EAN 2020
58th conference on experimental stress analysis

Wireless Signal Transmission at Testing Vehicle Response to Kinematic Excitation

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Keywords: Wireless transmission, Moving load, Roadway, Vehicle response, Experiment

Abstract. The article is devoted to monitoring the real effects of the moving load on the structure of the roadway. It solves the problem of wireless transmitting the measured signal from a moving vehicle to a stationary registration device. It describes the way of realization of experiment and specifies the parameters of individual devices. It presents the results of experimental measurements of vehicle response and did conclusions for real application in practice.

Introduction

The moving load is the predominant component of the load in the case of transport structures. It is important to know the real load and the change of the load over time for the design of the road structure and the issues related to its service life and reliability [1]. In order to know the real dynamic load, the experimental way is the best way to obtain the necessary information. Since moving loads are represented by transport means, it is the best to use absolute sensors during experiment, preferably acceleration sensors. Offer of developed acceleration sensors that could be used for this purpose is wide and the choice is really rich. So it is not a technical question but a financial one. The technical problem to be solved is the transmission of the signal from the sensor to the registration device. One way is to realize wireless signal transmission and take advantage of the Wi-Fi system. The transmitted signal can then be archived in digital form on a computer and then processed using suitable software. The results thus obtained can be used to verify numerical simulations.

Experimental technique and measuring line

The measurement was performed on a T815 lorry. The aim of the measurement was to detect vertical accelerations of the vehicle axles and consequently dynamic road loads. The measuring line consists of the following components: Sensor B&K 4507 or 4508, A/D interface NI 9234, Wi-Fi system NI cDAQ-9191, receiver Wi-Fi MOXA AWK-3121, operative computer PC-hp with software National Instruments (LabVIEW, Measurement Studio, Signal Express, DIAdem, MATRIXx, Developer Suite, VI Logger) [2].

For measurement of acceleration, it is advantageous to use sensors from Brüel & Kjær type BK 4507 or 4508 [3]. Miniature CCLD Accelerometers Types 4507 and 4508 are specifically designed to withstand the rough environment of the automotive industry. A combination of high sensitivity, low mass and small physical dimensions make them ideal for modal measurements, such as automotive body and power-train measurements, as well as for modal analysis on aircraft, trains and satellites. These are sensors of small dimensions of about 1 cm with a weight of 4.8 g, which operate in the frequency range 0.8 - 8000 Hz at temperatures –54 - +100 ° C. They have a high sensitivity of 100 mV/ms^{-2}. They are attached to a plastic base which is glued to the structure. The sensor itself and its installation on the front and rear axle of the vehicle is shown in Fig. 1.

Fig. 1: Sensor BK 4508 and its installation on the front and rear axle of the vehicle

The voltage signal from accelerometer is routed via coaxial cable to the National Instruments NI 9234 module which also works as amplifier and an A/D interface. The NI 9234 is a 4-channel, ±5 V, 24 Bit, C series sound and vibration input module for making high-accuracy measurements from integrated electronic piezoelectric (IEPE) and non-IEPE sensors such as accelerometers, tachometers, and proximity probes. The NI-9234 is also compatible with smart TEDS (Transducer Electronic Data Sheets) sensors. The NI 9234 delivers 102 dB of dynamic range and incorporates Integrated Electronics Piezoelectric (IEPE) signal conditioning at 2 mA constant current for accelerometers and microphones. The four input channels simultaneously acquire at rates up to 51.2 kS/s. It operates at temperatures –54 - +70 °C. In addition, the module includes built-in anti-aliasing filters that automatically adjust to your sampling rate. Compatible with a single-module USB carrier and NI CompactDAQ and CompactRIO hardware, the NI 9234 is ideal for a wide variety of mobile or portable applications such as industrial machine condition monitoring and in-vehicle noise, vibration, and harshness testing.

The wireless transmission of the signal is provided by the National Instruments NI cDAQ-9191 Wi-Fi system. The cDAQ-9191 is a Wi-Fi chassis designed for small, remote, or distributed sensor measurement systems. The chassis controls the timing, synchronization, and data transfer between C Series I/O modules and an external host. You can use this chassis with a combination of modules to create a mix of analog I/O, digital I/O, and counter/timer measurements. You can send data from the cDAQ-9191 to a host PC over Ethernet or IEEE 802.11 Wi-Fi. The chassis also has four 32-bit general-purpose counters/timers built in. You can access these counters through an installed, hardware-timed digital C Series module for applications that involve quadrature encoders, PWM, event counting, pulse train generation, and period or frequency measurement. Antenna (packaged with the cDAQ-9191 chassis). Antenna Connector Bulkhead RP-SMA connector Electrical performance VSWR Maximum 2.0 (2.4 GHz to 2.5 GHz) Impedance 50 Ω nominal Directivity Omni Maximum gain 2.0 dBi (2.4 GHz to 2.5 GHz).

The MOXA AWK-3121 can be used to receive wireless signals. The AWK-3121 Access-Point/Bridge and AP Client is ideal for applications that are hard to wire, too expensive to wire, or use mobile equipment that connects to a TCP/IP network. The AWK-3121 can operate at temperatures ranging from 0 to 60°C for standard models and -40 to 75°C for extended temperature models, and is rugged enough for any harsh industrial environment. Installation is easy, with either DIN-Rail mounting or wall mounting in distribution boxes. The DIN-Rail/wall mounting capability, wide operating temperature range, and IP30 housing with LED indicators make the AWK-3121 a convenient yet reliable solution for any industrial wireless application.

