Technology Focus: Test & Measurement

Magnetic-Field-Response Measurement-Acquisition System

Sensors are interrogated without physical connection to a power source, microprocessor, data-acquisition equipment, or electrical circuitry.

Langley Research Center, Hampton, Virginia

A measurement-acquisition system uses magnetic fields to power sensors and to acquire measurements from sensors. The system alleviates many shortcomings of traditional measurement-acquisition systems, which include a finite number of measurement channels, weight penalty associated with wires, use limited to a single type of measurement, wire degradation due to wear or chemical decay, and the logistics needed to add new sensors. Eliminating wiring for acquiring measurements can alleviate potential hazards associated with wires, such as damaged wires becoming ignition sources due to arcing.

The sensors are designed as electrically passive inductive-capacitive or passive inductive-capacitive-resistive circuits that produce magnetic-field re–sponses. One or more electrical parameters (inductance, capacitance, and resistance) of each sensor can be variable and corresponds to a measured physical state of interest. The magnetic-field-response attributes (frequency, amplitude, and bandwidth) of the inductor correspond to the states of physical properties for which each sensor measures.

For each sensor, the measurement-acquisition system produces a series of increasing magnetic-field harmonics within a frequency range dedicated to that sensor. For each harmonic, an antenna electrically coupled to an oscillating current (the frequency of which is that of the harmonic) produces an oscillating magnetic field. Faraday induction via the harmonic magnetic fields produces an electromotive force and therefore a current in the sensor. Once electrically active, the sensor produces its own harmonic magnetic field as the inductor stores and releases magnetic energy. The antenna of the measurement-acquisition system is switched from a transmitting to a receiving mode to acquire the magnetic-field response of the sensor. The rectified amplitude of the received response is compared to previous responses to prior transmitted harmonics, to ascertain if the measurement system has detected a response inflection. The "transmit-receive-compare" of sequential harmonics is repeated until the inflection is identified. The harmonic producing the amplitude inflection is the sensor resonant frequency. Resonant frequency and response amplitude are stored and then correlated to calibration data.

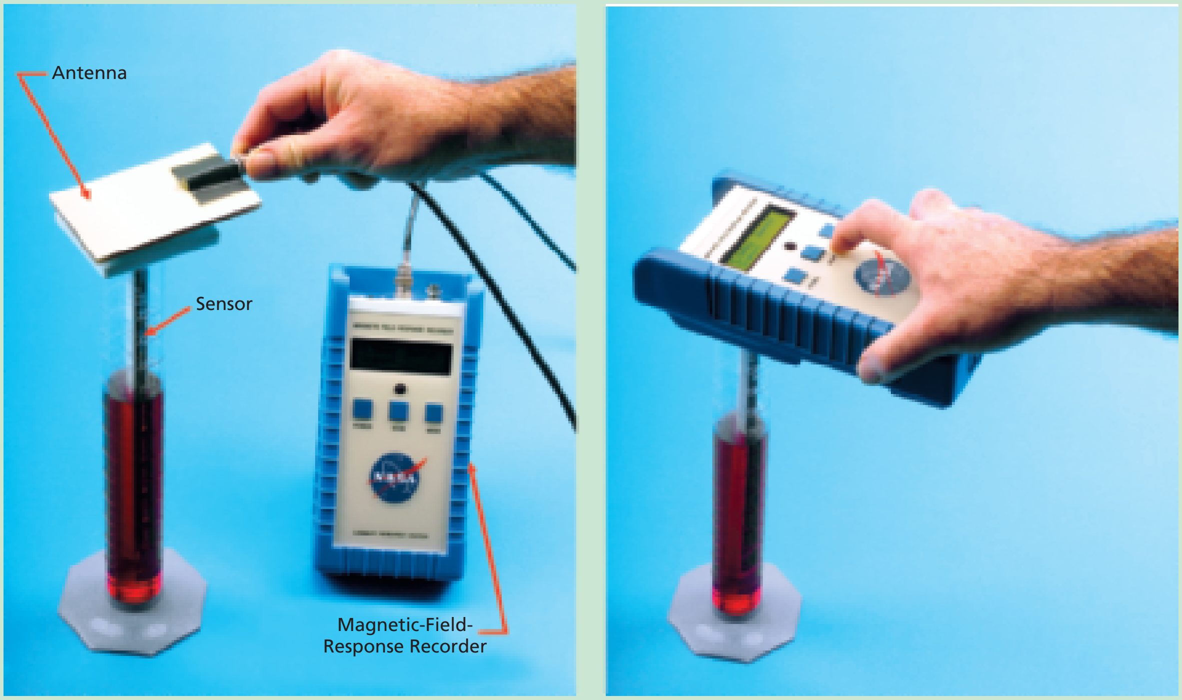
Multiple sensors can be interrogated using a single acquisition system. Each sensor must have a dedicated frequency partition of the antenna bandwidth, and the interrogation system must be augmented with a measurement correlation table for each sensor. The method eliminates the need for a data acquisition channel dedicated to each sensor. Any existing inductive or capacitive sensor can also be modified to be interrogated using this method.

