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Effect of Rayleigh Wave on Ultrasonic Underground Imaging

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Abstract

In order to acquire image with higher resolution and less error for detecting underground objects, a three dimensional ultrasonic underground imaging technique using an electromagnetic-induction type sound source and an amplitude correlation synthesis processing (ACSP) method has been proposed in our previous work. Depending on the conditions of the ground surface, Rayleigh waves propagating along the surface directly may be received with significant amplitude by the receiver array. That will cause interference with the reflect signal of the underground objects and will bring forth error images to the imaging result. In this paper, the Rayleigh wave with comparatively high amplitude is measured experimentally in a model field filled with mountain sands, and its waveform is estimated and simulated approximately by an exponentially decaying sinusoidal wave. The effect on the image of underground object is discussed by synthesizing the received signal with the modeled Rayleigh wave with various relative amplitudes. The result images calculated by ACSP method show that the effect of Rayleigh wave is not marked when its peak amplitude is not greater than that of the signal reflected from the underground object.

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Keywords: Rayleigh wave; ultrasonic imaging; underground; amplitude correlation synthesis processing

1. Introduction

An efficient method for nondestructively detecting underground objects such as pipelines or buried relics is expected. Owing to the serious unevenness of acoustic parameters and the large attenuation of high frequency waves

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in shallow underground, ultrasonic signals with poor time resolution and signal to noise ratio (SNR) will be received. In our previous work, an ultrasonic underground imaging method using an electromagnetic-induction (EMI) type sound source and an amplitude correlation synthesis processing (ACSP) method has been proposed [1, 2]. Based on the synthetic aperture focusing technique [3], a nonlinear processing method [4] is introduced to the underground imaging processing, in order to acquire images with little error and high resolution from comparatively few received signals with poor SNR and resolution.

Because the sound velocity of sand and soil is a very complicated parameter that depends on grain size, grain density, porosity, and moisture content, etc., up to now, the sound velocities we employed for signal processing were measured from buried receivers. As an attempt of improving the efficiency for field testing, we began to discuss this issue from study the relationship between velocities of ultrasound propagating underground and along ground surface. However, the results showed too little differences between the velocities of underground longitudinal wave and that of the wave propagating along ground surface [5].

In this paper, the ultrasonic waves propagating along ground surface are re-measured with different physical conditions of the ground surface. The results of sound velocity analysis suggest that a Rayleigh wave with comparatively high amplitude may be received. Moreover, by using simplified models of pulse wave reflected from underground object and Rayleigh wave propagating along ground surface, the effect of Rayleigh wave on imaging result is discussed.

2. Ultrasonic waves measured from ground surface

The measurement is carried out on a model sand bath. The size of the sand bath is 3 m cubic and is filled with mountain sands. The theoretical waveform radiated by the EMI sound source can be expressed as [6]

$$s(t) = \exp(-2 f_a t)\left[\sin\left(2\pi f_a t + \tan^{-1}\frac{1}{\pi}\right)\cdot\frac{1}{\sqrt{1+\pi^2}}\right] \tag{1}$$

where f_a is the main acoustical driving frequency, which is set to be 460 Hz in the experiment. Anyway, because of the attenuation of high frequency part, the main frequency in received signal is only about 300 Hz. Piezoelectric type acceleration sensors are employed as receivers, which has a very flat frequency response below 2 kHz.

The EMI sound source and 6 receivers are arranged as a linear array along the diagonal line of the sand bath. The receivers are placed with identical interval of 10 cm, and their distances to the center of the sound source are 1.0 m ~ 1.5 m, respectively.

During the measurement, we changed the moisture and hardness of the ground surface intentionally. Fig. 1 shows two signals received by the receiver at 1.0 m with different ground surface conditions. Though both the start times of the wave are similar at about 6 ms, the lower one shows a component with high amplitude from around 12 ms.

Figures 2(a) – 2(c) show the example of signals received at different distances, with the ground surface conditions same as the lower waveform shown in Fig. 1. These waveforms indicate that there are two different waves, one with lower amplitude and faster velocity, while the other with higher amplitude and slower velocity.

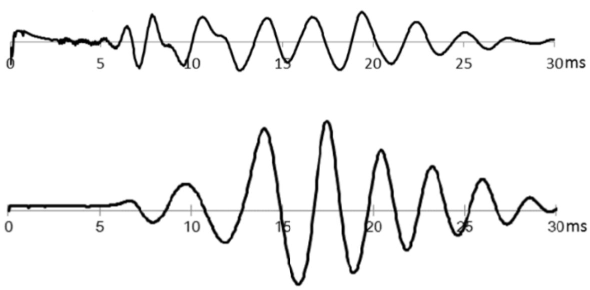

Fig. 1. Example of two waveforms received at 1.0 m with different ground surface conditions.