# Development of multi-transmission high speed survey system and the application of geyser monitoring

MOTOHARU JINGUUJI

National Institute of Advanced Industrial Science and Technology AIST Tsukuba Central #7, Tsukuba, Ibaraki 305-8567, Japan.

m.jinguuji@aist.go.jp

## Summary

A new resistivity survey system, which is capable of very fast data acquisition compared with conventional DC resistivity system, has been developed in AIST. The key feature to speed up the measurement is that the system transmits multiple currents of different frequencies from different transmitter electrodes simultaneously. The transmitted signals are separated in frequency domain at a receiver electrode is identified by each respective frequency. The receiver electrodes are also multiple and simultaneously measured by using a multiple receiving function. The newly developed system has been tested by measurements at some experiment yards and the result shows success. The new developed system can obtain many datasets of resistivity in short time. Therefore, this system is suitable for the data acquisition using the statistic methods of time series, and the high speed geological monitoring. This paper introduces the outline of this system and the example of application to the monitoring of a geyser.

## Introduction

A new resistivity survey system, which is capable of very fast data acquisition compared with conventional DC resistivity system, has been developed in AIST. The key feature is that the system transmits multiple currents of different frequencies from different transmitter electrodes simultaneously.

Figure 1 shows a conceptual diagram of the multi-transmission resistivity system and a conventional single transmission system. In the conventional system, a single frequency current is transmitted from an electrode pair.

The new developed system has a multi-channel transmission function, and currents that contain multiple frequencies are transmitted from multiple electrodes pairs. The new multi-transmission system sends electric currents from multiple electrodes simultaneously. Frequency of the current sent from one electrode pair is different from those of the other electrode pairs. Superimposed signals of these frequencies observed at a receiver electrode pair is separated into each frequency using a synchronized detection circuits.

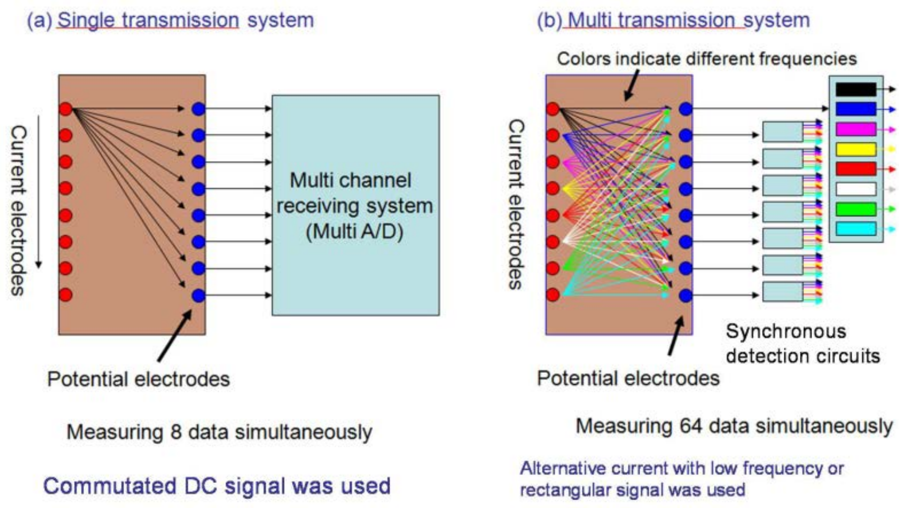


**Fig. 1:** Comparison of conceptual diagrams of the systems.

As in the case of the conventional system, the receiving function of the multi-electrode can be easily incorporated in the new system. As an example, Figure 1b shows a case of eight multiple current electrodes and eight multiple receiver electrodes. The new system can obtain 64 data at one time using 64 synchronized detection circuits, while the conventional system can measure eight data at once. The synchronized detection circuit that uses in the multi-transmission system has a very sharp band pass filter characteristic, in order to separate the frequencies of the signals. As a result, it can remove unwanted environmental noises efficiently. Therefore, the system can be used in the location of noisy environment.

