Physical Sciences

Multimode Directional Coupler for Utilization of Harmonic Frequencies From TWTAs

The design is easily scaled to higher frequency TWTAs.

John H. Glenn Research Center, Cleveland, Ohio

A novel waveguide multimode directional coupler (MDC) intended for the measurement and potential utilization of the second and higher order harmonic frequencies from high-power traveling wave tube amplifiers (TWTAs) has been successfully designed, fabricated, and tested. The design is based on the characteristic multiple propagation modes of the electrical and magnetic field components of electromagnetic waves in a rectangular waveguide.

The purpose was to create a rugged, easily constructed, more efficient waveguide-based MDC for extraction and exploitation of the second harmonic signal from the RF output of high-power TWTs used for space communications. The application would be a satellite-based beacon source needed for Q-band and V/W-band atmospheric propagation studies. The MDC could function as a CW narrow-band source or as a wideband source for study of atmospheric group delay effects on high-data-rate links.

The MDC is fabricated from two sections of waveguide — a primary one for the fundamental frequency and a secondary waveguide for the second harmonic — that are joined together such that the second harmonic higher order modes are selectively coupled via precision-machined slots for propagation in the secondary waveguide.

In the TWTA output waveguide port, both the fundamental and the second harmonic signals are present. These signals propagate in the output waveguide as the dominant and higher order modes, respectively. By including an appropriate mode selective waveguide directional coupler, such as the MDC presented here at the output of the TWTA, the power at the second harmonic can be sampled and amplified to the power level needed for atmospheric propagation studies.

The important conclusions from the preliminary test results for the multimode directional coupler are: (1) the second harmonic (Ka-band) can be measured and effectively separated from the fundamental (Ku-band) with no coupling of the latter, (2) power losses in the fundamental frequency are negligible, and (3) the power level of the extracted second harmonic is sufficient for further amplification to power levels needed for practical applications. It was also demonstrated that third order and potentially higher order harmonics are measurable with this device. The design is frequency agnostic, and with the appropriate choice of waveguides, is easily scaled to higher frequency TWTs. The MDC has the same function but with a number of important advantages over the conventional diplexer.

This work was done by Rainee N. Simons and Edwin G. Wintucky 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: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-19045-1.

Dual-Polarization, Multi-Frequency Antenna Array for use with Hurricane Imaging Radiometer

New approach promises to be more cost effective and can reduce on-station aircraft time.

Marshall Space Flight Center, Alabama

Advancements in common aperture antenna technology were employed to utilize its proprietary genetic algorithm-based modeling tools in an effort to develop, build, and test a dual-polarization array for Hurricane Imaging Radiometer (HIRAD) applications. Final program results demonstrate the ability to achieve a lightweight, thin, higher-gain aperture that covers the desired spectral band.

NASA employs various passive microwave and millimeter-wave instruments, such as spectral radiometers, for a range of remote sensing applications, from measurements of the Earth's surface and atmosphere, to cosmic background emission. These instruments such as the HIRAD, SFMR (Stepped Frequency Microwave Radiometer), and LRR (Lightweight Rainfall Radiometer), provide unique data accumulation capabilities for observing sea surface wind, temperature, and rainfall, and significantly enhance the understanding and predictability of hurricane intensity. These microwave instruments require extremely efficient wideband or multiband antennas in order to conserve space on the airborne platform. In addition, the thickness and weight of the antenna arrays is of paramount importance in reducing platform drag, permitting greater time on station.

Current sensors are often heavy, single-polarization, or limited in frequency coverage. The ideal wideband antenna will have reduced size, weight, and profile (a conformal construct) without sacrificing optimum performance. The technology applied to this new HIRAD array will allow NASA, NOAA, and other users to gather information related to hurricanes and other tropical storms more cost effectively without sacrificing sensor performance or the aircraft time on station.