The use of magnetic fields for powering sensors and for acquiring the measurements from them eliminates the need for physical connection from the sensors to a power source and data-acquisition equipment. Because magnetic fields are used to power the sensors that, in turn, respond with their own magnetic fields, the attributes of which are dependent upon the physical properties being measured, this class of sensors is referred to as magnetic-field-response sensors.

Figure 1. A **Portable Magnetic-Field-Response Recorder** is shown in a handheld version.

Because the functionality of the magnetic-field-response sensors is based upon magnetic fields, the sensors can be used under such conditions as in caustic environments, acids, high temperatures, cryogenic temperatures, high pressures, and radiative environments. Furthermore, the method allows acquiring measurements that were previously unattainable or logistically difficult because there was no practical means of getting power and data-acquisition electrical connections to a sensor. A novel feature of the method is that an individual sensor can be used to measure simultaneously more than one physical state. This is achieved by correlating combinations of different physical states to combinations of different sensor response attributes. Another novel feature of the method is that a sensor can be used to measure a permanent transition of one physical state to another. Once the new physical state has been achieved (e.g., material phase transition), the sensor can simultaneously measure other physical states.

The magnetic-field-response recorder shown in Figure 1 is a handheld version of the measurement-acquisition system using the method discussed. Figure 2 shows a fluid-level sensor being interrogated using the recorder internal antenna and an external antenna. The programmable recorder is designed to be simple to use and is capable of powering and acquiring measurements from any magnetic-field-response sensor. It can acquire and interpret measurements that correspond to either the amplitude, frequency, and/or bandwidth of the magnetic-field-response sensor. Resonant response frequency



FLUID-LEVEL SENSOR BEING INTERROGATED USING EXTERNAL ANTENNA

FLUID-LEVEL SENSOR BEING INTERROGATED USING INTERNAL ANTENNA

Figure 2. **Interrogation of a Wireless Fluid-Level Sensor** is shown using the magnetic-field-response recorder.

and amplitude of each sensor are displayed. The amplitude is dependent upon distance at which the sensor is interrogated. The recorder can be programmed to display the physical value of the measurement. The magnetic-field-response recorder has an internal antenna, connector for external antenna, and an analog output.

The measurement-acquisition method has many advantages over other methods currently in use. Once electrically excited, the sensors have very low voltage. If a short does occur in the sensor, the sensor will not be electrically active because a completed circuit is needed for Faraday induction. Hence, electrical arcing is prevented. Because the measurement system and sensors do not necessitate a physical connection to a power source or data-acquisition equipment, they are easy to implement into existing vehicles, structures, or other existing systems. The measurement system can be installed during any phase of vehicle life, and it is less costly to install new sensors than the traditional method of wiring a sensor to acquisition equipment. Such a system can be used to implement measurements that were not envisioned during design of a vehicle or structure but identified as needed during testing or operation. New measurements only require that the new sensors be placed within the magnetic field of the interrogating antenna(s). No wiring is required. Many of the sensors and interrogating antennas can be made lightweight and non-obtrusive by directly placing on the vehicle or structural components using metallic-film deposition methods.

This work was done by Stanley E. Woodard, Qamar A. Shams, and Robert L. Fox of **Langley Research Center** *and Virginia and Bryant D. Taylor of Swales Aerospace Corporation. Further information is contained in a TSP (see page 1).*
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Platform for Testing Robotic Vehicles on Simulated Terrain

Slope, ground material, and obstacles can be varied.

NASA's Jet Propulsion Laboratory, Pasadena, California

The variable terrain tilt platform (VTTP) is a means of providing simulated terrain for mobility testing of engineering models of the Mars Exploration Rovers. The VTTP could also be used for testing the ability of other robotic land vehicles (and small vehicles in general) to move across terrain under diverse conditions of slope and surface texture, and in the presence of obstacles of various sizes and shapes.

The VTTP consists mostly of a 16-ft-(4.88-m)-square tilt table. The tilt can be adjusted to any angle between 0° (horizontal) and 25°. The test surface of the table can be left bare; can be covered with hard, high-friction material; or can be covered with sand, gravel, and/or other ground-simulating material or combination of materials to a thickness of as much as 6 in. (≈15 cm).