Physical Sciences

Laser-Ranging Transponders for Science Investigations of the Moon and Mars

NASA's Jet Propulsion Laboratory, Pasadena, California

An active laser was developed ranging in real-time with two terminals, emulating interplanetary distances, and with submillimeter accuracy. In order to overcome the limitations to ranging accuracy from jitters and delay drifts within the transponders, architecture was proposed based on asynchronous paired one-way ranging with local references. A portion of the transmitted light is directed, via a reference path, to the local detector. This allows for compensation of any jitter in the timing of the emitted laser pulse. The same detector is used to measure the time of the received pulses emitted from the remote terminal. This approach removes any change in the delay caused by the detector or its electronics.

Two separate terminals using commercial off-the-shelf hardware were built to emulate active laser ranging over interplanetary distances. The communication link for the command to start recording pulse arrival times and data transfer from one terminal to the other was achieved using a standard wireless link, emulating free space laser communication. The deviation is well below the goal of 1-mm precision. This leaves enough margin to achieve 1-mm precision when including the fluctuations due to atmospheric turbulence while ranging to Mars through the Earth's atmosphere. The two terminals are mounted on translation stages, which can be moved freely on rails to yield a wide range of distances with fine adjustment. The two terminals were separated by approximately 16 meters.

This work was done by Hamid Hemmati, Yijiang Chen, and Kevin Birnbaum of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-48125

Ka-Band Waveguide Three-Way Serial Combiner for MMIC Amplifiers

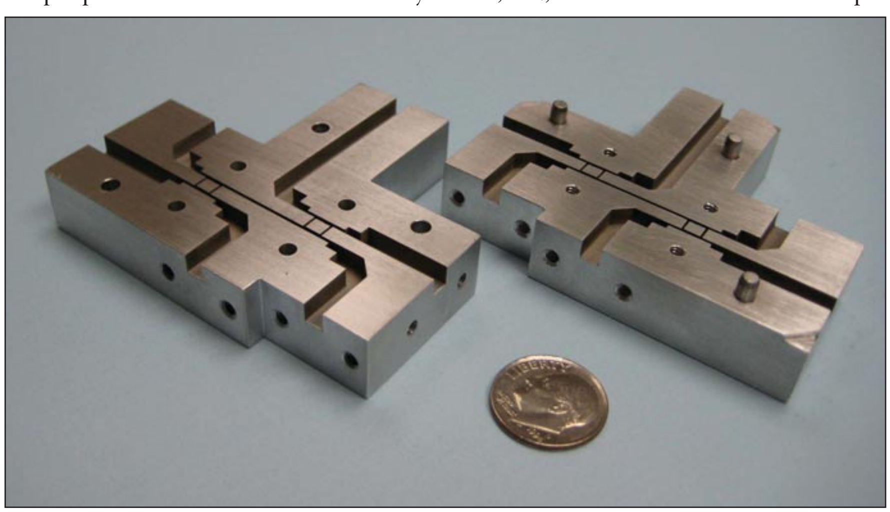
This device is a power combiner that can be used for a solid-state power amplifier.

John H. Glenn Research Center, Cleveland, Ohio

In this innovation, the three-way combiner consists internally of two branch-line hybrids that are connected in series by a short length of waveguide. Each branch-line hybrid is designed to combine input signals that are in phase with an amplitude ratio of two. The combiner is constructed in an E-plane split-block arrangement and is precision machined from blocks of aluminum with standard WR-28 waveguide ports. The port impedances of the combiner are matched to that of a standard WR-28 waveguide. The component parts include the power combiner and the MMIC (monolithic microwave integrated circuit) power amplifiers (PAs). The three-way series power combiner is a six-port device. For basic operation, power that enters ports 3, 5, and 6 is combined in phase and appears at port 1. Ports 2 and 4 are isolated ports. The application of the three-way combiner for combining three PAs with unequal output powers was demonstrated.

NASA requires narrow-band solid-state power amplifiers (SSPAs) at Ka-band frequencies with output power in the range of 3 to 5 W for radio or gravity science experiments. In addition, NASA also requires wideband, high-efficiency SSPAs at Ka-band frequencies with output power in the range of 5 to 15 W for high-data-rate communications from deep space to Earth. The three-way power combiner is designed to operate over the frequency band of 31.8 to 32.3 GHz, which is NASA's deep-space frequency band.

For the proof-of-concept demonstration of this innovation, three available PAs were selected with output powers of 0.1, 0.2, and 0.6 W to meet the ampli-



This photo of the fabricated **Serial Combiner** shows the split-block construction arrangement.

tude ratio of two. The 0.1- and 0.2-W PAs, which are in the 1:2 power ratio, are initially combined in a branch-line hybrid that has a coupling value of 4.77 dB. Likewise, the combined output of the first branch-line hybrid is combined with the output from the third PA in a second branch-line hybrid, also with a coupling value of 4.77 dB. The measured combining efficiency at the center frequency of 32.05 GHz is greater than 90% for a wide range of power ratios both below and above two. The measured return loss at the output port 1 and the isolation among the input ports 3, 5, and 6 of the three-way combiner are greater than 16 and 22 dB, respectively.

