Circuits Enhance Scientific Instruments and Safety Devices

Originating Technology/NASA Contribution

Since its founding in 1958, NASA has pioneered the use of different frequencies on the electromagnetic spectrum—including X-ray, microwave, and infrared wavelengths—to gather information about distant celestial bodies. During the 1962 Mariner 2 mission, NASA used microwave radiometers that operated in the range of 15–23 gigahertz (GHz) to assess the surface temperature of Venus and to determine the percentage of water vapor in its atmosphere.

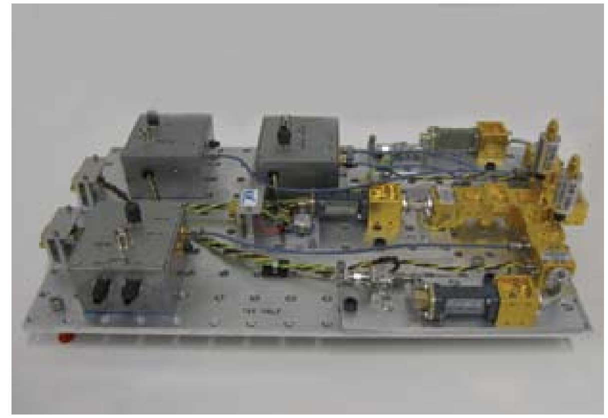
Today, there is another area on the spectrum proving uniquely useful to scientists: the terahertz (THz) range, spanning from about 100 GHz–10,000 GHz. (1 THz equals approximately 1,000 GHz.) Terahertz frequencies span the lesser-known gap on the electromagnetic spectrum between microwave radiation and infrared (and visible) light, falling within the spectral range where most simple molecules resonate. This molecular resonance makes terahertz particularly useful for chemical spectroscopy and the remote sensing of specific molecules. In the 1990s, NASA began using frequencies above 300 GHz (more than an order of magnitude higher than the instrumentation on Mariner 2) to perform spectral analysis of molecular clouds and planetary atmospheres. Instruments using these higher frequencies have included the Microwave Limb Sounder (MLS) on the Upper Atmosphere Research Satellite (UARS), deployed from 1991–2001, and the Microwave Instrument for the Rosetta Orbiter (MIRO), launched in 2004. With UARS-MLS, NASA used advanced terahertz receivers to measure the emission signatures from atmospheric molecules, providing researchers with valuable data about the changes in the Earth's protective ozone layer. MIRO, set to rendezvous with the comet 67P Churyumov-Gerasimenko in 2014, will use terahertz instrumentation to analyze the comet's dust and gasses.

Virginia Diodes Inc. (VDI) has found commercial success with its high-frequency integrated diodes, which are key components in VDI's vector network analyzer (VNA) extenders.

Although NASA has been a driving force behind the development of terahertz technology, scientific equipment for terahertz research—including transmitters, receivers, and basic test and measurement equipment—is not widely available, making scientific experiments in this range between traditional electronics and quantum photonics more costly and greatly limiting commercial development in the field. Given NASA's interest in studying distant bodies in space as well as in improving life on Earth, the Agency has collaborated with private industry to develop terahertz technologies.

Partnership

In the early 1980s, University of Virginia professor Thomas Crowe and research scientist William Bishop worked with NASA to develop high-frequency diodes for UARS-MLS instrumentation. In 1996, Bishop and Crowe founded Virginia Diodes Inc. (VDI), based in Charlottesville, Virginia. A few years later, the company began developing and selling terahertz components and subsystems, with a mission to make the terahertz region of the electromagnetic spectrum as useful for scientific, military, and commercial applications as the microwave and infrared frequency bands have become.



VDI's VNA extenders enable engineers to create and test products in the terahertz range. Products that use terahertz span a variety of areas in research, manufacturing, and security monitoring.

As a subcontractor on a 1999 Phase I **Small Business Innovation Research (SBIR)** contract from the Goddard Space Flight Center, VDI collaboratively developed three state-of-the-art frequency multipliers with output center frequencies of 182 GHz, 250 GHz, and 384 GHz. Building on these early successes with concurrent Phase II SBIR contracts from Goddard and the Jet Propulsion Laboratory in 2001, VDI developed a highly compact 870 GHz receiver and a compact frequency tunable source for frequencies at 1.5 THz.

Today Goddard uses these VDI technologies in the airborne Conical Scanning Submillimeter-wave Imaging Radiometer to make airborne measurements of ice crystals as proof of concept for the next generation of spaceborne instruments for Earth and space exploration. In addition to its continuing collaboration with NASA to develop terahertz technology for current and future missions, VDI has found commercial success with its terahertz components and testing equipment, particularly its integrated diode circuits, which are key components in VDI's vector network analyzer (VNA) extenders.

Product Outcome

Because of the unique characteristics of terahertz radiation—such as its ability to image items hidden behind common materials (such as clothing), and to detect and identify a wide range of chemicals—there is a growing demand for terahertz components for a variety of systems. Applications include security imaging systems to detect concealed items, hazardous chemical and biological-agents detectors, plasma diagnostic instruments, and industrial process monitors. In order to create these new products, engineers need components that can operate in the terahertz range, such as high-frequency mixers and multipliers, amplifiers that operate in terahertz frequencies, and advanced testing equipment like VNAs.

VDI's advanced integrated diode circuits have increased the frequency range of VNAs (and VNA extenders) by an order of magnitude, from 100 GHz to 1,000 GHZ (1 THz). The company's extenders now expand the range of current commercial 4-port VNAs to the 780–850 GHz range while maintaining high dynamic range (80 decibels). "The frequency multipliers and frequency mixers are the key technology," says Crowe, now VDI's president. "They have diode circuits that were primarily developed under the SBIRs." Crowe also states that VDI's advantage in the VNA extender field is the company's ability "to make very efficient and cost effective mixers and multipliers that work all the way to 1 THz and beyond." These VNA extenders allow engineers to design systems and make measurements that were scarcely possible only 5 years ago.

While most customers—including many universities—come to VDI for components for high-frequency test systems, Crowe expects VDI's terahertz-ready VNA extenders and diodes will spur the development for many other research instruments and commercial products, including security imaging systems. One security system currently using terahertz components from VDI is ThruVision's T5000 Imaging System, now in use at some international airports. Because terahertz radiation is a shorter wavelength than radio or microwave frequencies, a terahertz scan of a person displays hidden objects with higher spatial resolution. It also can detect a greater variety of materials, including metals, wood, ceramics, and plastics. Terahertz photons also have very low energy and, unlike X-rays, terahertz radiation is non-ionizing and not considered to be harmful to people. In fact, terahertz imaging systems like the T5000 can be totally passive, detecting only the terahertz energy that is naturally emitted by the subject.

New security imaging products use the VDI diodes to detect passive terahertz waves, which can reveal images hidden behind common materials. The image on the left, returned from the security system, shows a gun hidden under the man's jacket.

These imaging systems are possible only because of developments in terahertz components and test equipment, and Crowe expects demand to increase noticeably in the coming years as VDI's terahertz components improve. VDI's goals include increasing the dynamic range to greater than 100 decibels throughout the entire frequency range, and extending the modular systems to greater than 1 THz. Transmitter power will improve as more power inevitably becomes available from broadband amplifiers. VDI also expects continued improvement of the multipliers, particularly near the band edges.

According to Crowe, VDI has grown to over 30 full-time employees and continues to grow at 30 percent per year, growth he credits to the company's successful commercialization of terahertz products developed under the NASA contracts. The company has over 200 customers in over two dozen countries, including major university and government research laboratories. ❖

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