Guest Editors' Overview

THE terahertz frequency band spanning the spectral range from 100 GHz to 10 THz is one of the last major windows in the electromagnetic spectrum to be explored. The primary applications for terahertz technology has been basic scientific research including astrophysics, atmospheric physics, plasma diagnostics, and laboratory spectroscopy. The rotational emission lines of the simpler molecules occur in this band. Measurements of these spectra allow the determination of abundances, distributions, and kinematic properties of the medium in which the molecules are located. More recently radar and communications systems are employing this spectral range to combine the frequency resolution and agility available in the microwave regime with the high spatial resolution using modest apertures typical of optical technology. Because the earth's atmosphere is opaque except for a few discrete windows in this frequency range, much of the technology development is being directed toward space qualifiable components. Achieving the full potential of the terahertz region has been limited by the lack of suitable technology. The design of high performance receivers and transmitters present a major challenge to the scientific and technical community.

Much of the technology developed for this frequency range employs heterodyne detection techniques. Heterodyne receivers provide the best sensitivity for applications in this frequency range which require high spectral resolution. A heterodyne receiver downconverts the terahertz signal from a remote source by mixing it with a local oscillator source. The elements of the heterodyne receivers presented here include the terahertz mixer, local oscillator source and coupling components.

Mixers currently available for the terahertz band include superconducting tunnel junctions, Schottky diodes, and extrinsic photoconductors. Superconducting tunnel junctions operate with single quasiparticle tunneling current (Dayem–Martin effect) or pair tunneling current (Josephson effect). The acronym SIS (superconductor-insulator-superconductor) is generally used for devices employing the first effect, which has been found to yield the best performance in the millimeter wave band. In addition to the inherent low noise, one of the primary advantages of SIS mixers is the low level of local oscillator power required. Further, SIS devices are fabricated using photolithographic techniques and are therefore more easily formed in arrays. The primary disadvantage of SIS tunnel junction mixers is that they operate at cryogenic temperatures. GaAs Schottky diodes have long been the "workhorse" mixer for millimeter waves. They operate at room temperature, though their performance is improved when cooled. Most GaAs Schottky mixers to date have been fabricated using whisker contracts. Recently, however, advances have been made in reducing parasitics associated with a planar implementation of these devices. GaAs Schottky mixers require higher local oscillator power for optimum performance, about a milliwatt.

Candidate technologies for local oscillators include both fundamental oscillators and frequency multiplied sources. The traditional laboratory sources, gas lasers and backward wave oscillators require high levels of dc power and have relatively short lifetimes. Solid state sources are more attractive for space applications. New solid state fundamental oscillators are emerging such as quantum well and Josephson junction oscillators. These solid state approaches though less mature and of high technical risk, have the potential of revolutionizing remote sensing spectroscopy in the terahertz band. Harmonic generation is less efficient than fundamental oscillation, but extends the frequency range available from solid state oscillators. Recently several advances have been made in the modeling, fabrication, and design of the nonlinear element in the multiplier, the varactor.

The standard antenna for millimeter-wave and submillimeter-wave radiometric receivers is the machine conical horn antenna and the corner-cube antenna. However, these antennas are difficult to machine for submillimeter-wave frequencies. A monolithic receiver, which consists of a planar antenna integrated with a matching network and a mixer, is an attractive solution for the millimeter- and sub millimeter frequency range. The integration also allows the use of linear or two-dimensional arrays for imaging applications without a dramatic increase in cost and weight of the system. A lot of research was done on integrated circuit antennas in the last decade and many of the problems associated with electrically thick dielectric substrates, such as substrate modes and poor radiation patterns, have been understood and solved. It is now possible to build integrated circuit antennas with performance comparable to the best waveguide antennas and the best candidates include the integrated horn antenna, the double-slot antenna and the wideband spiral and log-periodic antennas on substrate lenses.

This Mini-Special Issue contains articles that address some of the issues for terahertz technology. Recent results related to the development of planar antennas, sensitive mixers and receivers, solid state sources and power combining topologies. The papers report three different antenna designs suitable for integration with SIS and Schottky mixers, two SIS receivers with extremely low noise performance at 250 GHz, and a study of the Josephson effect on gain and noise in SIS mixers. In addition, also presented is a 750 GHz Schottky varactor multiplier local oscillator source, the effect of current saturation in semiconductor varactors, novel device struc-

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tures for high efficiency multiplication, and three papers on quasi-optical stabilization and power combining of solid state sources. All twelve articles were originally presented among many others at the NASA-sponsored Second International Symposium on Space Terahertz Technology (Pasadena, CA, March 3–4, 1991) and was organized by NASA-JPL and the NASA Center for Space Terahertz Technology at the University of Michigan.

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Guest Editors

Gabriel M. Rebeiz (S'86–M'88) was born in December 1964 in Beirut, Lebanon. He graduated in 1982 from the American University in Beirut with a B.E. (Honors) in electrical engineering. In September 1982, he joined the California Institute of Technology, and earned the Ph.D. in electrical engineering in June 1988.

He joined the faculty of the University of Michigan in September 1988 where he is now an Assistant Professor in the Electrical Engineering and Computer Science Department.

Dr. Rebeiz has been awarded a NASA-Certificate of Recognition Award for his contribution to the millimeter-wave space program (March 1990) and the Best Paper Award at the 1990 International Conference on Antennas, Nice, France. He received an NSF Presidential Young Investigator Award in 1991. His research interests lie in planar millimeter-wave antennas, receivers and transmitters, and fabrication and measurements of novel millimeter-wave transmission-lines and devices.

Margaret A. Frerking (M'91) is a radio astronomer and submillimeter receiver design engineer. She received the B.S. and Ph.D. degrees in physics from the Massachusetts Institute of Technology. As a graduate student at MIT she built the first infrared all solid-state heterodyne receiver, using HgCdTe photo-conductors and PbSnSe lasers. She employed this receiver to observe ozone in the terrestrial atmosphere.

She initiated her astronomy career at Bell Laboratories studying protostellar star formation in dark molecular clouds. Upon joining the JPL staff in 1980, she became the cognizant engineer for the development of the 205 GHz radiometer for the Microwave Limb Sounder on the Upper Atmospheric Research Satellite. She is the principal investigator for the Submillimeter Sensors Program sponsored by NASA OAST that includes research into new solid state sources for the submillimeter regime, submillimeter SIS tunnel junction mixers, and quasi-optical planar array architectures and coupling techniques. She is also a member of the JPL team responsible for the KAO water vapor radiometers which currently operates at 183,380, and 546 GHz. In 1986 she was appointed supervisor of the Advanced Devices Group that carries out submillimeter-wave technology research.

Dr. Frerking is on the editorial board for the IEEE Microwave and Guided Wave Letters and the *International Journal of Infrared and Millimeter Waves*.