circuitry. In an analog embodiment, the histogram of the signal would be captured by a tree of window comparator/integrators, there being one branching level of the tree for each of n compartments of the histogram. The final analog calculation of the aspect of shape of the histogram that encodes the desired information would be performed by various hard-wired combinations of n-level summing amplifiers. A digital embodiment would include a single analog-to-digital converter operating at a sampling rate high enough to avoid aliasing. The PDF modulation would be detected by software that would examine the histogram table.

Regardless of the analog or digital nature of the receiver circuitry, the transmitter would best be embodied in a combination of digital and analog circuitry: The waveform-shaping computations for encoding the information to be conveyed would be performed digitally. The resulting numbers would be fed as input to a digital-to-analog converter to generate the analog waveform to be amplified and used to generate the transmitted signal.

The main advantage of the method would lie in its value as the basis of an electronic form of steganography. Because a message would be encoded in statistical characteristics of a waveform, neither the existence nor the contents of the message could easily be discerned by simple inspection of the waveform.

Some types of PDF-modulation waveforms are expected to be resilient in the presence of interference and jamming if properly used in digital-signal-processing radio-relay systems: examples include sawtooth and square waveforms. On the other hand, at low receiver signal-to-noise ratios, decoding can be problematic in cases in which users do not take care to select modulation waveforms that are easily recognizable in the presence of noise.

This work was done by Glenn L. Williams of Glenn Research Center. 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: Steve Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17650-1.

Ku Telemetry Modulator for Suborbital Vehicles

Goddard Space Flight Center, Greenbelt, Maryland

A modulator utilizing the Ku-band instead of the usual S-band has been developed to improve transmission rates for suborbital platforms. The unit operates in the 14.5–15.5-GHz band and supports data rates up to 200 Mbps.

In order to keep the modulator costs low, the modulator is based on the LCT2 [Low Cost TDRSS (Tracking and Data Relay Satellite System)] Transceiver design, which utilizes a single-board modulator incorporating an Analog Devices quadrature modulator IC, with I&Q [inphase (I) and quadrature (Q)] bandwidths of 70 MHz. A pin-compatible version of the chips with I&Q bandwidths of up to 160 MHz is used to achieve the higher data rates. To support the higher data rate, an LVDS (low-voltage differential signaling) user interface will be incorporated into the modulator board. The LCT2 configuration uses a 1×4 in. (≈2.5×10.2 cm) high-power S-band amplifier module. The new amplifier printed circuit board (PCB) module is replaced with a compact S-band to Ku-band upconverter, with an RF output of +5 dBm.

A key feature is the unit's small form factor of 4×5×1.5 in. (≈10.2×12.7×3.8 cm). It has a low complexity, consisting of two PCBs and a DC/DC converter. This keeps the cost down, which is an important feasibility issue for the types of missions that it is designed for — low-cost suborbital. This modulator is useful for any suborbital platform such as sounding rockets, balloons, unmanned aerial vehicles (UAVs), and expendable launch vehicles.

This work was done by Steven Bundick of Goddard Space Flight Center and Jim Bishop, David Newman, and Nazrul Zaki of LJT & Associates. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-15456-1

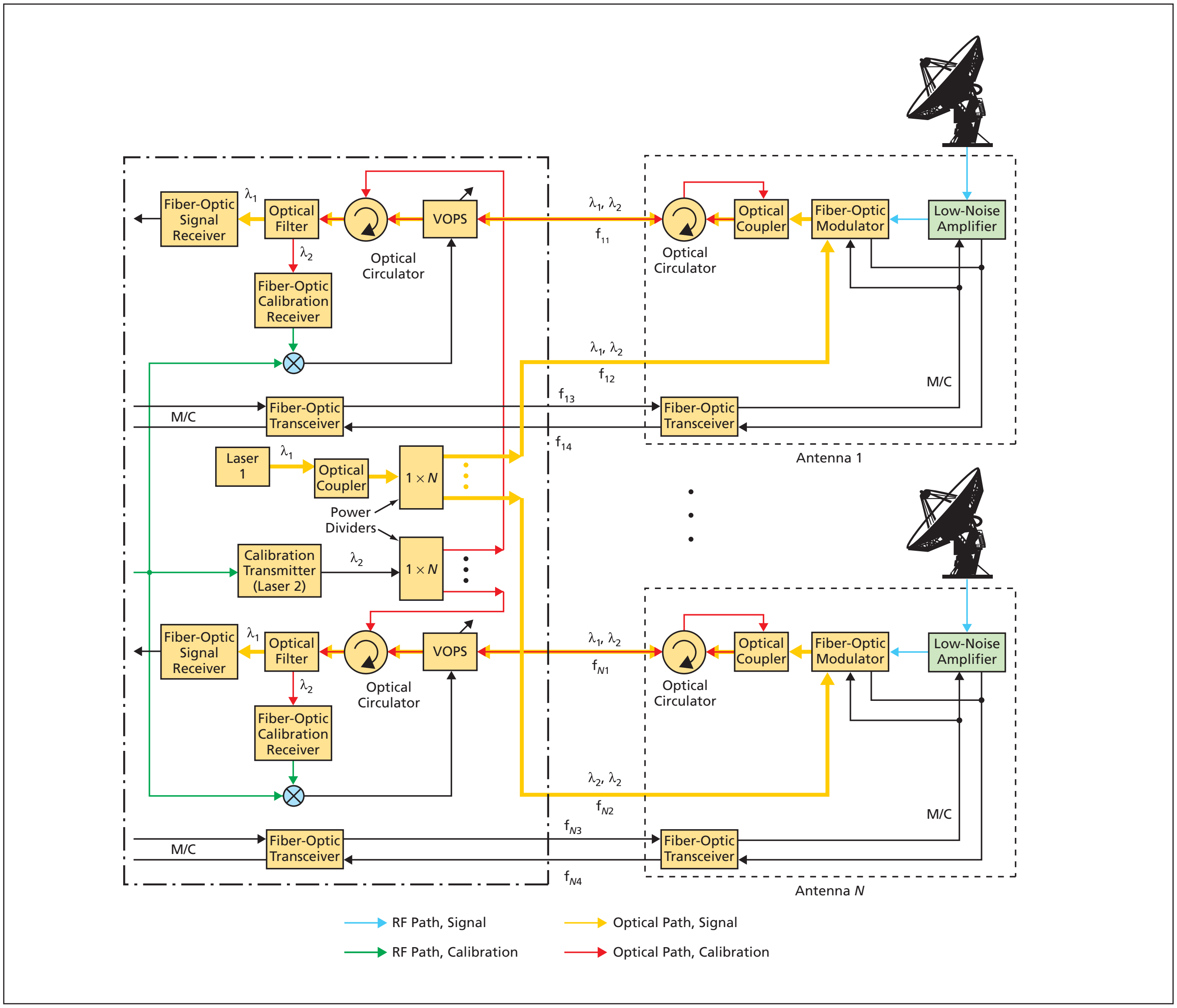
Photonic Links for High-Performance Arraying of Antennas