Figure 2 shows the comparison of 2D inversion images between the multi-transmission system and the ordinary system using Pole-Pole method.

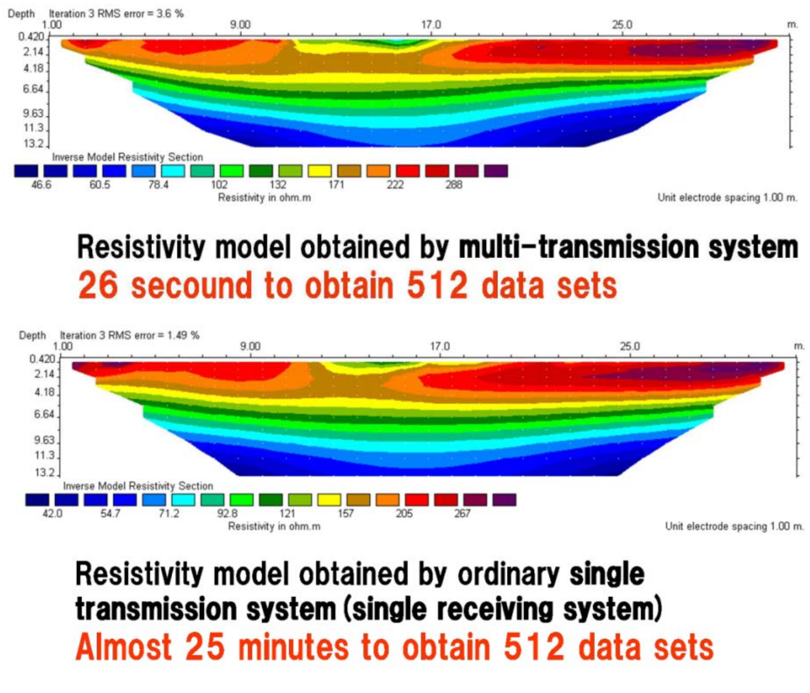


**Fig. 2:** Comparison of 2D inversion images between the multi-transmission system and the ordinary system.

Almost same images obtain from these instruments. However the multi transmission system is much faster than the ordinary single transmission system. Multi-transmission system can obtain data much faster than that of ordinary system. So, this system is suitable for the high speed monitoring.

## Application of geyser monitoring

Multi-transmission system is suitable for high speed monitoring of geological phenomenon, because the system can be enable to the high speed data acquisition. The geyser is the one of the geological phenomenon that changes rapidly. In this section, we show an example of the geyser monitoring that used multi-transmission system.


