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## Radiometer on a Chip

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Submillimeter-wave radiometers have traditionally been built by packaging each chip with a distinct function separately, and then combining the packaged chips to form subsystems. Instead of packaging one chip at a time, the radiometer on a chip (ROC) integrates whole wafers together to provide a robust, extremely powerful way of making submillimeter receivers that provide vertically integrated functionality. By integrating at the wafer level, customizing the interconnects, and planarizing the transmission media, it is possible to create a lightweight assembly performing

the function of several pieces in a more conventional radiometer. This represents a greater than 50-fold decrease in both volume and mass. The act of combining the individual radiometer functions into a sequence of chips will also improve inter-component matching and reduce the loss associated with the power combining that accompanies today's radiometers.

Most of the gain fluctuations in present-day radiometers are the result of thermal gradients. By reducing the size and mass of the radiometer, the thermal gradients are reduced, thus also reduc-

ing their effect on thermal stability. This results in greater measurement stability.

With a size reduction of this magnitude, ROCs will be able to be used in balloons, landers, rovers, and any other place where a complete remote chemical laboratory might be required.

*This work was done by Goutam Chattopadhyay, John J. Gill, Imran Mehdi, Choonsup Lee, Erich T. Schlecht, Anders Skalar, John S. Ward, Peter H. Siegel, and Bertrand C. Thomas of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact [iaoffice@jpl.nasa.gov](mailto:iaoffice@jpl.nasa.gov). NPO-46542*

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## Measuring Luminescence Lifetime With Help of a DSP

*Lyndon B. Johnson Space Center, Houston, Texas*

An instrument for measuring the lifetime of luminescence (fluorescence or phosphorescence) includes a digital signal processor (DSP) as the primary means of control, generation of excitation signals, and analysis of response signals. In contrast, prior luminescence-lifetime-measuring instruments have utilized primarily analog circuitry to perform these functions. Such instruments are typically used as optical chemical sensors.

Like the prior instruments, the present instrument is based on the principle of illuminating a specimen with sinusoidally

varying light to excite sinusoidally varying luminescence and measuring either the phase shift ( $\phi$ ) between the luminescence oscillations and the excitation signal at a specified frequency ( $f$ ) or the frequency that results in a specified fixed phase shift (typically,  $90^\circ$ ). The fluorescence lifetime ( $\tau$ ) is then calculated using  $\tau = \tan \phi / (2\pi f)$ . The primary limitation of prior analog instruments was lack of reconfigurability: it was necessary to rewire components to change operating modes for different specimens. In contrast, the DSP hardware in the present instrument makes it possible to switch among a vari-

ety of operating modes by making changes in software only.

*This work was done by J. D. S. Danielson of PhotoSense LLC for Johnson Space Center. Further information is contained in a TSP (see page 1).*

*In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:*

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## Modulation Based on Probability Density Functions

**This method would have steganographic value.**

*John H. Glenn Research Center, Cleveland, Ohio*

A proposed method of modulating a sinusoidal carrier signal to convey digital information involves the use of histograms representing probability density functions (PDFs) that characterize samples of the signal waveform. Although almost any modulation can be characterized as amplitude, phase, or frequency modulation or some combination of two or all three of them, the proposed method is independent of traditional modes of amplitude, phase, and frequency modulation and neither

explicitly includes nor explicitly excludes them.

The method is based partly on the observation that when a waveform is sampled (whether by analog or digital means) over a time interval at least as long as one half cycle of the waveform, the samples can be sorted by frequency of occurrence, thereby constructing a histogram representing a PDF of the waveform during that time interval. Commonly known data-analysis and statistical techniques (e.g., those of pattern

recognition or correlation), implemented in software, can reveal a trend in the histogram associated with some aspect of the shape of the sampled segment of the waveform. In the proposed method, the waveform would be shaped, at the transmitter, such that the trend in the histogram to be generated at the receiver would encode a digital datum (e.g., a one or a zero in the case of binary encoding).

A receiver according to this method could be embodied in analog or digital

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.*

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## 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 [in-phase (I) and quadrature (Q)] bandwidths of 70 MHz. A pin-compatible ver-

sion 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 up-converter, 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*

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## 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-pho-

tonic 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  $\lambda_1$ ) 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-