Newsletter on the Latest Technologies Developed by RTRI

Railway Technology Avalanche

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GENERAL INFORMATION

ARTICLES

Two Problems Heading Our Way in 2007

Kenji SHIRATORI
Executive Director

Japan will be jolted by two problems in 2007. One problem is that most baby boomers born in the 1947-1949 period — the sons and daughters of men who returned from the war and quickly married and had children — will soon be retiring. (Perhaps I should mention that I was born in 1948.) Many technical experts with years of experience and know-how will disappear from the workplace. This will be a problem for all of Japan, because these experts will no longer be available to pass their technical skills on to the next generation of workers.

This is a major problem for the Japanese rail industry, too. Railway operators, large and small, are anxious about how they will maintain and improve their technologies in the years ahead.

During January 2006 at J-RAIL 2005 (an annual symposium on railway technology held by the Japan Society of Civil Engineers, the Institute of Electrical Engineers of Japan and the Japan Society of Mechanical Engineers), I chaired a panel discussion labeled "The Maintenance and Transfer of Railway Technology Now at Stake: How to Prevent the Loss of Railway Technology." The discussion came to the conclusion that all players in the Japanese rail industry should cooperate in resolving this problem, and that they should make good use of the expertise of retirees.

The other problem looming ahead, ready to strike in 2007, involves the public pension system. According to pension law reforms, beginning in 2007 wives will have the right to claim half of their husband's pension. It seems that quite a few wives are thinking of getting divorced when the new rule kicks in. The most critical time is right after the husband receives a handsome retirement allowance. Husbands are well advised to take care not to be left alone with just half of their retirement allowance and half of their pension!

白取健治

New Supercomputer Now in Operation at Railway Technical Research Institute

Toshio HIROTA
Deputy Director, Information Management Division

The Railway Technical Research Institute (RTRI) replaced its supercomputer with a new and more powerful model in December 2005. For many years, RTRI had successfully used a supercomputer for various types of research, including analysis of the behavior of Shinkansen and conventional railway infrastructure during earthquakes, analysis of vibrations of superconducting magnets for maglev, analysis of pantograph-related noise, and determination of optimum pantograph shape.

A committee of researchers who use supercomputers regularly was organized to select the ideal supercomputer to replace RTRI's existing one. Keeping in mind the fact that the new supercomputer would be used for RTRI's future research projects, the committee considered hardware specifications (including required number of CPUs), memory capacity, computing speed, software specifications (including compatibility with existing software), and cost. The committee finally decided on a model that would permit use of existing calculation packages and original RTRI software without major modifications, that would provide far greater computing capabilities, and that would offer much better cost-performance than the existing model.

The newly introduced supercomputer is an SGI Altix 3700 Bx2 having 112 Intel Itanium® 2 processors (64-bit CPUs) with a 1.5GHz 4MB cache. Main memory capacity is 224 GB and theoretical peak performance is 672 GFlop/s. Auxiliary storage devices are a 3 TB magnetic disk unit and a 6 TB magnetic tape unit for backup. The operating system is Linux® OS. Applications include ELF/MAGIC, FLUENT, I-DEAS, IMSL, MARC, NASTRAN, PAMCRASH, S-FLUSH and SYSNOISE. FORTRAN 77 and FORTRAN 90 are also applicable. The supercomputer is compatible with programs developed by RTRI.

The new supercomputer has a theoretical peak performance about six times greater than the former supercomputer. Main memory capacity is about three times greater. Since the new supercomputer is capable of performing complicated calculations with higher speed and greater accuracy, we are confident it will make our R&D efforts even more successful.