Swivel-type antennas (2dBi, RP-SMA, 2.4&5GHz). The modules described above [4-6] are shown in Fig. 2.

Fig. 2: A/D interface NI 9234, Wi-Fi NI cDAQ9191, receiver MAXA AWK 3121

The rod antenna of the NI cDAQ-9191 module can be replaced by a panel antenna of the JPA-9 type, for example, of 123 x 123 x 13 mm, Fig. 3, [7]. The antenna operates in the 2.4 - 2.485 GHz frequency band, horizontal or vertical polarization, radiation angle of 65 ° in both planes. Both the NI 9215 and the cDAQ-9191 require a power supply. It is possible to use 14.4 V LiTon batteries, 83.5 kWh, max current 3A.

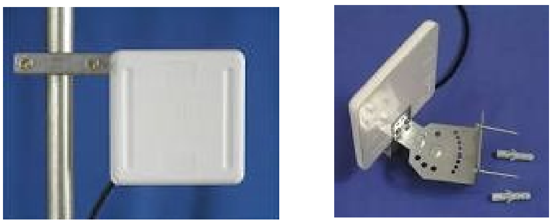

Fig. 3: Panel antenna JPA.9

Results of experimental testing

Measurements according to the above methodology were performed on the Tatra T815 lorry. The road section on which the vehicle response was registered was 120 m long. The passage time of the vehicle along this section was measured. The average speed of the vehicle was calculated from the measured time and the known length. The measurements were carried out in the campus of the University of Žilina on the newly built roadway, which can be classified in category A according to ISO 8608 [8]. The record of acceleration on the vehicle front axle at the speed of 18 km/h is shown in Fig. 4 and the record of the acceleration on the rear axle is shown in Fig. 5.

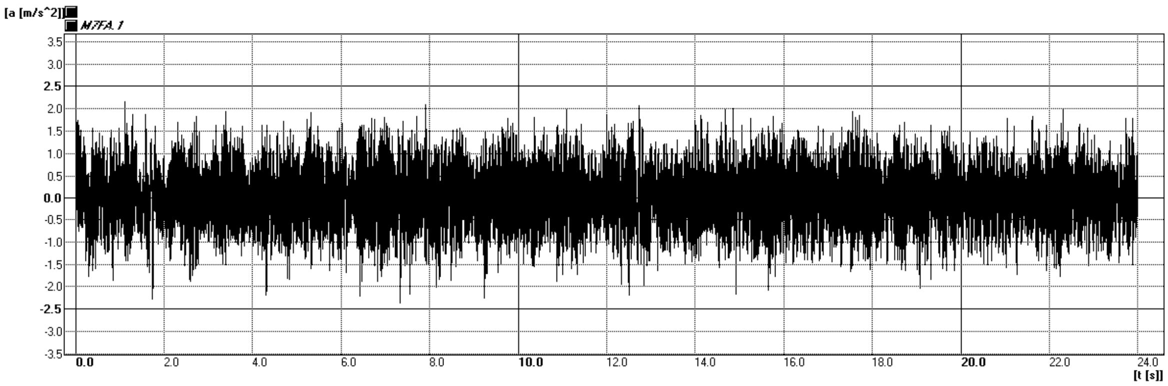

Fig. 4: Acceleration record on the vehicle front axle

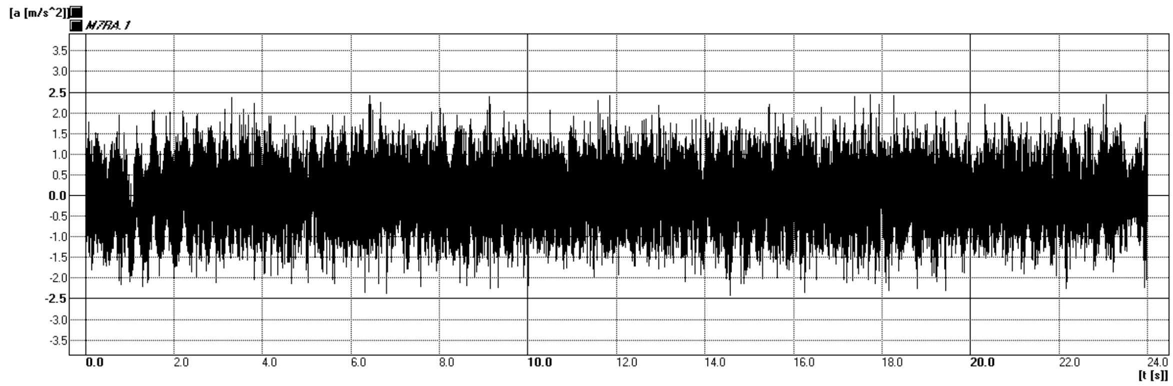

Fig. 5: Acceleration record on the vehicle rear axle

Conclusions

The wireless transmission of the signal from the measured point to the registration device is advantageous, especially when measured on vehicles. For signal transmission it is possible to use WiFi system and e.g. devices of the firm National Instruments. As long as there is no barrier between the transmitter and receiver antennas ("the antennas see each other") the methodology described above gives good results and is reliable. Problems may arise if the antennas "do not see each other". The methodology can also be used to measure the response of bridges. It spares pulling a large number of cables.

Acknowledgements

This work was supported by the Grant National Agency VEGA of the Slovak Republic, grant No. 1/0006/20.

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