



Schottky Heterodyne Receivers With Full Waveguide Bandwidth

New receivers are designed for high-resolution spectroscopic studies.

Goddard Space Flight Center, Greenbelt, Maryland

Compact THz receivers with broad bandwidth and low noise have been developed for the frequency range from 100 GHz to 1 THz. These receivers meet the requirements for high-resolution spectroscopic studies of planetary atmospheres (including the Earth's) from spacecraft, as well as airborne and balloon platforms. The ongoing research is significant not only for the development of Schottky mixers, but also for the creation of a receiver system, including the LO chain.

The new receivers meet the goals of high sensitivity, compact size, low total power requirement, and operation across complete waveguide bands. The exceptional performance makes these receivers ideal for the broader range of scientific and commercial applications. These include the extension of sophisticated test and measurement equipment to 1 THz and the development of low-cost imaging systems for security applications and industrial process monitoring. As a particular example, a WR-1.9SHM

(400–600 GHz) has been developed (see Figure 1), with state-of-the-art noise temperature ranging from 1,000–1,800 K (DSB) over the full waveguide band. Also, a Vector Network Analyzer extender has been developed (see Figure 2) for the WR1.5 waveguide band (500–750 GHz) with 100-dB dynamic range.

This work was done by Jeffrey Hesler and Thomas Crowe of Virginia Diodes, Inc. for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15798-1

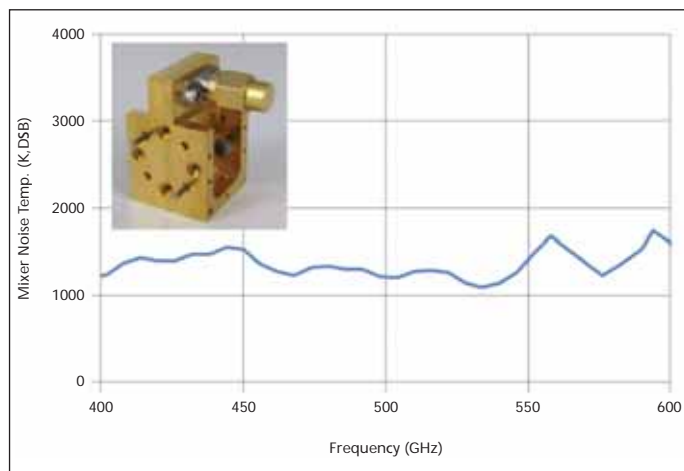


Figure 1. Measured Performance of a WR-1.9 (400–600 GHz) subharmonic mixer (shown in inset).

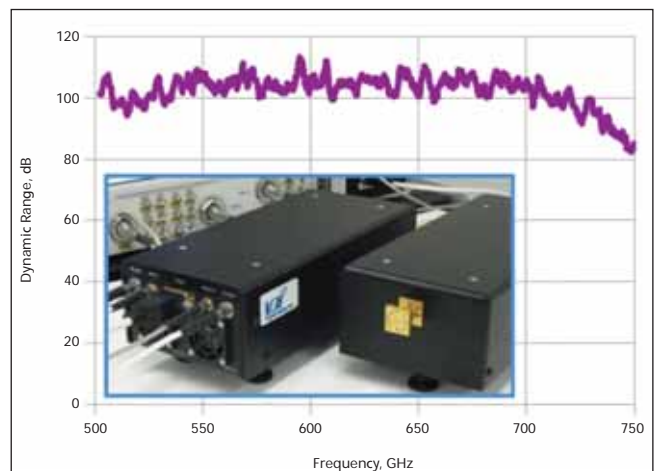


Figure 2. Measured Dynamic Range of a VDI WR-1.5 (500–750 GHz) VNA frequency extender module.

Carbon Nanofiber-Based, High-Frequency, High-Q, Miniaturized Mechanical Resonators

These miniature resonators can be used in portable electronics, communications systems, and other wireless systems.

NASA's Jet Propulsion Laboratory, Pasadena, California

High Q resonators are a critical component of stable, low-noise communication systems, radar, and precise timing applications such as atomic clocks. In electronic resonators based on Si integrated circuits, resistive losses increase as a result of the continued reduction in device dimensions, which decreases their Q values. On the other hand, due to the

mechanical construct of bulk acoustic wave (BAW) and surface acoustic wave (SAW) resonators, such loss mechanisms are absent, enabling higher Q-values for both BAW and SAW resonators compared to their electronic counterparts. The other advantages of mechanical resonators are their inherently higher radiation tolerance, a factor that makes them

attractive for NASA's extreme environment planetary missions, for example to the Jovian environments where the radiation doses are at hostile levels. Despite these advantages, both BAW and SAW resonators suffer from low resonant frequencies and they are also physically large, which precludes their integration into miniaturized electronic systems.