WCRR 2006 Coming Soon to Montréal, Canada

Hisashi TANAKA
Deputy Manager, International Affairs Division

2006 WCRR Montréal
PROGRESSING TOGETHER
Le progrès, ensemble

7th World Congress on Railway Research

June 4 – 8, 2006
Fairmont Queen Elizabeth Hotel
Montréal, Canada

The 7th World Congress on Railway Research (WCRR 2006) will be held in Montréal, Canada from June 4 to 8, 2006. The World Congresses' roots go back to when the Railway Technical Research Institute (RTRI) hosted the International Railway Research Seminar in Tokyo in 1992. Since then RTRI has participated as a member of the WCRR Organizing Committee and Executive Committee. It also served as the WCRR Secretariat to help plan and organize the Congress in Tokyo in 1999.

The WCRR 2006 theme is "Progressing Together." Participants from about 30 countries will present results of their research (some 300 reports), exhibit rail technology, and take part in technical visits. RTRI plans to present 22 reports and organize a display booth with the JR Group.

Please visit the WCRR 2006 Secretariat's website www.wcrr2006.org for more information on the Congress. We hope to see you in Montréal this June!

Evaluating How an Increase in Train Speed Will Affect Ground Vibrations

Hidefumi YOKOYAMA
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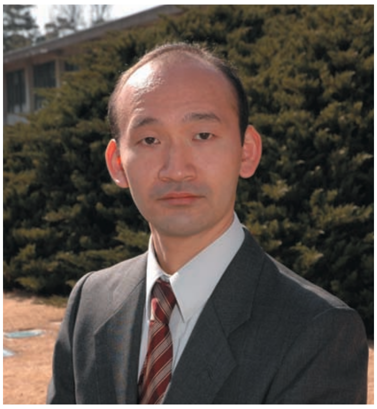

Since the Tokaido Shinkansen began operations in 1964, Shinkansen train speed has increased dramatically. But to avoid seriously impacting the trackside environment, it is important to quantitatively estimate the increase in ground vibrations that will result from higher train speeds.

Generally speaking, the relationship between train speed and ground vibration is expressed by the power of velocity law. Accordingly, when train speed changes from V_0 to V the increase in ground vibration level, ΔVL (dB), can be expressed as:

$$\Delta VL = 10\, n \log_{10} (V/V_0)$$

In the above equation, the speed power exponent n represents the train speed dependency of ground vibration level. For example, when n = 3.0, the ground vibration increases by about 1.4 dB as the train speed increases from 270 to 300 km/h. Even for the same line, the value of n varies according to ground conditions and other factors. In other words, an increase in train speed on a line may cause one localized part of the ground to vibrate more than the average ground vibration on that line. Additional measures would therefore be required to reduce vibrations there.

A recent study revealed that when Shinkansen train speed exceeded 300 km/h, under certain ground conditions a ground vibration of a very low frequency band of around 4 Hz prevailed. Until that study, such a low frequency band had been ignored as being inconsequential. Fig. 1 shows examples of ground vibration spectra obtained at comparatively soft parts of the ground. In those areas, the value of n was as large as 5.0 to 5.9. On the other hand, at comparatively satisfactory parts of ground, vibrations in the range of 12.5 to 16.0 Hz were prevalent, and the value of n was about 2.7.

Taking advantage of past and recent research results, we conducted research to develop a simple method for quantitatively evaluating the effect that an increase in train speed has on ground vibrations.

When a standard Shinkansen train runs at speeds of from 200 to 350 km/h, peak ground vibrations appear in each of three frequency bands — very low (2 to 4 Hz), low (6.3 to 12.5 Hz) and medium (20 to 40 Hz) — as shown in Fig. 2 (a). With the increase in train speed, these frequency bands shift toward the higher frequency range, and the peak value in each frequency band varies (Fig. 2 (b)). Of the five parameters (dS0, dS1, dVL0, dVL1 and dVL2) shown in Fig. 2, dS0 and dS1 represent ground vibration spectra characteristics before train speed increased, while dVL0, dVL1 and dVL2 indicate the degree of change of peak in each of the above three frequency bands. For each line, a vibration calculation model was created based primarily on a model for theoretical calculation of the effect of periodic axle load, a simple model for dynamic characteristics of the ground, and the results of train speed-up tests.

