Observing Vibrations from 300 m to Diagnose Infrastructure Deterioration

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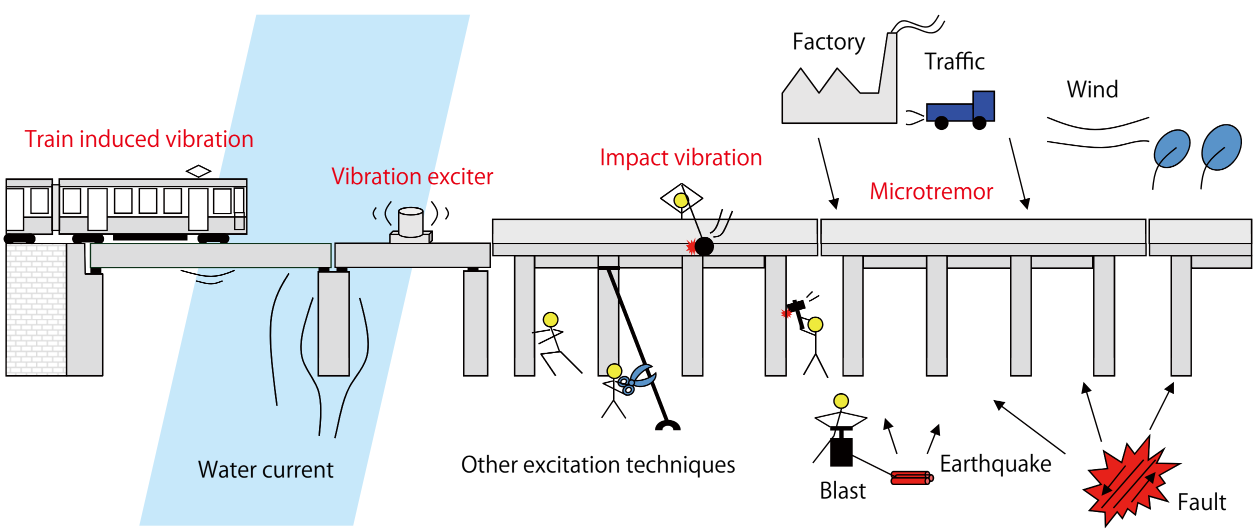
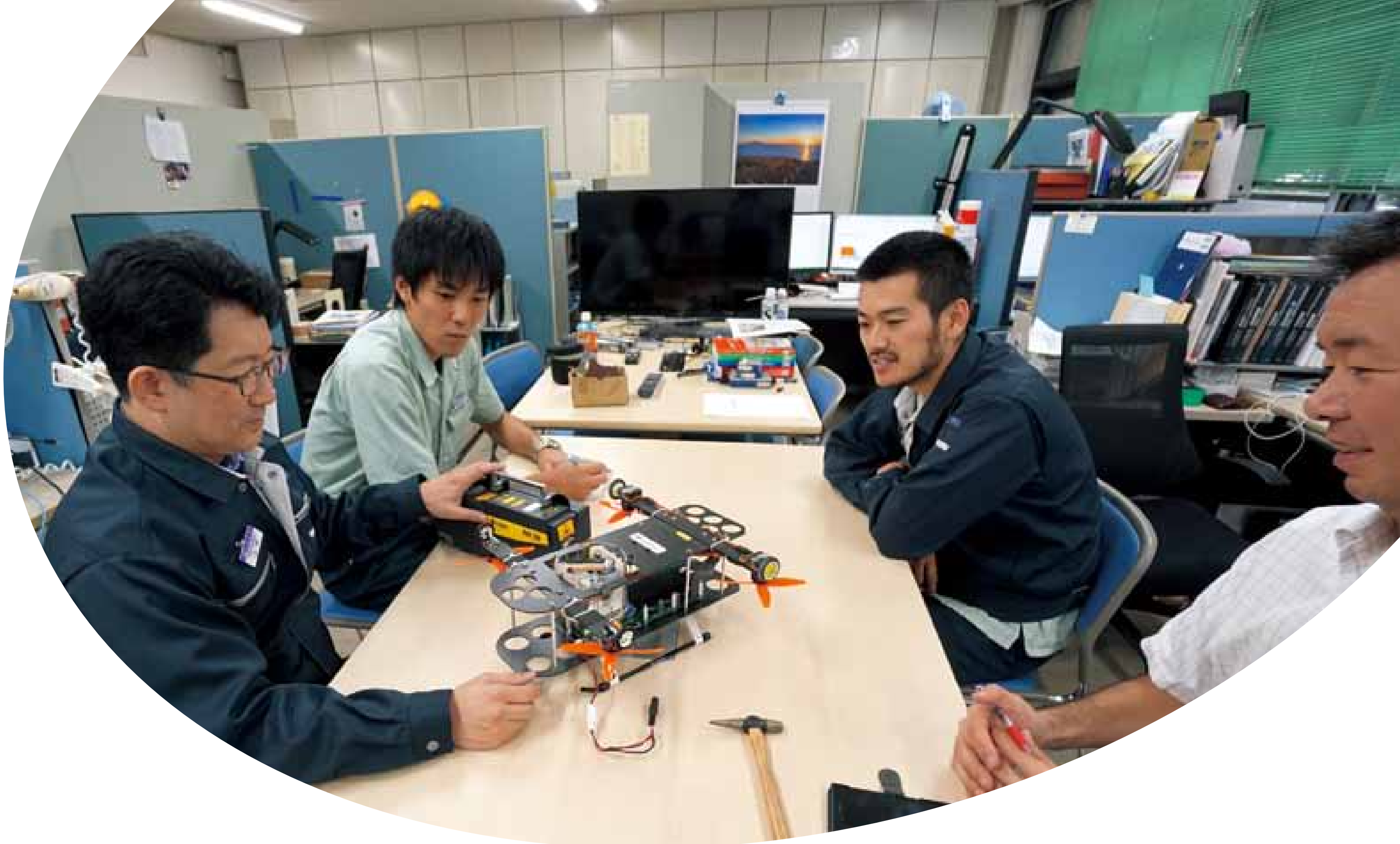
The ageing of existing railway facilities, including bridges, and of the workers who inspect them is increasingly calling for more efficient and safer inspection methods. With this in mind, RTRI developed the Long-range U-Doppler by improving the U-Doppler. U-Doppler is a noncontact vibration measurement system for diagnosis of structures developed earlier by RTRI and already being used in practical applications. The Long-range U-Doppler enables inspection of railway bridges without the need for scaffolding. It detects not only changes in bridge behavior with deteriorating health but also harmful changes in condition.

