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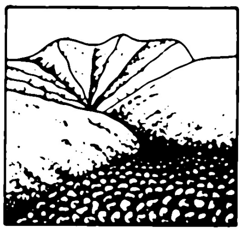

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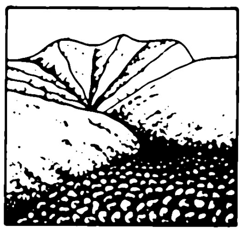

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Infrasonic behaviour of debris flow and infrasonic warning device

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Инфразвуковой режим селя и инфразвуковой прибор для оповещения

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Инфразвук – это звуковой сигнал, имеющий частоту менее 20 Гц. Человек не может слышать его. Поэтому инфразвук называют неслышимым звуком. Имеется явная инфразвуковая составляющая среди звуков, которые создаются при формировании и движении селя. Инфразвуковой сигнал селя является определяемым. Это простая гармоническая синусоидальная волна, и сила звука зависит от масштаба и типа селевого потока, обычно 0.1–10 Па. Преобладающая частота составляет около 5–15 Hz (см. рис. 1–2). Она может распространяться в атмосфере со скоростью 344 м/с. Инфразвуковой сигнал не ослабляется при прохождении значительного расстояния. Он также может проходить через очень небольшую преграду. Инфразвуковое оборудование для оповещения разрабатывается с 1990-х гг., с учетом инфразвуковых свойств селевого потока. Это оборудование было успешно использовано для оповещения о более 20 селевых событиях. Оно может применяться в других областях – при изучении лавин, обвалов, оползней и т.п.

Infrasound is a sound signal, which has frequency below 20 Hz. People cannot hear it. Therefore, the infrasound is named ‘an inaudible sound’. There is an obvious infrasonic composition in the sound emission of the debris flow being formed and moving. Infrasound of debris flow is a definable signal. It is a simple harmonic sine wave and the sound pressure has a relationship with the scope and type of a debris flow, usually varying within 0.1–10 Pa. The predominant frequency is about 5–15 Hz (see Fig. 1-2). It can propagate through the atmosphere at a rate of 344 m/s. The infrasonic signal is not attenuated for a long distance. It can also pass through a very small fence. The infrasonic warning device has been developed according to infrasonic behaviours of debris flows since the 1990s. This device has been used for the successful warning of more than twenty events of debris flow. It can be used for other hazards, such as avalanches, rock falls, landslides etc.

1 Introduction

The infrasonic subject is a branch of acoustics. It is young subject. Some infrasonic signals from natural, for example, tornadoes, strong earthquakes, aurora, volcanic eruptions, snow avalanches, and thunderstorm, etc, have been familiarized by researchers (Cook, 1962; Evers and Haak, 2003). In the meantime the research of monitor and array to infrasonic signals from nuclear bomb has promoted the development of infrasonic subject since last century

(Brown, 2003). At present the attention on environment and hazards accelerates research with relative phenomena which there are infrasonic signals.

Debris flow is a Non-Newton fluid composed of sediment, stones, and boulders. It moves along steep gully with tremendous energy. It impacts and washes stone wall and bed of gully. And sends a sound likes thunder. Sometime the eyewitness feels palpitation. Therefore we judge that there is an infrasonic composition in sound emission routing of debris flow. We have made the system of measurement and analysis to gain an infrasonic data about tens of prototype events of debris flow since 1990's (Zhang et al., 2004).The data included Sichuan, Yunnan, Taiwan, and Austria. The research result proves that infrasonic signal of debris flow is definite signal. Its sound pressure and predominant frequency is 0.1–10 Pa and 5-15 Hz. Because there are two types of debris flow mainly, i.e., viscous and low-viscous debris flow (Zhang, 2003). The sound pressure and predominant frequency will be different to these types.

