complex, and can be prone to errors. The errors can be compounded because of approximations in the model and inaccurate assumptions about the radiative coupling between the atmosphere and the terrain. The errors can increase the uncertainty of the TOA radiance estimates used to perform the radiometric calibration.

In comparison, the simplified approach does not use atmospheric radiative transfer models and involves fewer assumptions concerning the radiative transfer properties of the atmosphere. This new technique uses two neighboring uniform ground target areas having different reflectance values. The target areas can be natural or artificial and must be large enough to minimize adjacent-pixel contamination effects. The radiative coupling between the atmosphere and the terrain needs to be approximately the same for the two targets. This condition can be met for relatively uniform backgrounds when the distance between the targets is within a few hundred meters.

For each target area, the radiance leaving the ground in the direction of the satellite is measured with a radiometrically calibrated spectroradiometer. Using the radiance measurements from the two targets, atmospheric adjacency and atmospheric scattering effects can be subtracted, thereby eliminating many assumptions about the atmosphere and the radiative interaction between the atmosphere and the terrain. In addition, the radiometrically calibrated spectroradiometer can be used with a known reflectance target to estimate atmospheric transmission and diffuse-to-global ratios without the need for ancillary sun photometers.

Several comparisons between the simplified method and traditional techniques were found to agree within a few percent. Hence, the simplified method reduces the overall complexity of performing vicarious calibrations and can serve as a method for validating traditional radiative transfer models.

This work was done by Thomas Stanley of Stennis Space Center and Robert E. Ryan, Kara Holekamp, and Mary Pagnutti of Science Systems and Applications, Inc.

Inquiries concerning this technology should be addressed to the Intellectual Property Manager, Stennis Space Center, (228) 688-1929. Refer to SSC-00301-1, volume and number of this NASA Tech Briefs *issue, and the page number.*

Phase-Conjugate Receiver for Gaussian-State Quantum Illumination

Active optical sensors have application in military surveillance.

NASA's Jet Propulsion Laboratory, Pasadena, California

An active optical sensor probes a region of free space that is engulfed in bright thermal noise to determine the presence (or absence) of a weakly reflecting target. The returned light (which is just thermal noise if no target is present, and thermal noise plus a weak reflection of the probe beam if a target is present) is measured and processed by a receiver and a decision is made on whether a target is present.

It has been shown that generating an entangled pair of photons (which is a highly nonclassical state of light), using one photon as the probe beam and storing the other photon for comparison to the returned light, has superior performance to the traditional classical-light (coherent-state) target detection sensors. An entangled-photon transmitter and optimal receiver combination can yield up to a factor of 4 (i.e., 6 dB) gain in the error-probability exponent over a coherent state transmitter and optimal receiver combination, in a highly lossy and noisy scenario (when both sensors have the same number of transmitted photons). However, the receiver that achieves this advantage is not known. One structured receiver can close half of the 6-dB gap (i.e., a 3-dB improvement). It is based on phase-conjugating the returned light, then performing dual-balanced difference detection with the stored half of the entangled-photon pair.

Active optical sensors are of tremendous value to NASA's missions. Although this work focuses on target detection, it can be extended to imaging (2D, 3D, hyperspectral, etc.) scenarios as well, where the image quality can be better than that offered by traditional active sensors. Although the current work is theoretical, NASA's future missions could benefit significantly from developing and demonstrating this capability.

This is an optical receiver design whose components are, in principle, all implementable. However, the work is currently entirely theoretical. It is necessary to:

1. Demonstrate a bench-top proof of the theoretical principle,
2. Create an operational prototype off-the-bench, and
3. Build a practical sensor that can fly in a mission.

This work was done by Baris I. Erkmen of Caltech and Saikat Guha of BBN Technologies for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47152

Improved Tracking of an Atomic-Clock Resonance Transition

The resonance frequency is repeatedly estimated from sequences of three measurements.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved method of making an electronic oscillator track the frequency of an atomic-clock resonance transition is based on fitting a theoretical nonlinear curve to measurements at three oscillator frequencies within the operational frequency band of the transition (in other words, at three points within the resonance peak). In the measurement process, the frequency of a microwave oscillator is repeatedly set at various offsets from the nominal resonance