# Observation of frequency transfer function using FM ACROSS deployed in the huge tunnel at Kazunogawa site

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## 1. Introduction

This research is related to the ACROSS that is a system developed for active geophysical monitoring. Kazunogawa site is one of the test fields of ACROSS and is characterized by the deployment of the source that is fixed in a deep tunnel. This feature is able to make the source and its response stable.

The objective of this research is to obtain an accurate frequency transfer function at Kazunogawa site. In this research, we change the driving mode of ACROSS source to the mode of Frequency Modulation and carry out some experiments to observe frequency transfer functions. In the following sections, we discuss the problems of original seismic source fixed at Kazunogawa site and its improvements.

## 2. Problems of the original ACROSS source in Kazunogawa site and its improvement

The original ACROSS source in the Kazunogawa site was installed by Higashihara, et al (2002) and the source was able to excite only a harmonic wave with single frequency. The driving frequency of ACROSS source was manually changed if you wanted to observe the other frequency components. This kind of operation caused some problems:

1) Decrease in the efficiency (emitted energy/time)

2) Human errors

3) Temporal variation of the response after ACROSS source starts working. (If you want an accurate response for all frequency components, you need enough time to assure the response stable for every frequency components.)

Because of these problems, it was difficult to obtain an accurate frequency transfer function at Kazunogawa site. Therefore, we tried to change its driving mode to the mode of Frequency Modulation.

## 3. Acquisition of the frequency transfer function and waveform analysis

In an observation, the ACROSS source is frequency-modulated in the following way: 1) The frequency band is 15 to 25 Hz; 2) The modulation type is linear variation; 3) The sweep length is 20 seconds. As the results, we are able to obtain about 200 line spectra from 15 to 25 Hz at 0.05 Hz pitch.

In the analysis, at first, the observed time series data with 100 seconds length is repeatedly stacked by 36 times. This stacked data is Fourier transformed and the line spectra corresponding to the ACROSS signals are collected. Therefore, next the line spectra are decomposed by the source function and characteristics of sensors. Then, we obtain the frequency transfer function between the source and a sensor.

In order to investigate the wave components included in the frequency transfer function, we Inverse-Fourier-Transform the frequency transfer function to time series data and compare it with the theoretical wave form of a single point force in full space homogeneous medium. At the sensor #1 that is 3 meters away from the source, the observed waveform and the theoretical waveform are almost similar to each other. At the senor #2 that is about 260 meters away from the source, the amplitude of the observed waveform is larger than that of the theoretical waveform. However, the form itself seems very similar. At the sensor #3 that is about 960 meters away from the source, the observed waveform is remarkably different with the theoretical one. Therefore, it seems that the waveform at sensor #3 includes the reflected waves or scattered waves as well as the direct waves.

## 4. Summary

In this research, we install the Frequency Modulation to the ACROSS source at Kazunogawa site and carry out some experiments to obtain an accurate frequency transfer function. We also analyze the waveform by comparing the observed waveform with the theoretical waveform that assumes a single point source and full homogeneous space. From this analysis, it is made clear that the sensor #3 includes some wave components except for the direct waves.

In our future works, we will try to detect the temporal variation of the waveform and investigate the difference of temporal variation between wave components.