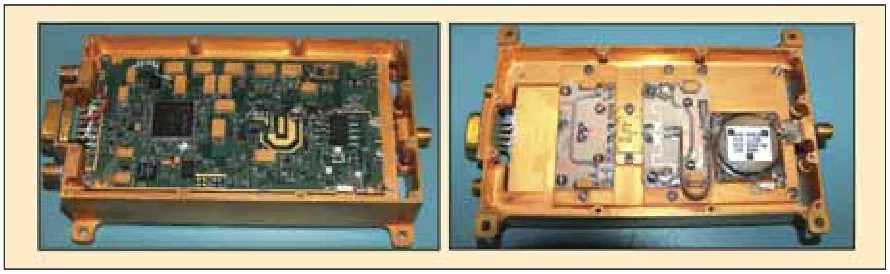
L-Band Transmit/Receive Module for Phase-Stable Array Antennas

A self-calibrating interferometric synthetic aperture radar instrument uses an electronically steerable radar antenna to achieve greater accuracy.

NASA's Jet Propulsion Laboratory, Pasadena, California

Interferometric synthetic aperture radar (InSAR) has been shown to provide very sensitive measurements of surface deformation and displacement on the order of 1 cm. Future systematic measurements of surface deformation will require this capability over very large areas (300 km) from space. To achieve these required accuracies, these spaceborne sensors must exhibit low temporal decorrelation and be temporally stable systems. An L-band (24-cm-wavelength) InSAR instrument using an electronically steerable radar antenna is suited to meet these needs. In order to achieve the 1-cm displacement accuracy, the phased array antenna requires phase-stable transmit/receive (T/R) modules. The T/R module operates at L-band (1.24 GHz) and has less than 1-deg absolute phase stability and less than 0.1-dB absolute amplitude stability over temperature. The T/R module is also high power (30 W) and power efficient (60-percent overall efficiency). The design is currently implemented using discrete components and surface mount technology.



The photo shows the **T/R Module** on the front side and the **30-W Power Amp** on the reverse side.

The basic T/R module architecture is augmented with a calibration loop to compensate for temperature variations, component variations, and path loss variations as a function of beam settings. The calibration circuit consists of an amplitude and phase detector, and other control circuitry, to compare the measured gain and phase to a reference signal and uses this signal to control a precision analog phase shifter and analog attenuator. An architecture was developed to allow for the module to be bidirectional, to operate in both transmit and receive mode. The architecture also includes a power detector used to maintain a transmitter power output constant within 0.1 dB.

The use of a simple, stable, low-cost, and high-accuracy gain and phase detector made by Analog Devices (AD8302), combined with a very-high-efficiency T/R module, is novel. While a self-calibrating T/R module capability has been sought for years, a practical and cost-effective solution has never been demonstrated. By adding the calibration loop to an existing high-efficiency T/R module, there is a demonstrated order-of-magnitude improvement in the amplitude and phase stability.

*This work was done by Constantine Andricos and Wendy Edelstein of Caltech and Vladimir Krimskiy of Santa Barbara Applied Research for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*NPO-45147

Microwave Power Combiner/Switch Utilizing a Faraday Rotator

Either or both of two input ports could be coupled to one output port.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed device for combining or switching electromagnetic beams would have three ports, would not contain any moving parts, and would be switchable among three operating states:

- Two of the ports would be for input; the remaining port would be for output.
- In one operating state, the signals at both input ports would be coupled through to the output port.
- In each of the other two operating states, the signal at only one input port would be coupled to the output port. The input port would be selected through choice of the operating state.

In one potential application, the device would be used to switch or combine microwave signals in a quasi-optical transmission-line assembly that would be part of a millimeter-wave radar or telecommunication system. In another potential application, a modified version of the device would be used to switch or combine light signals in a fiber-optic telecommunication link.

