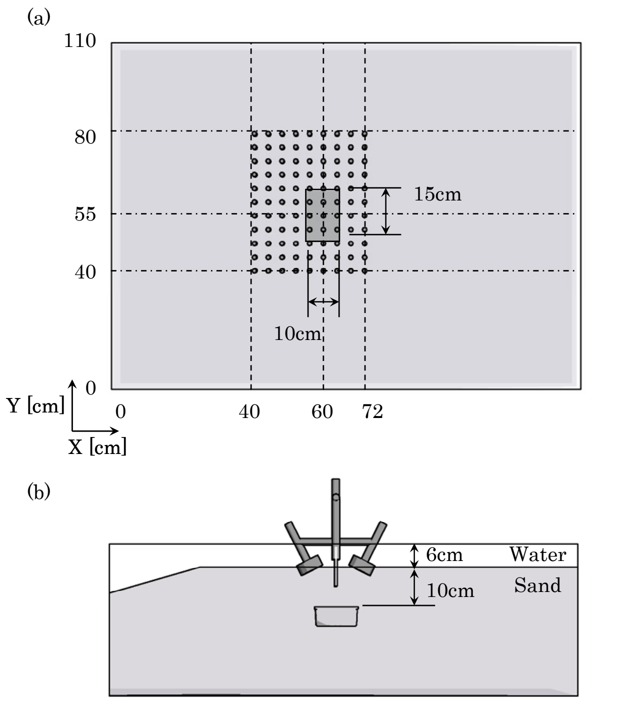

Fig. 8. Outline of the experiment for three dimensional image: (a) Top view. Small circles in this figure show measurement points, (b) Side view. Focal length is adjusted to buried depth of the target.

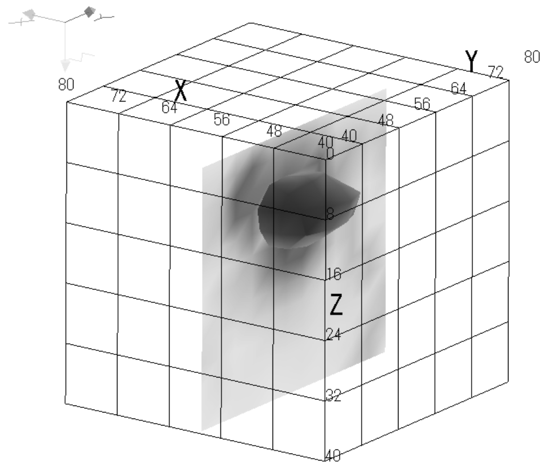

Fig. 9. Three dimensional image of shallow under ground.

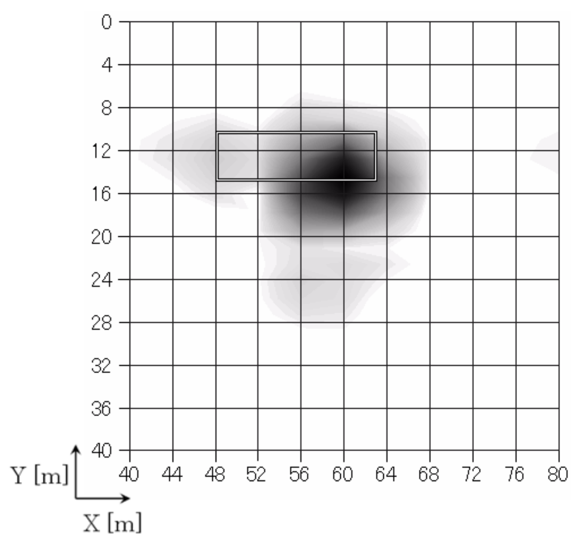

Fig. 10. Cross section where x is 56 cm. A rectangle line shows size and buried point of the target.

4 Conclusions

Ultrasound propagating very shallow area in submerged sand is confirmed. As propagation properties of ultrasound at 120 kHz, the acoustic velocity is estimated at about 1500m/s and the attenuation is estimated at about -19 dB/m. And with this wave, underground images in the water tank simulating the submerged soil are obtained. Then acoustic shielding boards can block wave which propagates specific route. This will make another exploration method possible.

References

[1] M.A.Biot, Theory of elastic waves in a fluid-saturated porous solid. 1. Low frequency range, J.Acoust. Soc.Am, 28 (1956) 168-178.

[2] M.A.Biot, Theory of elastic waves in a fluid-saturated porous solid. 2. High frequency range, J.Acoust.Soc.Am, 28 (1956) 179-191.

[3] M.Kimura, Basics of marine acoustics - unconsolidated sediment -, MASJ, 2000 (in Japanese)