2 Infrasonic behaviours of debris flow

Fig.1 is typical wave of infrasonic signals of debris flow. It is a simple harmonic sine wave and a low frequency signal. We can calculate the sound pressure from graph. The U is numeric of peak to peak The Sn is sensitivity of sensor, 50–60 mv/Pa usually. So sound pressure is P=0.707 U/Sn. It is relative with discharge of debris flow, the bigger the discharge, the higher the sound pressure. Besides the sound pressure of viscous debris flow is higher than low-viscous debris flow when their discharge is the same. We can not gain an exact quantitative relationship between sound pressure and discharge of debris flow now. But we have a rough range defined from analysis of data, i.e., sound pressure is less than 1 Pa when discharge is less than 100 cubic meter per second, is 1–5 Pa when discharge is 100-500, more than 5 Pa when more than 500. However the discharge is not a parameter only. This quantity relationship will become very confusion when many boulders mixed in the fluid of debris flow. Furthermore the ravine pattern is an important to them. In the same condition of discharge the sound pressure of debris flow canalized (the ratio of wide to depth is about 20) is more than non-canalized (>>20). Because the latter' moving likes on accumulation fan. Its energy is not focus and sound emission ability and sound pressure is less than the former.

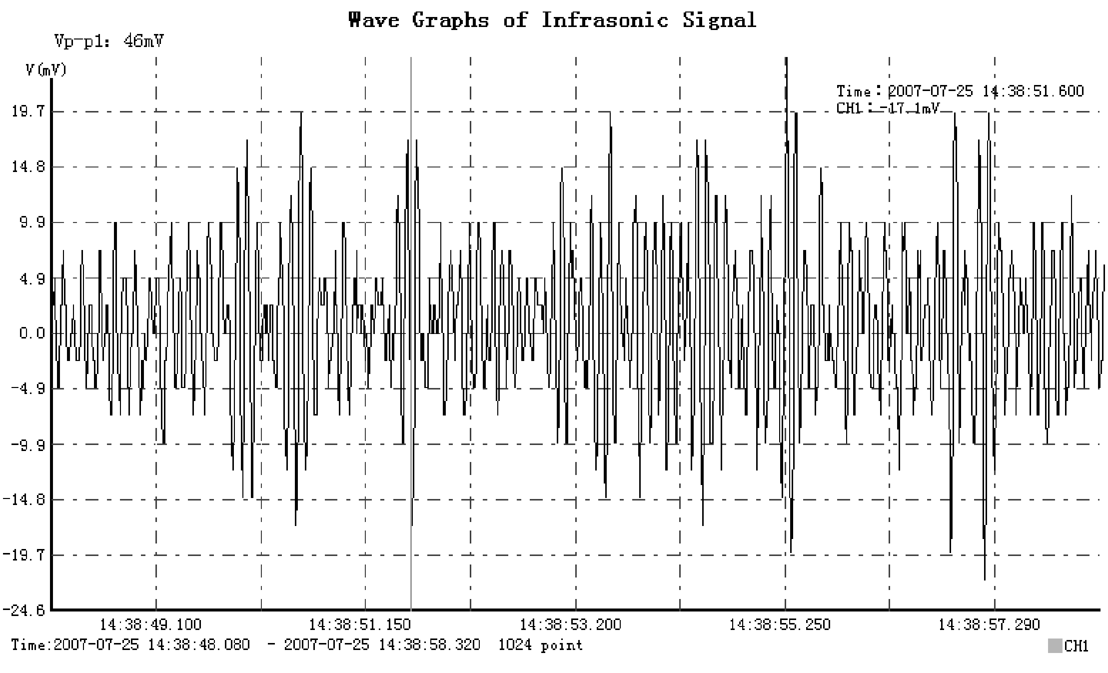

Fig.1. The wave graphs of infrasonic signal of debris flow.

We obtain the behaviours of frequency domain of debris flow infrasound from spectrum analysis. Fig.2 is typical spectrum graph. A lot of data fully testify that its predominant frequency is about 5-15 Hz, and 5–10 Hz for viscous debris flow. However we know the contribution on predominant frequency is a lot of stones and boulders of different size except the energy of fluid of debris flow. They will push it to low place in spectrum graph. Sometime there is a sharp peak in 1–3 Hz in spectrum graph when some very big boulders mixed in the fluid.