Because there is a need to move the resonant frequency of oscillators to the order of gigahertz, new technologies and materials are being investigated that will make performance at those frequencies attainable. By moving to nanoscale structures, in this case vertically oriented, cantilevered carbon nanotubes (CNTs), that have larger aspect ratios (length/thickness) and extremely high elastic moduli, it is possible to overcome the two disadvantages of both bulk acoustic wave (BAW) and surface acoustic wave (SAW) resonators.

Nano-electro-mechanical systems (NEMS) that utilize high aspect ratio nanomaterials exhibiting high elastic moduli (e.g., carbon-based nanomaterials) benefit from high Qs, operate at high frequency, and have small force constants that translate to high responsiveness that results in improved sensitivity, lower power consumption, and improved tunability. NEMS resonators have recently been demonstrated using top-down, lithographically fabricated approaches to form cantilever or bridge-type structures. Top-down approaches, however, rely on complicated and expensive e-beam lithography, and often require a release mechanism. Resonance effects in structures synthesized using bottom-up approaches have also recently been reported based on carbon nanotubes, but such approaches have relied on a planar two-dimensional (2D) geometry. In this innovation, vertically aligned tubes synthesized using a bot-

tom-up approach have been considered, where the vertical orientation of the tubes has the potential to increase integration density even further.

The simulation of a vertically oriented, cantilevered carbon nanotube was performed using COMSOL Multiphysics, a finite element simulation package. All simulations were performed in a 2D geometry that provided consistent results and minimized computational complexity. The simulations assumed a vertically oriented, cantilevered nanotube of uniform density (1.5 g/cm^3). An elastic modulus was assumed to be 600 GPa, relative permittivity of the nanotube was assumed to be 5.0, and Poisson's ratio was assumed to be 0.2. It should be noted that the relative permittivity and Poisson's ratio for the nanotubes of interest are not known accurately. However, as in previous simulations, the relative permittivity and Poisson's ratios were treated as weak variables in the simulation, and no significant changes were recognized when these variables were varied.

Of interest in the simulations of a CNT resonator were the structural strain and deflection of the nanotube, and the electrostatic interactions between the nanotube and nanomanipulator probe. Structural boundary conditions were arranged such that the exposed lengths and tip of the nanotube were allowed to move freely while all other surfaces were held fixed (including the nanotube base). These conditions simulated a

fixed, cantilevered beam in a domain adjacent to a nanomanipulator probe of infinite elastic modulus. Electrostatic boundary conditions were chosen such that the nanotube was grounded, an AC voltage with DC bias was applied to the surface of the nanoprobe adjacent to the nanotube, and all other boundaries in the system were selected such that no electrical charge exists on, or outside of, those surfaces. The solution domain was simulated as a vacuum. Preliminary experiments have suggested that electro-mechanical coupling can occur between a scanning electron microscope (SEM) beam and a vertically oriented, cantilever carbon nanofiber (CNF) causing the CNF to mechanically resonate with displacements two or three times larger than the tube diameters.

This work was done by Anupama B. Kaul and Larry W. Epp of Caltech and Leif Bagge of the University of Texas for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.

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Ultracapacitor-Based Uninterrupted Power Supply System

This technology provides essential backup power, increases safety, and reduces environmental impact.

John H. Glenn Research Center, Cleveland, Ohio

The ultracapacitor-based uninterrupted power supply (UPS) system enhances system reliability; reduces life-of-system, maintenance, and downtime costs; and greatly reduces environmental impact when compared to conventional UPS energy storage systems. This design provides power when required and absorbs power when required to smooth the system load and also has excellent low-temperature performance. The UPS used during hardware tests at Glenn is an efficient, compact, maintenance-free, rack-mount, pure sine-wave inverter unit.

The UPS provides a continuous output power up to 1,700 W with a surge rating of 1,870 W for up to one minute at a nominal output voltage of 115 VAC. The ultracapacitor energy storage system tested in conjunction with the UPS is rated at 5.8 F. This is a bank of ten symmetric ultracapacitor modules.

Each module is actively balanced using a linear voltage balancing technique in which the cell-to-cell leakage is dependent upon the imbalance of the individual cells. The ultracapacitors are charged by a DC power supply, which can provide up to 300 VDC at 4 A. A

constant-voltage, constant-current power supply was selected for this application. The long life of ultracapacitors greatly enhances system reliability, which is significant in critical applications such as medical power systems and space power systems. The energy storage system can usually last longer than the application, given its 20-year life span. This means that the ultracapacitors will probably never need to be replaced and disposed of, whereas batteries require frequent replacement and disposal. The charge-discharge efficiency of rechargeable batteries is ap-