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PHYSICAL ACOUSTICS

Experimental Measurement of Acoustic Properties in Snow[1]

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Abstract—This paper presents the results of field experiments done for the measurement of attenuation constant and speed of sound in the snow medium. The field experiments were conducted at two locations corresponding to relatively dry and wet snow. The main objective of our method is to overcome the potential limitations of the other methods. There are two major concerns: one is sound signal leakage and the other is the measurement need to be done within a same layer of snowpack. The reflections from the boundaries will affect the measurements. In our experiments the transducers are kept far from the snowpack boundaries, so that there will be no likelihood of strong reflected signals from the boundaries. These issues have not been addressed by the other researchers. This work adds to the measurement results of the attenuation constant and speed of sound in snow that are available in the research literature. It is found that sound signal attenuation greatly depends on the frequency of sound signal and wetness of snow.

Keywords: snow, attenuation constant, sound speed

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1. INTRODUCTION

The attenuation constant of acoustic signal is one of the useful physical parameter of snow. Also, the sound speed in snow is another important parameter required to be known in many applications like snow characteristics determination using acoustic reflectometry. In the research literature, little field experiment data is available about the attenuation constant and the speed of the sound signal in snow medium [1–5]. Also, the available attenuation constant results are not consistent with each other. Recently, researchers have shown their interest in non-invasive acoustic techniques for finding the properties of snow [6, 7]. Snowpacks generally consist of snow with different physical properties, like tortuosity, porosity and density. The practical usability of acoustic methods for finding snow properties depends on the amount of attenuation of the acoustic signal in snow. In this paper, the attenuation constant as a function of frequency and the sound speed at various frequencies in snow obtained through field measurements are reported.

The attenuation constants determined in [2, 4, 5] were measured in the laboratory using snow columns with dimensions of few centimeters kept in metal structures. So, there will be strong multipath signals due to reflections from the walls. These reflected signals will potentially affect the measurements. Also, the signal can travel through the metal structure and arrive at the receiver transducer, as it is coupled with the structure [5]. Our experiments were conducted in natural snowpacks in the field, and it was ensured that there would be minimal disturbance to the snowpack. At each location only two readings were taken to find the attenuation constant. In view of the available environment conditions, the experiment could not be repeated more times, nor at more locations. It is carefully ensured that there is no air gap after the microphone is inserted. If the air gap is present, the signal will also travel through the air that will affect the estimated attenuation constant.

The next section describes the experimental setup for finding the attenuation constant of an acoustic signal in snow. The third section focuses on the experimental procedure for finding attenuation constant of acoustic signal in snow. In the fourth section, the mea-

[1] The article is published in the original.

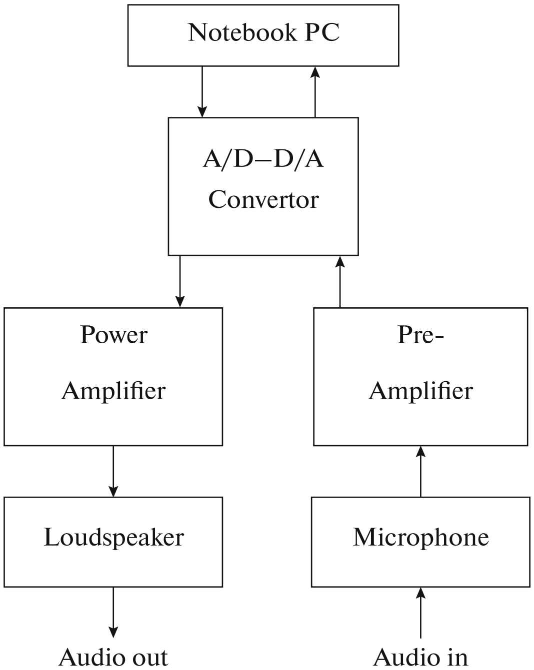

Fig. 1. Block diagram of an attenuation constant measurement system.

surements of the attenuation constant by field experiments are given. The final section contains the conclusions of the paper.

2. EXPERIMENTAL SETUP

Figure 1 shows the block diagram of the experiment setup. The appropriate test signal is generated by a notebook PC and converted into an analog signal. This conversion is done using a digital-to-analog converter. The signal is then amplified by a power amplifier. The amplified signal is transmitted through the loudspeaker, facing downwards parallel to the surface of the ground. The acoustic signal is recorded using a microphone inserted in the snow at a given depth after pre-amplification, the analog recorded signal is digitized using a 24-bit A/D converter and stored in the notebook PC. The distance between the speaker and the snow surface is 70 cm. The important specifications of the equipment used in the block diagram are given in Table 1. All the devices used in the attenuation constant measuring system are rated for –10°C. The designed experimental setup is versatile and can also be used for other applications like measurement of attenuation of sound in the foam medium, estimation of parameters of porous road pavement etc. [8, 9].

3. EXPERIMENTAL PROCEDURE

To measure the sound signal attenuation, a microphone of diameter 10 mm is inserted in the snowpack parallel to the snow surface, as shown in Fig. 2. The attenuation constant analysis of sound signal in snow is carried out by directly recording the acoustic signal

Table 1. Specifications of components of the attenuation constant measurement system

Power amplifier	Bandwidth (–3 dB)	1 Hz–70 kHz
	Power output	80 W
	Signal-to-noise ratio	115 dBA
Pre-amplifier	Bandwidth (–3 dB)	15 Hz–50 kHz
	Gain	60 dB
	Input impedance	100 kOhm
Loudspeaker	Bandwidth (–3 dB)	80 Hz–20 kHz
	Sensitivity (1 W@1 m)	60 dB
	Average power	60 W
	Rated SPL	105 dB
Microphone	Bandwidth (–3 dB)	10 Hz–70 kHz
	Sensitivity	31 mV/Pa
	Maximum SPL	138 dB
	Pickup pattern	Omni-directional
DAQ card	ADC resolution	24 bits
	DAC resolution	16 bits
	PC communication	USB 2.0
	Sampling rate	102.4 kS/s