Advantages over RF arraying architecture would include reduced cost and increased reliability.

NASA's Jet Propulsion Laboratory, Pasadena, California

An architecture for arraying microwave antennas in the next generation of NASA's Deep Space Network (DSN) involves the use of all photonic links between (1) the antennas in a given array and (2) a signal-processing center. As used here, "arraying" refers generally to any or all of several functions that include control and synchronization functions; coherent combination of signals received by multiple antennas at different locations in such a way as to improve reception, as though one had a single larger antenna; and coherent radiation of signals for transmission of an intense, narrow beam toward a distant spacecraft or other target. This all-photonic arraying architecture can also be adapted to arraying of radio antennas other than those of the DSN. In this architecture, all affected parts at each antenna pedestal [except a front-end low-noise amplifier for the radio-frequency (RF) signal coming from the antenna and an optical transceiver to handle monitor and control (M/C) signals] would be passive optical parts. Potential advantages of this all-photonic link architecture over the RF architecture now in use include cost savings, increased stability of operation, increased reliability, and a reduction in the time and materials expended in maintenance at each antenna.

A basic arraying system according to this architecture (see figure) would utilize only a single high-power laser (emitting at wavelength λ_1) and several lower-power lasers in the signal-processing center to drive fiber-optic links between the center and N antennas. In the future DSN appli-



The **All-Photonic Arraying Architecture** is depicted here in simplified form: For the sake of clarity in illustrating the underlying principles, such details as partly separate paths for handling X- and Ka-band RF signals are omitted.

cation as now envisioned, the lengths of the fiber-optic links would be of the order of a kilometer. The λ_1 laser signal would be split by a 1×*N* power divider then distributed to all *N* antennas in the array via optical fibers denoted in the figure as f_{12} ... f_{N2}. At each antenna, the incoming λ_1 laser signal would be coupled into a fiber-optic modulator, which would be driven by an amplified version of the RF signal received by the antenna. The modulated λ_1 light would pass through an optical coupler and an optical circulator, from whence it would travel to the signal-processing center via optical fibers (f_{11} ... f_{N1}). These aspects of the architecture eliminate the need for radio-frequency (RF) down-conversion, phased-locked-loop, and other equipment traditionally used at each antenna to process the signal(s) received by that antenna.

At the center, the incoming λ_1 signal light would pass through a variable optical phase shifter (VOPS), an optical circulator, and an optical filter to reach a fiber-optic receiver, which would recover the RF signal and deliver it to other circuitry for further processing. The same optical fibers used to carry the modulated λ_1 signals to the center would also be used to carry a continuous-wave-RF-modulated calibration signal of wavelength λ_2 between the center and the antennas for use in stabilizing the phase of the λ_1 signals in the face of predominantly thermally induced fluctuations in the lengths of the optical fibers.

The λ_2 calibration light returning to the center from each antenna would be separated from the λ_1 light by an optical filter and sent to another fiber-optic receiver, which would recover the continuous-wave RF calibration modulation. The RF output of this receiver would be compared with the original continuous-wave RF calibration modulation to obtain an error signal, which would be used as feedback to control the VOPS to compensate for any change in phase in propagation through the optical signal/calibration optical fiber and other optical components of the system.

Additional optical fibers (f_{13} ... f_{N3}, f_{14} ... f_{N4}) would be used to carry the M/C signals. Inasmuch as the modulation on these signals would be at relatively low frequencies, there would be no need to stabilize them by use of VOPSs.

This work was done by Shouhua Huang and Robert Tjoelker of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-44130