This work was done by Rainee N. Simons, Edwin G. Wintucky, and Jon C. Freeman of Glenn Research Center; and Christine T. Chevalier of QinetiQ North America Corp. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18688-1

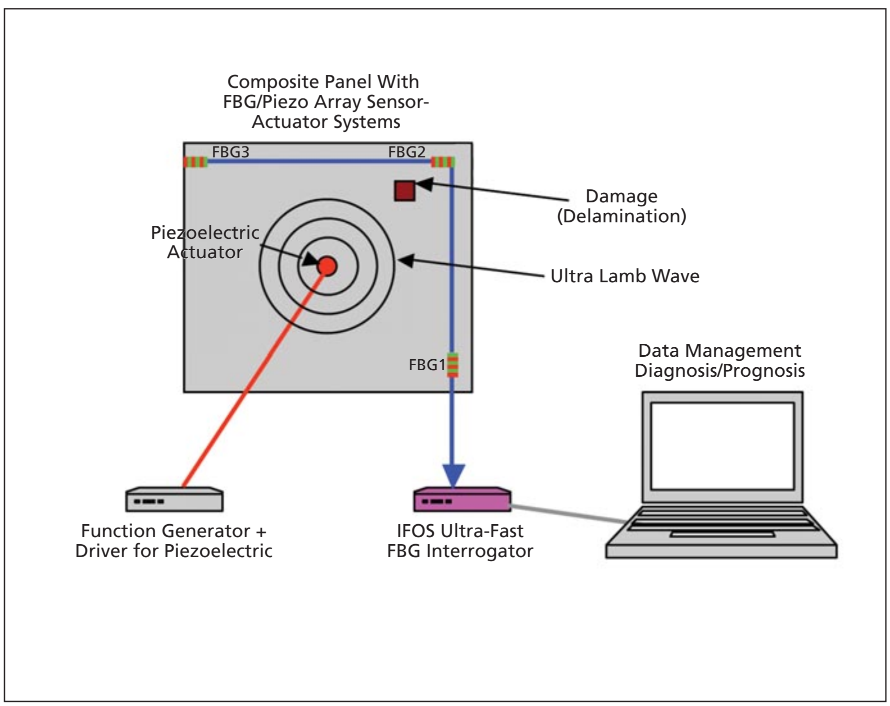
Structural Health Monitoring With Fiber Bragg Grating and Piezo Arrays

A nondestructive damage identification and assessment capability can be used in monitoring systems for maintenance and disaster avoidance.

Dryden Flight Research Center, Edwards, California

Structural health monitoring (SHM) is one of the most important tools available for the maintenance, safety, and integrity of aerospace structural systems. Lightweight, electromagnetic-interference-immune, fiber-optic sensor-based SHM will play an increasing role in more secure air transportation systems. Manufacturers and maintenance personnel have pressing needs for significantly improving safety and reliability while providing for lower inspection and maintenance costs. Undetected or untreated damage may grow and lead to catastrophic structural failure.

Damage can originate from the strain/stress history of the material, imperfections of domain boundaries in metals, delamination in multi-layer materials, or the impact of machine tools in the manufacturing process. Damage can likewise develop during service life from wear and tear, or under extraordinary circumstances such as with unusual forces, temperature cycling, or impact of flying objects. Monitoring and early detection are key to preventing a catastrophic failure of structures, especially when these are expected to perform near their limit conditions.



The **Fiber Bragg Grating/Piezo Array** sensor-actuator system as a concept demonstration for structural health monitoring.

The ultimate goal of SHM technology is to develop autonomous (preventive) maintenance systems for continuous monitoring, inspection, and damage detection of structures with minimum labor involvement in real time, and in order to prevent catastrophic structural failure with timely service/maintenance. The ultimate solution will include both advanced hardware and advanced mathematical algorithms.

On the hardware side, a high-speed, high-channel-count fiber-optic sensor interrogation system was developed. On the SHM algorithmic side, algorithmic methods were developed for characterizing the damage from sensory data collected over several strategically placed sensors.

A dynamic response-based damage detection technique is relatively easy to implement and offers a wealth of differential diagnostic capabilities. The basic assumptions of this technique are that the dynamic parameters such as natural frequencies, mode shapes, transfer functions, or response functions depend on the physical properties across the structures. Therefore, the changes in these dynamic characteristics can be used to locate and assess problem areas. Smart optical fiber Bragg grating (FBG) sensors have been increasingly used in SHM, and they could be either surface-bonded or embedded within the structures, and form an array of sensors for dynamic response measurement. For a small-scale demonstration, Lamb waves are excited by a single piezoelectric actuator and captured by three FBG sensors whose response is in turn captured by a parallel processing FBG interrogator ca-