The two input ports would be configured to accommodate signals having mutually orthogonal linear polarizations. A polarizer would be positioned to bisect the right angle formed by the longitudinal axes of the input ports, and its polarization would be oriented to so that it would allow one input signal to pass through and would reflect the other input signal. The orientations of the aforementioned components would be such that after impinging on the polarizer, both input signals would propagate toward a three-state Faraday rotator. The components of the Faraday rotator would be a ferrite disk, a solenoidal electromagnet coil for applying magnetic bias, and two impedance-matching plates — one on each side of the ferrite disk. The output port would be positioned on the side opposite the input side of the Faraday rotator and would be oriented to support polarization at an angle of 45° relative to both of the input polarizations.

The operating state would be selected by adjusting the magnetic bias to select one of three states of the Faraday rotator. In one state, the magnetic bias would be set to cause the polarization of a propagating signal to rotate through an angle of +45° so as to allow one of the input signals to propagate to the output port. In another state, the direction of the magnetic bias would be set at the reverse of that of the first-mentioned state to obtain a polarization rotation of 45°, thereby allowing the other input signal to propagate to the output port.

The third state would be used for combining the powers of two mutually coherent input signals that, in an ideal case, would be of equal magnitude and would differ in phase by 90°. In this state, the magnetic bias (and thus, the Faraday rotation) would be set to zero and the superposition of the input signals would result in a 45°-polarized sum signal that would propagate to the output port. In practice, because of magnetic hysteresis, this state could not be obtained by simply abruptly turning off the current in the electromagnet: It would be necessary to apply a damped sinusoidal excitation to the electromagnet coil to effect degaussing.

This work was done by Raul Perez of Caltech for NASA's Jet Propulsion Laboratory.

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Refer to NPO-44316, volume and number of this NASA Tech Briefs *issue, and the page number.*

Compact Low-Loss Planar Magic-T

These wireless communications components are useful for base-station receivers, consumer electronics, and industrial microwave instrumentation.

Goddard Space Flight Center, Greenbelt, Maryland

This design allows broadband power combining with high isolation between the H port and E port, and achieves a lower insertion loss than any other broadband planar magic-T. Passive microwave / millimeter-wave signal power is combined both in-phase and out-of-phase at the ports, with the phase error being less than ±1°, which is limited by port impedance.

The in-phase signal combiner consists of two quarter-wavelength-long transmission lines combined at the microstrip line junction. The out-of-phase signal combiner consists of two half-wavelength-long transmission lines combined in series. Structural symmetry creates a virtual ground plane at the combining junction, and the combined signal is converted from microstrip line to slotline. Optimum realizable characteristic impedances are used so that the magic-T provides broadband response with low return loss.

The magic-T is used in microwave- and millimeter-wave frequencies, with the operating bandwidth being approximately 100 percent. The minimum isolation obtainable is 32 dB from port E to port H. The magic-T VSWR is less than 1.1 in the operating band. Operating temperature is mainly dependent on the variation in the dielectric constant of the substrate. Using crystallized substrate, the invention can operate in an extremely broad range of temperatures (from 0 to 400 K). It has a very high reliability because it has no moving parts and requires no maintenance, though it is desirable that the magic-T operate in a low-humidity environment. Fabrication of this design is very simple, using only two metallized layers. No bond wires, via holes, or air bridges are required. Additionally, this magic-T can operate as an individual component without auxiliary components.

This work was done by Kongpop U-yen, Edward J. Wollack, Terence Doiron, and Samuel H. Moseley of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15353-1

Using Pipelined XNOR Logic to Reduce SEU Risks in State Machines

Risk is reduced by use of fast state-machine and error-detection logic.

NASA's Jet Propulsion Laboratory, Pasadena, California

Single-event upsets (SEUs) pose great threats to avionic systems' state machine control logic, which are frequently used to control sequence of events and to qualify protocols. The risks of SEUs manifest in two ways: (a) the state machine's state information is changed, causing the state machine to unexpectedly transition to another state; (b) due to the asynchronous nature of SEU, the state machine's state registers become metastable, consequently causing any combinational logic associated with the metastable registers to malfunction temporarily. Effect (a) can be mitigated with methods such as triple-modular redundancy (TMR). However, effect (b) cannot be eliminated and can degrade the effectiveness of any mitigation method of effect (a).

Although there is no way to completely eliminate the risk of SEU-in-