**Fig. 3:** A location of Onikobe geyser in Japan (Referenced by Google map).

**Fig. 4:** A photo of Onikobe geyser.

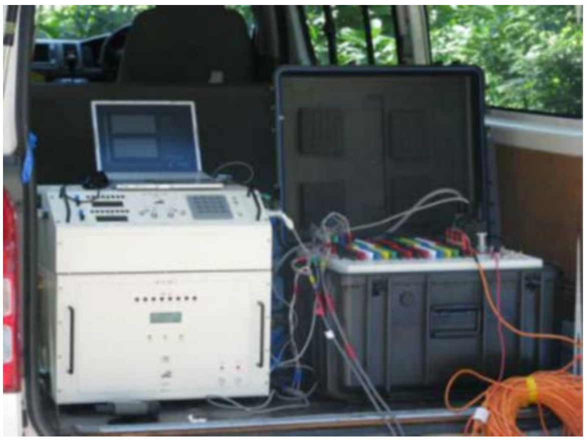

**Fig. 5:** A photo of multi-transmission resistivity meter.

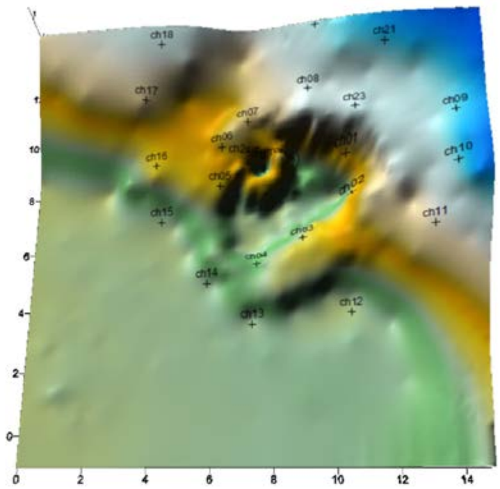

**Fig. 6:** 3D terrain and superimposed electrodes location.

Onikobe geyser in Yamagata Prefecture, the cycle time of eruption is from 6 minutes to 12 minutes, duration time is from 60 seconds to 90 seconds and erupt up to 15m high degree, is one of the famous tourist destination geyser in Japan (Fig. 3 and Fig. 4). In general, geysers are considered its eruption cycle has a certain period, but the eruption cycle of Onikobe geyser has some other certain variability regularity of duration and cycle of eruption.

Generally speaking, geyser's eruption cycle and duration time are limited in short time, relatively. In order to observe the geyser by using resistivity monitoring, it needs the electrical resistivity meter which is faster than ever. The multi-transmission high-speed resistivity meter developed by AIST can measure much faster than ordinary system (Fig. 5).

This instrument can measure 64 datasets (8x8) at a time. The numbers of electrode of the monitoring of Onikobe geyser are 8 electrodes for the transmission, and 16 electrodes for the receiving. Therefore, the sampling time of the measurement of Onikobe geyser is about 11 seconds including switch of scanner.
Onikobe geyser is located in the dimpled terrain. Figure 6 shows the view of three-dimensional terrain using the non-prism laser survey instrument and superimposed electrodes location.

**Fig. 7:** Electrodes used for monitoring of geyser.

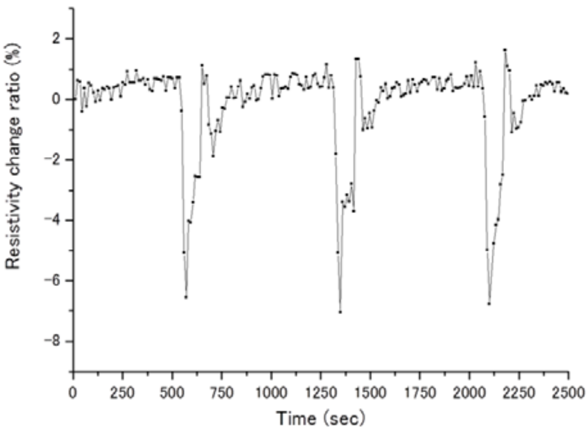


**Fig. 8:** Resistivity change with time at an electrode which connected casing pipe of geyser.

The Pole-pole method was used for the resistivity measurement. 24 Electrodes were set around geyser (Fig. 7). The electrodes from ch1 to ch8 were used for the current, and the electrodes from ch9 to ch24 were used for the potential. The electrode ch24 was connected to the iron casing pipe of geyser.

Figure 8 shows the resistivity change with time at the electrode which connected casing pipe of geyser (Current ch1, Potential ch24). The resistivity change reflects the geological status around casing pipe. The clear decrease of resistivity was confirmed during eruption status of geyser. The pattern of resistivity change is almost same pattern observed by MISHIMA et al. (2007). In the figure, the resistivity change ratio is the normalized with respect to the initial value. The resistivity decrease is almost 6 % at maximum.

Multi-transmission system can obtain 128 time series data within 11 seconds. So, we tried to the analysis of apparent resistivity using other electrodes data.

Figure 9 shows the plan view of the apparent resistivity during eruption of the geyser. In the figure, the depth information does not use and the only horizontal information uses for the plot. The data position of apparent resistivity is the center of the current electrode and potential electrode.