An example of calculation of the speed power exponent n using our proposed method is shown in Fig. 3. With our proposed model, it is easy to estimate how much an increase in train speed will change ground vibrations, using only a modest amount of ground information - mainly the thickness and average N value of the ground surface layer. We therefore consider it worthwhile to carry out a more detailed preliminary study on measures to estimate and control the increase in ground vibrations when planning to increase train speed.

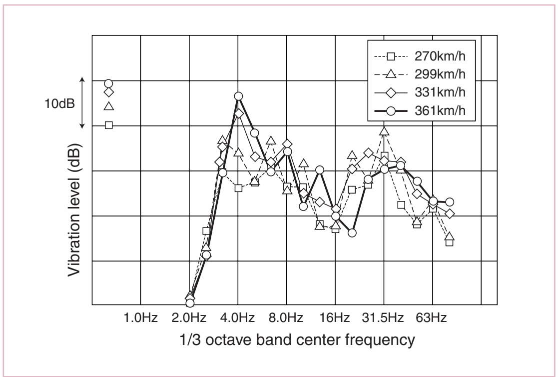

Figure 1. One-third octave band spectrums of measured ground vibrations

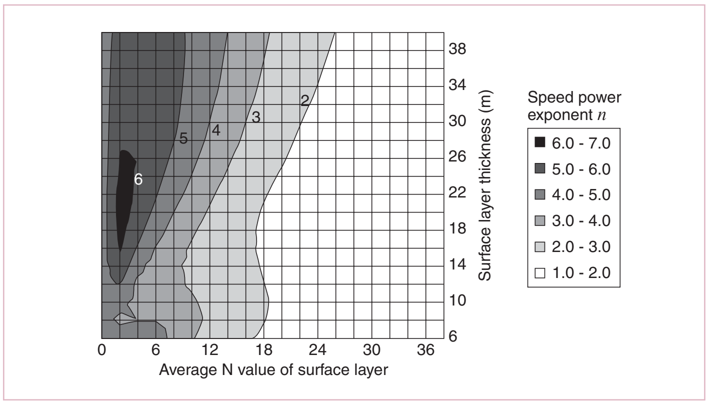

Figure 3. Example of calculation of speed power exponent n

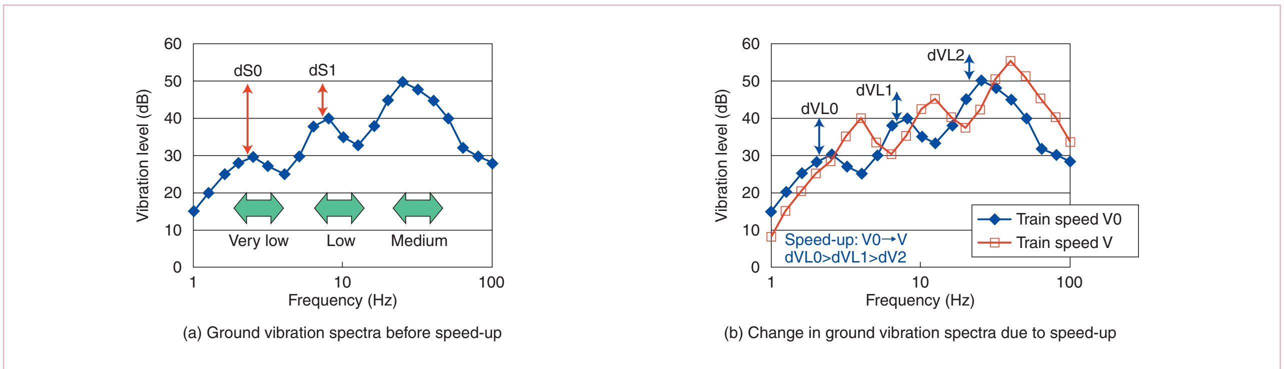

Figure 2. Change in ground vibration spectra due to speed-up

A New System to Validate Algorithms for Early Earthquake Detection

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1. Introduction

The Railway Technical Research Institute has developed algorithms for estimating an earthquake's elements (hypocenter, magnitude, etc.) using the initial tremor of its seismic wave, and for automatically distinguishing between seismic waves and noise (such as the noise of ground vibrations caused by a running train, or electromagnetic noise). Future plans may call for the replacement of existing trackside seismographs with new ones that are based on these new algorithms. But first, it would be necessary to validate application of the new algorithms for the early detection of earthquakes, using data on earthquakes and noises previously obtained from existing seismographs. We therefore developed a new system that permits the efficient validation of the new algorithms with huge volumes of data.

2. System development background

Many different types of seismographs are installed along railway lines. When different types of seismographs store waveform data in different formats, it is impossible to process the data of all those seismographs using the same method. We therefore devised a unified format of standard text type ("JR format") for the data format. We then developed (i) "DataStation," a tool for converting differently formatted seismographic data into data in the JR format, and (ii) "DataCraft," a system to efficiently analyze large volumes of waveform data. During the recent study, we developed a new algorithm for the early detection of earthquakes in DataCraft.

