Very-Long-Distance Remote Hearing and Vibrometry

Optical returns from weakly illuminated targets would be processed by advanced techniques.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed development of laser-based instrumentation systems would extend the art of laser Doppler vibrometry beyond the prior limits of laser-assisted remote hearing and industrial vibrometry for detecting defects in operating mechanisms. A system according to the proposal could covertly measure vibrations of objects at distances as large as thousands of kilometers and could process the measurement data to enable recognition of vibrations characteristic of specific objects of interest, thereby enabling recognition of the objects themselves. A typical system as envisioned would be placed in orbit around the Earth for use as a means of determining whether certain objects on or under the ground are of interest as potential military targets. Terrestrial versions of these instruments designed for airborne or land- or sea-based operation could be similarly useful for military or law-enforcement purposes.

Prior laser-based remote-hearing systems are not capable of either covert operation or detecting signals beyond modest distances when operated at realistic laser power levels. The performances of prior systems for recognition of objects by remote vibrometry are limited by low signal-to-noise ratios and lack of filtering of optical signals returned from targets. The proposed development would overcome these limitations.

A system as proposed would include a narrow-band laser as its target illuminator, a lock-in-detection receiver subsystem, and a laser-power-control subsystem that would utilize feedback of the intensity of background illumination of the target to adjust the laser power. The laser power would be set at a level high enough to enable the desired measurements but below the threshold of detectability by an imaginary typical modern photodetector located at the target and there exposed to the background illumination. The laser beam would be focused tightly on the distant target, such that the receiving optics would be exposed to only one speckle. The return signal would be extremely-narrow-band filtered (to sub-kilohertz bandwidth) in the optical domain by a whispering-gallery-mode filter so as to remove most of the background illumination. The filtered optical signal would be optically amplified. This combination of optical filtering and optical amplification would provide an optical signal that would be strong enough to be detectable but not so strong as to saturate the detector in the lock-in detection subsystem.

The laser emission would be modulated by an optical modulator driven by a low-frequency oscillator. The same oscillator would drive a lock-in amplifier in the lock-in-detection receiver subsystem. It has been estimated that the lock-in amplification would contribute 30 dB to the signal-to-noise ratio.

It has been estimated that a system of this type operating at a laser power of 0.2 W could enable recognition of an object at a distance of 1,000 miles (≈1,600 km). Examples of objects of potential military significance that could be recognized include particular machines shielded under the roof of a factory or deep underground, fake garages or factories, fake weapons, land mines, and improvised explosive devices. Vibrations induced by nearby motorized vehicles are expected to be sufficient to enable recognition of buried land mines.

This work was done by Lute Maleki, Nan Yu, Andrey Matsko, and Anatoliy Savchenkov of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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Using GPS to Detect Imminent Tsunamis

Reliable tsunami warnings could be generated within minutes of causative earthquakes.

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A promising method of detecting imminent tsunamis and estimating their destructive potential involves the use of Global Positioning System (GPS) data in addition to seismic data. Application of the method is expected to increase the reliability of global tsunami-warning systems, making it possible to save lives while reducing the incidence of false alarms.

Tsunamis kill people every year. The 2004 Indian Ocean tsunami killed about 230,000 people. The magnitude of an earthquake is not always a reliable indication of the destructive potential of a tsunami. The 2004 Indian Ocean quake generated a huge tsunami, while the 2005 Nias (Indonesia) quake did not, even though both were initially estimated to be of the similar magnitude. Between 2005 and 2007, five false tsunami alarms were issued worldwide. Such alarms result in negative societal and economic effects.

GPS stations can detect ground motions of earthquakes in real time, as frequently as every few seconds. In the present method, the epicenter of an earthquake is located by use of data from seismometers, then data from coastal GPS stations near the epicenter are used to infer sea-floor displacements that precede a tsunami. The displacement data are used in conjunction with local topographical data and an advanced theory to quantify the destructive potential of a tsunami on a new "tsunami scale," based on the GPS-derived tsunami energy, much like the Richter Scale used for earthquakes. An important element of the derivation of the advanced theory was recognition that horizontal sea-floor motions contribute much more to generation of