In the Fig. 9, we can confirm an obvious decrease anomaly of resistivity at the right upper of the location of geyser (ch24). Also, the increase area of resistivity is confirmed obviously around this decrease anomaly. Figure 10 shows resistivity changes at the point of low resistivity anomaly (Current ch5, Potential ch9), increase of resistivity (Current ch2, Potential ch12) and the casing pipe of geyser (Current ch1, Potential ch24), respectively.

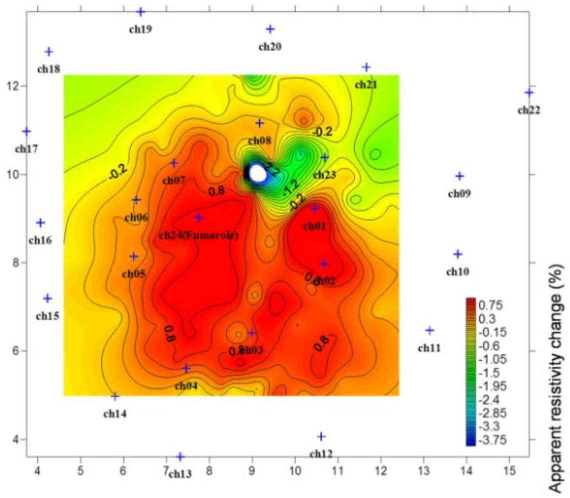


**Fig. 9:** A plan view of the apparent resistivity change during eruption of geyser.

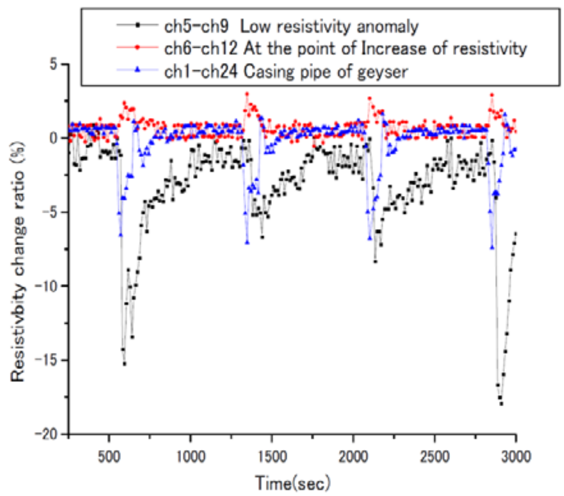


**Fig. 10:** Resistivity changes at the point of typical changes.

The drops of peek of resistivity at low resistivity anomaly are slightly delayed as compared to the drop of peek at the position of casing pipe. In addition, the resistivity changes at the anomaly late to recover compared with the resistivity change at the position of casing pipe. At the area of resistivity increase, the resistivity increase when the eruption seems to be occurred. But, the change is small. Figure 11 shows plan views of the change of resistivity per 45 seconds.

We can interpret of the eruption mechanism of the geyser from these changes of resistivity. It is estimated that the location of chamber of hot water is the low resistivity anomaly which is 2m away from the geyser. The low resistivity anomaly indicates the existence of flows of hot water to the chamber. This resistivity drop of the low resistivity anomaly has begun to late compare with the resistivity drop at the casing pipe. And then, foaming of hot water occurs due to the reducing of pressure by discharge of the hot water. The eruption of geyser is begun by the foaming. The resistivity increases due to the low water saturation during the foaming. The area of increasing of resistivity is 5m2 surrounding the geyser, but its change is not so large. The change of resistivity (change ratio) is only few percent, too. This shows the foaming of hot water is occurred in the relatively wide area.

The resistivity at the low resistivity anomaly recovers slowly and continuously until the next eruption. This shows that the water level of hot water at the chamber drops slowly after eruption has finished.

## Conclusion

We developed a new resistivity survey system, which is capable of very fast data acquisition compared with conventional DC resistivity systems and carried out the resistivity monitoring at Onikobe geyser. As a result, the clearly changes of resistivity were observed during eruption of the geyser. These changes do not inconsistent with the eruption mechanism of Onikobe geyser that has been considered so far.