3. System application example: Distinguishing between an earthquake and noise

As an example for application of the new verification system, we conducted tests aimed at distinguishing between an earthquake and train-induced ground vibrations. For the tests we used about 520 items of seismic data previously obtained at government-maintained observation points, and about 600 items of data on train-induced ground vibrations (noises) recorded by trackside seismographs.

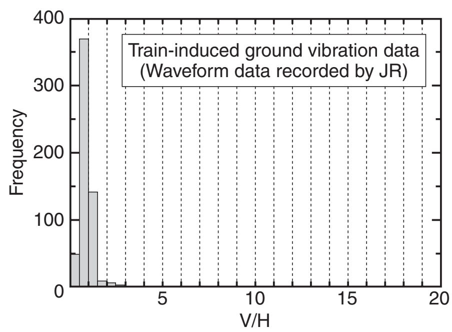

Figure 1. V/H frequency distribution obtained from data on train-induced ground vibrations

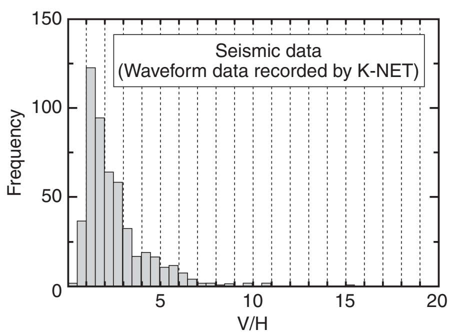

Figure 2. V/H frequency distribution obtained from seismic data during 2 seconds of initial tremors

3.1 Identification by V/H

Seismic waves propagate almost vertically from the hypocenter to observation points, whereas train-induced ground vibrations propagate horizontally from the track. Thus, it is possible to roughly distinguish between seismic vibrations and train-induced ground vibrations using the difference in V/H, that is, the ratio of the maximum amplitude of the vertical component (V) to the maximum amplitude of the horizontal component (H). Fig. 1 shows a V/H frequency distribution obtained from data on train-induced ground vibrations, while Fig. 2 shows the distribution obtained from earthquake data. The figures indicate that if a vibration whose V/H is less than 1.5 can always be identified as a noise, it is safe to judge that 97% of noise data represents noise.

3.2 Identification by increase rate B

Increase rate B, which was devised while developing the new algorithm for early earthquake detection, is an indicator for the rate of increase in the amplitude of initial P-waves. The higher the increase rate B, the more rapidly the P-waves increase. Generally speaking, a high increase rate B indicates that the hypocenter (epicenter) is close to the observation point. Fig. 3 shows the relationship between increase rate B and the true distance to the epicenters of actual earthquakes. According to the figure, increase rate B in earthquakes varies widely from 0.01 to about 100. On the other hand, it was found that in more than 90% of train-induced ground vibrations, the calculated value of increase rate B was less than 0.3. Thus, we consider that when B is less than a certain value (e.g., 0.3), the vibration can be judged as a train-induced vibration (noise).

