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.

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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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-induced errors, the risk can be made very small by use of a combination of very fast state-machine logic and error-detection logic. Therefore, one goal of two main elements of the present method is to design the fastest state-machine logic circuitry by basing it on the fastest generic state-machine design, which is that of a one-hot state machine. The other of the two main design elements is to design fast error-detection logic circuitry and to optimize it for implementation in a field-programmable gate array (FPGA) architecture: In the resulting design, the one-hot state machine is fitted with a multiple-input XNOR gate for detection of illegal states. The XNOR gate is implemented with lookup tables and with pipelines for high speed.

In this method, the task of designing all the logic must be performed manually because no currently available logic-synthesis software tool can produce optimal solutions of design problems of this type. However, some assistance is provided by a script, written for this purpose in the Python language (an object-oriented interpretive computer language) to automatically generate hardware description language (HDL) code from state-transition rules.

This work was done by Martin Le, Xin Zheng, and Sunant Katanyoutant of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-42401

Quasi-Optical Transmission Line for 94-GHz Radar

This apparatus functions as a very-low-loss, three-port circulator.

NASA's Jet Propulsion Laboratory, Pasadena, California

A quasi-optical transmission line (QOTL) has been developed as a low-loss transmission line for a spaceborne cloud-observing radar instrument that operates at a nominal frequency of 94 GHz. This QOTL could also readily be redesigned for use in terrestrial millimeter-wave radar systems and millimeter-wave imaging systems.

In the absence of this or another low-loss transmission line, it would be necessary to use a waveguide transmission line in the original radar application. Unfortunately, transmission losses increase and power-handling capacities of waveguides generally decrease with frequency, such that at 94 GHz, the limitation on transmitting power and the combined transmission and reception losses (> 5 dB) in a waveguide transmission line previously considered for the original application would be unacceptable.

The QOTL functions as a very-low-loss, three-port circulator. The QOTL includes a shaped input mirror that can be rotated to accept 94-GHz transmitter power from either of two high-power amplifiers. Inside the QOTL, the transmitter power takes the form of a linearly polarized beam radiated from a feed horn. This beam propagates through a system of mirrors, each of which refocuses the beam to minimize diffraction losses. A magnetically biased ferrite disc is placed at one of the foci to utilize the Faraday effect to rotate the polarization of the beam by 45°. The beam is then transmitted via an antenna system.

The radar return (scatter from clouds, and/or reflections from other objects) is collected by the same antenna and propagates through the Faraday rotator in the reverse of the direction of propagation of the transmitted beam. In the Faraday rotator, the polarization of the received signal is rotated a further 45°, so that upon emerging from the Faraday rotator, the received beam is polarized at 90° with respect to the transmitted beam. The transmitted and received signals are then separated by a wire-grid polarizer.

This work was done by Raul M. Perez and Watt Veruttipong of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-44236

Next Generation Flight Controller Trainer System

Lyndon B. Johnson Space Center, Houston, Texas

The Next Generation Flight Controller Trainer (NGFCT) is a relatively inexpensive system of hardware and software that provides high-fidelity training for space-shuttle flight controllers. NGFCT provides simulations into which are integrated the behaviors of emulated space-shuttle vehicle onboard general-purpose computers (GPCs), mission-control center (MCC) displays, and space-shuttle systems as represented by high-fidelity shuttle mission simulator (SMS) mathematical models. The emulated GPC computers enable the execution of onboard binary flight-specific software. The SMS models include representations of system malfunctions that can be easily invoked. The NGFCT software has a flexible design that enables independent updating of its GPC, SMS, and MCC components.

This work was done by Scott Arnold, Matthew R. Barry, Isaac Benton, Michael M. Bishop, Steven Evans, Jason Harvey, Timothy King, Jacob Martin, Al Mercier, Walt Miller, Dan L. Payne, Hanh Phu, James C. Thompson, and Ron Aadsen of United Space Alliance for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-23617-1