Controlled source electromagnetic approach with EM-ACROSS signal

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The electromagnetic accurately controlled, routinely operated signal system (EM-ACROSS) is a system which was ported from the seismic monitoring system and applied in controlled source electromagnetism (CSEM) sounding technique. We specially designed this system for a CSEM experiment at Kusatsu-Shirane volcano to investigate the subterranean space in this volcano region.

We firstly made an initial experiment for confirming the ability of this system by comparing with the magnetotelluric (MT) measurement. In this initial experiment in 2017, a signal was designed by superposition of 11 harmonics with binary frequencies, same amplitudes and random phases. A function generator, which was synchronized with a GPS clock, stored the above-mentioned signal and continuously sent it to an amplifier after a pulse trigger. The amplifier increased the voltage of the input signal 80 times then outputted the amplified signal to electrode dipole. The output signal from both the function generator and the amplifier were recorded by a digital signal logger. The transmitter system sent the signal by electromagnetic wave from southern foot of Motoshirane volcano to the receivers which located at Mount Kusatsu-Shirane. We chose the MTU-5/5A series MT units to be receivers. The receivers continuously measured the electromagnetic field from two electrode dipoles and three inductive coil censors with 15 Hz sampling rate. The initial experiment was run for four days. The transmitter system which was used in second stage experiment was modified to two amplifiers, and the transmitted signal was redesigned with pseudo binary frequencies from primary number to avoid the harmonic distortion.

The frequency spectrum of the data from both function generator and transmitter should be also checked for the accuracy of transmitted signal. The first step of the receiver data processing was time series data division. The whole time series data was divided into many ¥'frames¥' with same data length. The linear detrending method was chosen to remove the effects from strong, long term nature noise. The second step was converting the data from time domain to frequency domain by fast Fourier¥'s transform (FFT) by each frame. The third step was removing the outlier in frequency domain which either the real part or imaginary part was out of two standard deviation range then stacking the data. We calculated the impedance from the received data which was sent from different polarizations of dipoles, and the approximate apparent resistivity and impedance phase to compare with the value from MT.

The frequency spectrum of received data presented the enhancement in the signal-to-noise ratio (SNR) by data stacking. The anti-noise ability of this system was confirmed with a data from one site which measured some broadband continuous anthropogenic noise. The MT data was strongly affected by that noise which presented abnormal apparent resistivity and impedance phase. Nevertheless, the approximate apparent resistivity and impedance phase from EM-ACROSS was much closer to the value in other sites. The initial experiment in our first stage presented the requirement of a greater number of the frames to reduce the noise floor in longer period, that is the reason of the decision for running a long-term measurement in the second stage.

The initial experiment pointed out several details for improvement which were considered while we modified the design of transmitter system. It provided at least twice of the frames in one day by using two amplifiers with parallel injections. The forward modeling which used the parameter from transmitter data from the initial experiment in the first stage can be used to check the radiation pattern of this system, and be a reference for the allocation of new sites.