4. Conclusion

In the future, more and more existing seismographs will be replaced with new ones capable of earlier earthquake detection. It is expected that our new system will be employed to validate the application of our new algorithm for the early detection of earthquakes.

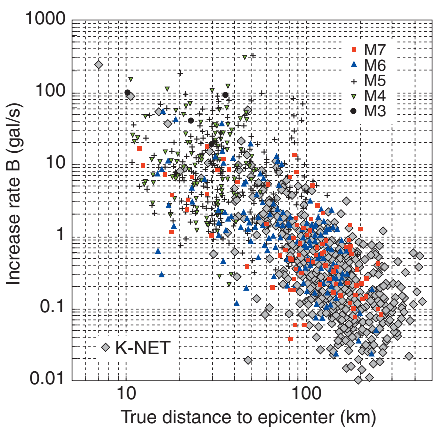

Figure 3. Relationship between increase rate B during 2 seconds of initial tremors and the true distance to epicenter

A New System for Detecting Obstacles in Front of a Train

Masato UKAI
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To ensure the safety of train operations, it is absolutely essential that we prevent trains from hitting an obstacle and possibly derailing. At present, however, detection of an obstacle in front of the train depends largely on the sight of the driver. We therefore developed an onboard system that detects obstacles in front of the train for the driver.

Two conventional methods employed to detect obstacles are: the active method using millimeter wave radar or laser radar, and the passive method using image recognition (machine vision). The former is now being put into practical use for motor vehicles. However, this method has several problems that remain to be solved, such as insufficient spatial resolution and short detection distance. The method is still not suitable for railway operations, where the required detection distance is as long as several hundred meters. We therefore decided to apply a passive detection method using a single-lens camera. We chose a low-brightness CCD camera that can be used day and night, to permit use of the system even in the dark.

Processing images from an onboard camera faces the following problems.

Figure 1. Extraction of rails through application of the Hough transformation

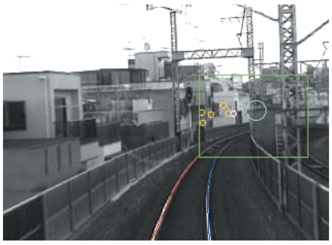

Figure 2. Detection of rail vanishing point

Figure 3. Pan head for automatically tracking rail vanishing point

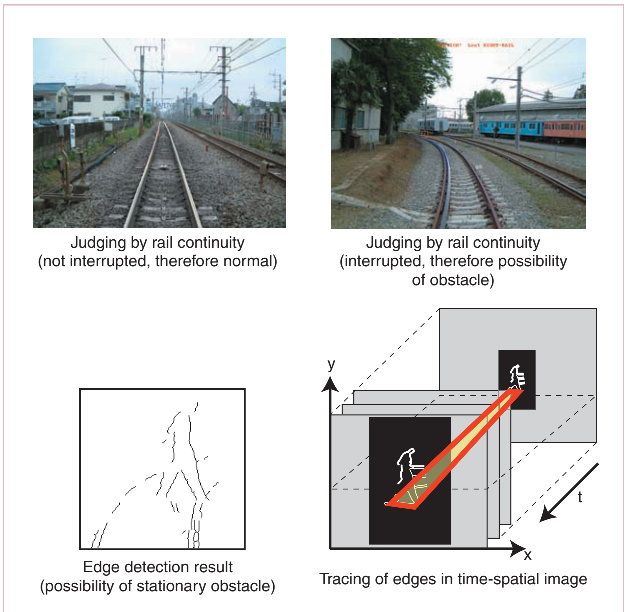

Figure 4. Results of detection of stationary obstacle

First of all, since a telephoto lens is used to monitor long-distance perspectives, images are susceptible to blurring, especially when vehicle vibrations are large. When blurring occurs, a moving vector (optical flow) consisting of horizontal and vertical components appears on the entire monitor screen. Therefore, when an optical flow in a certain direction is observed on the entire screen, it should be judged ascribable to a blur. Another problem is that when the train is moving, the background also appears to be moving, although it is of course stationary. We devised image processing techniques that compensate for these factors.