We show that these resistance changes are explained by the eruption mechanism. On the other hand, the area which the foaming has occurred is relatively wide. The comprehensive validation is required using other monitoring method data in future.

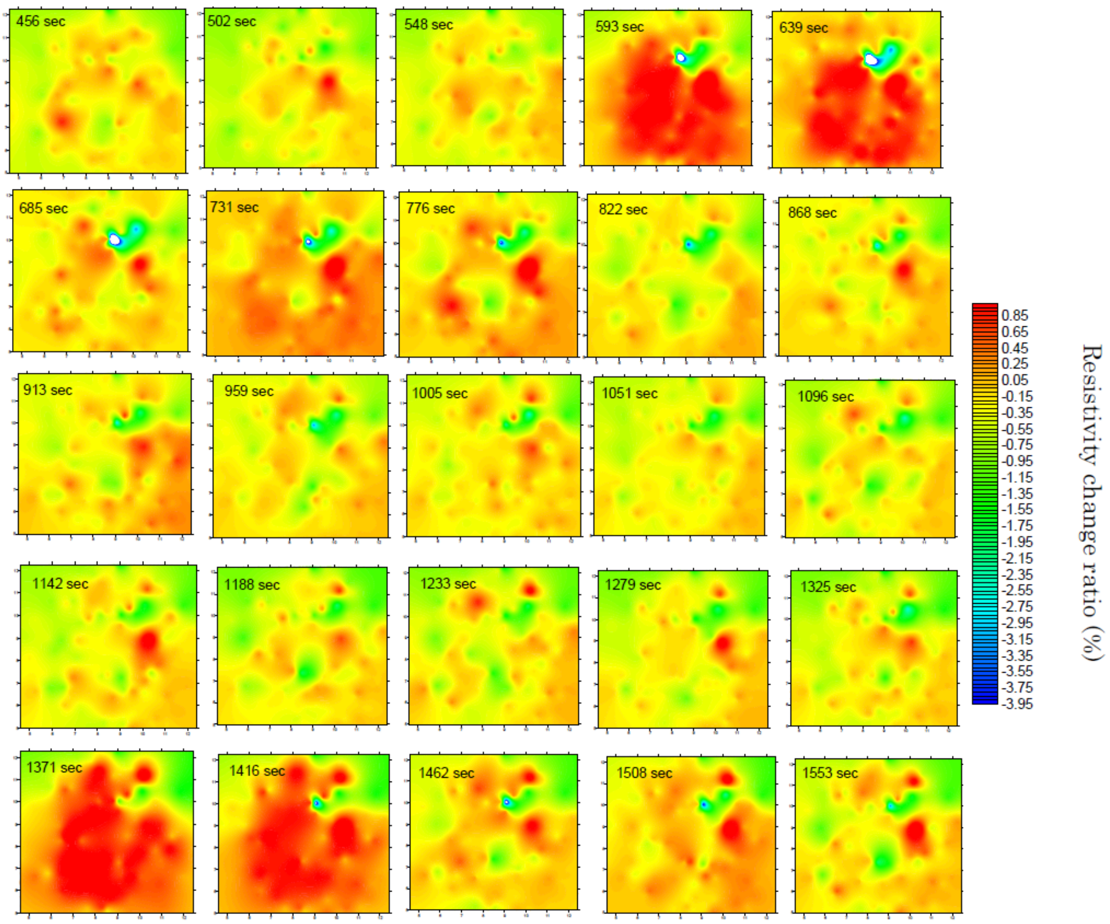


**Fig. 11:** Plan views of the change of resistivity per 45 seconds.

## Reference

MISHIMA, S., OGAWA, Y., SABO, K. and TAKAKURA, S., 2007: Observation of resistivity change of Onikobe geyser. – Conductivity Anomaly 2007, 60-65.