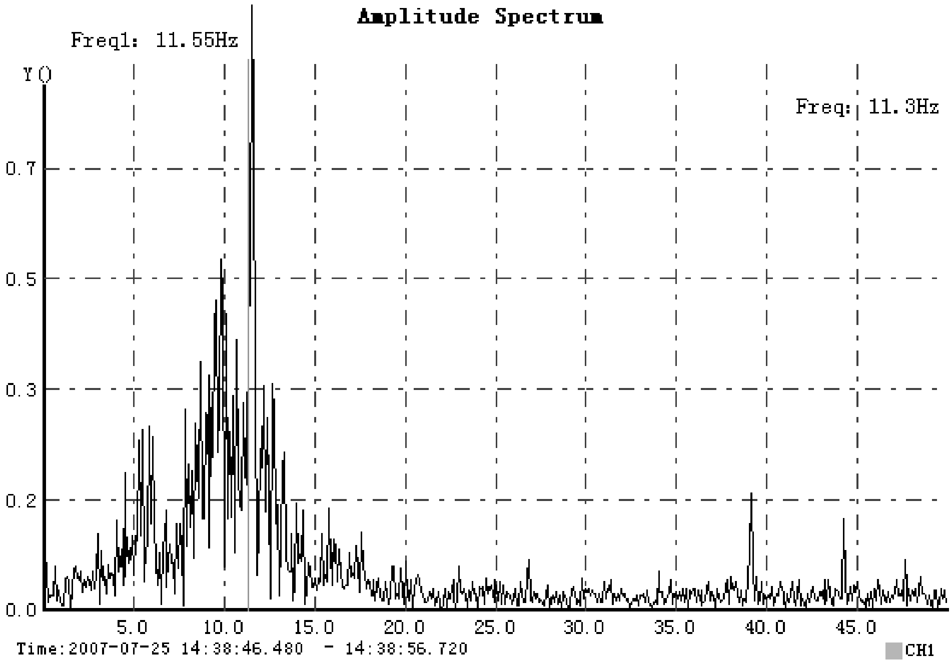

Fig. 2. The spectrum graph of infrasonic signal of debris flow.

The infrasonic signal is reduced by molecules absorption and visco– heat- conduction loss mainly. Theoretical analysis exhibits that .infrasonic attenuation with distance is very small. Cook (1962) thinks the absorption coefficient of 0.1 Hz as a plane wave is 5×10^{-8} dB/km at sea level. Its energy loss is 1% only when signal is propagated to 20000 km far away. The predominant frequency of infrasound of debris flow is 5–15 Hz. The signal absorption coefficient is about 10^{-4} dB/km. It can propagate about hundreds of kilometer theoretically. We can easy receive the signal about 5–15 km from source place of debris flow occurring.

3 Infrasonic warning device of debris flow

According to the infrasonic behaviours of debris flow first author of this paper cooperated with Acoustics Institute, CAS and has developed first generation of infrasonic warning, DFW-I Model since 1990'. It has been used on China and other countries for mitigation hazards and cooperation research. It is used in about 20 events of debris flow successfully. No one event is lost or wrong. The time between warning and coming in of debris flow is 10 min-1 hour. For this time people have enough time to escape. Recently we develop third generation warning device, named DFW-I III Model. It has been controlled by monolithic processor of PT18 F-8722 and can process and store data. The electric supply is with market and battery together. They can exchange automatically. The battery can work about 30 hours alone. The flash storage can store infrasonic data about 270 hours when the frequency of collecting sample is 100 Hz. Key part of device is sensor. The electric capacitive microphone developed by Acoustics Institute, CAS has been used for this device. This sensor, named Model CHZ system is used for comparison measurement with Model 4190, B&K (made in Denmark) and MK222 (made in Germany). The result proves they have the same characteristics. The infrasonic warning device can set indoor and far off source of debris flow. It has an obvious advantage compared with other warning ways (Zhang et al., 2004), for example, cutwire and geosound etc. The early warning system, rain gauge, camera of infra-red included will be more reliable if DFW-I III is inserted to this system. DFW-I III can be used on other fields as well, avalanche, landslide, rockfall, and dambreak of lakes and reservoirs, etc.

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