In order to detect an obstacle accurately, it is necessary to have a clear sense of the railway track space. The system we developed detects the rails on which the train is running, and narrows down the search region from the positional relationship between the rail and obstacle. Since the rails can be thought of as two parallel lines extending straight ahead from the place of observation, we extracted the rails by applying one linear detection technique, the Hough transformation (Fig. 1). To enable the system to capture the target within its field of vision even in a curved rail section, the distant rail vanishing point was obtained (Fig. 2) and the camera's field of vision was controlled so that the vanishing point appeared at or near the center of the monitor screen (Fig. 3).

When the obstacle is a moving object, it is effective to analyze the optical flow in its images on the monitor screen. Since the obstacle is a rigid body and its optical flow inside its region is almost uniform, the extent of danger posed by the obstacle can be judged by the optical flow's size, direction of movement, and position.

When the obstacle is stationary, it is extremely difficult to distinguish it from a stationary point in the background. We therefore worked out the following method:

When an interruption in rail continuity was detected, we assumed the possibility of a stationary obstacle resting on or beside the rail(s). Paying attention to the fact that an obstacle shows a brightness distribution representing a change from the background, and the fact that it contains a comparatively higher number of horizontal and vertical edges, we isolated the region in which the obstacle existed by analyzing the average and dispersion of brightness and the brightness profiles projected horizontally and vertically. The edges and other characteristic points of the obstacle were extracted from the isolated region and analyzed on time-spatial photographic images laid out on a time-serial basis. Since the loci of groups of characteristic points of an identical obstacle are linearly plotted in the direction of the time axis, we could detect a stationary obstacle by emphatically correlating the point groups that converged linearly (Fig. 4).

Development of a Highly Sensitive 3-Axis Optical Electric Field Sensor for EMC Measurements in Railway Vehicles

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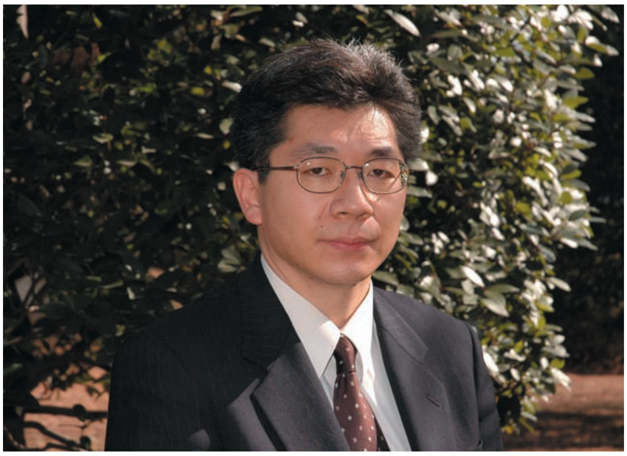

Standardized methods have already been established for the measurement and analysis of radio frequency interference caused by railway systems, and international standards on radiated emission from railway systems to the outside world (IEC 62236-2) were issued in 2003. Even so, there have been no suitable instruments or methods for measuring radio frequency interference inside railway vehicles.

With recent advances in railway drive systems, the introduction of information technology (IT), and the growing demand for EMC (ElectroMagnetic Compatibility) standardization, a better method is needed for measuring and analyzing radio frequency interference inside railway vehicles. We therefore developed a highly sensitive 3-axis optical electric field sensor (Fig. 1) suitable for taking measurements in railway vehicles. It is a compact, wide-band optical electric field sensor with high sensitivity and three axes (one vertical axis, two horizontal axes). We also developed methods for the sensor to be used to measure and analyze the electric field strength of radio disturbance waves.