The railway industry has a long history of studying techniques to inspect structures by measuring the vibration induced by passing trains and other sources. Some of these techniques have been released for practical applications. The amplitude and natural frequency of vibration of structures are functions of a number of factors including deterioration in strength, damage caused by earthquakes, and bearing capacity reduced by swollen rivers. Structures can be evaluated for the extent of damage and deterioration by comparing their vibration data with corresponding parameters measured in a healthy state, their design reference values, or statistically or analytically calculated reference values. The vibration can be caused by artificial excitation, such as from passing trains and impacts from a weight, and by microtremors and other vibration sources.



Sources of vibration for inspection of structures



The conventional method of vibration measurement requires many hours spent on the installation and removal of sensors, recorders, connection cables and other items. It occasionally involves work high above the ground, near tracks, and in other hazardous places. For these reasons, RTRI studied the possibility of developing noncontact, remote techniques for measuring the vibration of structures.

As part of the effort, RTRI improved a Laser Doppler Velocimeter (LDV), a noncontact vibration sensor, by making it usable for the outdoor measurement of large structures. One of the key features of the system is a technology that compensates for the vibration of the LDV sensor itself caused by external disturbances such as wind and ground motion. Hence the name "U-Doppler" (Undisturbed laser DOPPLER velocimeter), with the "U" standing for "Undisturbed" by external disturbances.

The U-Doppler beams a laser at structures several dozen meters away to measure their vibration. It is mostly used to measure the vibration (strain) of bridges during the passage of trains and the natural frequencies of viaducts and piers. The U-Doppler eliminates the need to install sensors at high and otherwise hazardous places, making structure inspection involving vibration measurement more efficient and safer. The U-Doppler I, which was released in 2007 for application to practical purposes, has since been used for inspection of a range of structures along railway lines. In 2016, the U-Doppler II was developed, which is smaller and lighter than the U-Doppler and can communicate by radio.

The U-Doppler, which is mostly used for the measurement of railway bridge strain and viaduct natural frequency, has a relatively short range (10 m to 30 m). However, a measurement range of a few hundred meters is typically required for the inspection of long bridges, long sequences of viaducts and other long structures.

To meet this requirement, the Long-range U-Doppler was developed, which uses an invisible light laser in place of the red laser that is used on the U-Doppler. The invisible light laser is less harmful to the eyes and has a higher output power with the same level of safety as before. In addition, the Long-range U-Doppler automatically detects remote targets and searches for, and automatically sights on, spots on well-reflective targets and are suitable for remote noncontact measurement. With all these improvements combined, the

Long-range U-Doppler

Long-range U-Doppler offers a noncontact measurement range of non-reflective targets that is more than ten times longer than that of the U-Doppler. It enables noncontact measurement of targets a few hundred meters away without the installation of reflectors on the structure being measured.

The cables on long cable-stayed bridges need to be monitored and maintained at the correct tension. Currently, cable tension is estimated by hitting the cable with a hammer, measuring the vibration caused using a vibrometer installed on the cable and analyzing the measurement. The Long-range U-Doppler remotely sights on the cables one by one and measures microtremors to estimate the cable tension without any manual excitation. Inspection of a cable-stayed bridge is typically conducted during night hours over four days with the conventional method. With the Long-range U-Doppler, the same amount of inspection can be completed in approximately one hour during the daytime with measurement accuracy equivalent to that of the conventional method.

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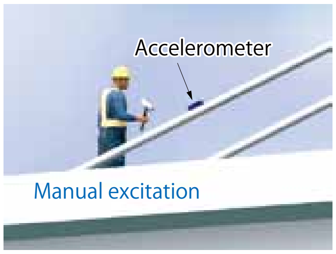
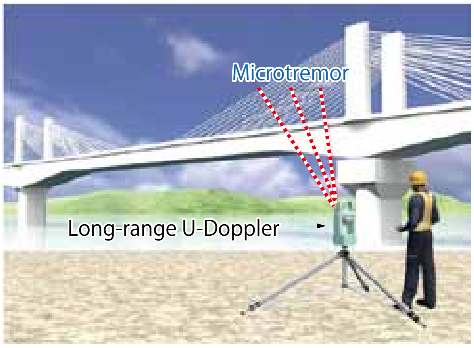


Conventional cable vibration measurement



Remote noncontact measurement

Change of vibration measurement method of cable-stayed bridge cables