The results of the initial analysis and numerical design indicated strong potential for an antenna array that would satisfy all of the design requirements for a replacement HIRAD array. Multiple common aperture antenna methodologies were employed to achieve exceptional gain over the entire spectral frequency band while exhibiting superb VSWR (voltage standing wave ratio) values.

Element size and spacing requirements were addressed for a direct replacement of the thicker, lower-performance, stacked patch antenna array currently employed for the HIRAD application. Several variants to the multiband arrays were developed that exhibited four, equally spaced, high efficiency, "sweet spot" frequency bands, as well as the option for a high-performance wideband array. The 0.25-in. (≈6.4-mm) thickness of the antenna stack-up itself was achieved through the application of specialized antenna techniques and meta-materials to accomplish all design objectives.

This work was done by John Little of Spectra Research, Inc. for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-33005-1.

Complementary Barrier Infrared Detector (CBIRD) Contact Methods

NASA's Jet Propulsion Laboratory, Pasadena, California

The performance of the CBIRD detector is enhanced by using new device contacting methods that have been developed. The detector structure features a narrow gap adsorber sandwiched between a pair of complementary, unipolar barriers that are, in turn, surrounded by contact layers. In this innovation, the contact adjacent to the hole barrier is doped n-type, while the contact adjacent to the electron barrier is doped p-type.

The contact layers can have wider bandgaps than the adsorber layer, so long as good electrical contacts are made to them. If good electrical contacts are made to either (or both) of the barriers, then one could contact the barrier(s) directly, obviating the need for additional contact layers. Both the left and right contacts can be doped either n-type or p-type. Having an n-type contact layer next to the electron barrier creates a second p-n junction (the first being the one between the hole barrier and the adsorber) over which applied bias could drop. This reduces the voltage drop over the adsorber, thereby reducing dark current generation in the adsorber region.

This work was done by David Z. Ting, Cory J. Hill, and Sarath D. Gunapala of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47042

Autonomous Control of Space Nuclear Reactors

Autonomous operation and safety are addressed simultaneously.

John H. Glenn Research Center, Cleveland, Ohio

Nuclear reactors to support future robotic and manned missions impose new and innovative technological requirements for their control and protection instrumentation. Long-duration surface missions necessitate reliable autonomous operation, and manned missions impose added requirements for failsafe reactor protection. There is a need for an advanced instrumentation and control system for space-nuclear reactors that addresses both aspects of autonomous operation and safety.

The Reactor Instrumentation and Control System (RICS) consists of two functionally independent systems: the Reactor Protection System (RPS) and the Supervision and Control System (SCS). Through these two systems, the RICS both supervises and controls a nuclear reactor during normal operational states, as well as monitors the operation of the reactor and, upon sensing a system anomaly, automatically takes the appropriate actions to prevent an unsafe or potentially unsafe condition from occurring. The RPS encompasses all electrical and mechanical devices and circuitry, from sensors to actuation device output terminals.

The SCS contains a comprehensive data acquisition system to measure continuously different groups of variables consisting of primary measurement elements, transmitters, or conditioning modules. These reactor control variables can be categorized into two groups: those directly related to the behavior of the core (known as nuclear variables) and those related to secondary systems (known as process variables). Reliable closed-loop reactor control is achieved by processing the acquired variables and actuating the appropriate device drivers to maintain the reactor in a safe operating state. The SCS must prevent a deviation from the reactor nominal conditions by managing limitation functions in order to avoid RPS actions.

The RICS has four identical redundancies that comply with physical separation, electrical isolation, and functional independence. This architecture complies with the safety requirements of a nuclear reactor and provides high availability to the host system. The RICS is intended to interface with a host computer (the computer of the spacecraft where the reactor is mounted).

The RICS leverages the safety features inherent in Earth-based reactors and also integrates the wide range neutron detector (WRND). A neutron detector provides the input that allows the RICS to do its job. The RICS is based on proven technology currently in use at a nuclear research facility. In its most basic form, the RICS is a ruggedized, compact data-acquisition and control system that