The new sensor can measure a wide range of frequencies, from 100 kHz to 3 GHz. And, since it is smaller (diameter, 11 cm; length, 40 cm) than a conventional EMC measuring antenna, it can be used to measure electric field strength at any point inside a railway vehicle. By using the sensor and a real-time spectrum analyzer capable of real-time frequency analysis, we were able to ascertain the radio frequency electromagnetic environment inside various types of inverter-controlled vehicles. Our results confirmed that the sensor permits measuring time-serial changes in frequency characteristic of the electric field strength inside railway vehicles (Fig. 2), and that it also permits the ascertaining of radiation direction. Measuring those characteristics and quantitatively ascertaining electric field strength distribution will facilitate research into effective measures to ensure the desired electromagnetic environment for railway vehicles, and to verify the effect of such measures. The sensor is also very effective for taking measurements that cannot be taken with a conventional EMC measuring antenna.

Our research received financial assistance from the Ministry of Land, Infrastructure and Transport.

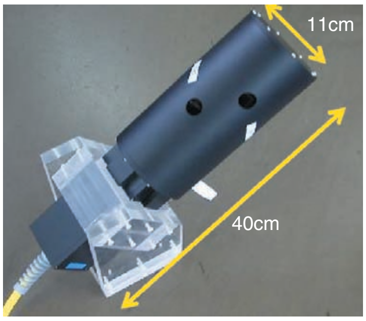

Figure 1. Highly sensitive 3-axis optical electric field sensor for railway vehicles

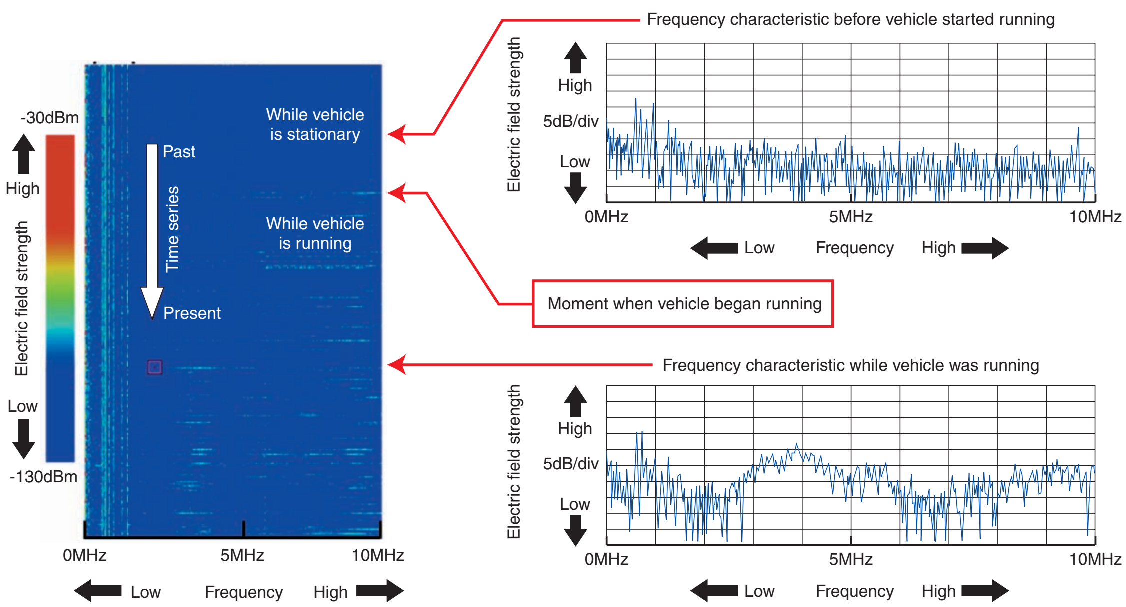

Figure 2. Example of measured time-serial changes in frequency characteristic of electric field strength in an experimental inverter-controlled vehicle