

VII. MICROWAVE AND MILLIMETER WAVE TECHNIQUES

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RESEARCH OBJECTIVES AND SUMMARY OF RESEARCH

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1. Low-Temperature Millimeter Wave Receivers

Joint Services Electronics Program (Contract DAAB07-74-C-0630)

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This program is directed toward the development of extremely sensitive coherent receivers at millimeter wavelengths. Initial work involves development of cryogenic mixers and IF amplifiers, with emphasis placed on accurate modeling of the device properties so that optimization can be performed and performance limits established.

An effort to develop cooled GaAs FET IF amplifiers is also under way. These broadband amplifiers will operate at frequencies as high as several gigahertz.

Since antenna temperatures at these frequencies can be as low as a few degrees Kelvin, mixer noise temperatures well below room temperature are desirable. Because of mixer conversion loss, the IF noise temperature should be even lower to make best use of low-noise mixers.

We are also making mixer studies at microwave frequencies where measurements and modeling can be performed more easily and accurately.

A 118-GHz mixer has been fabricated, but difficulties in contacting the diodes have delayed the planned measurements. The diodes, supplied by the M. I. T. Lincoln Laboratory, are Pt-GaAs Schottky barrier devices, 1-12 μm in diameter. We should be able to cool the system to 77° K, and perhaps to 4° K. When the diodes are installed, we shall measure the mechanical, dc, and IF properties of the mixer and compare the results with theoretical predictions.

A model of this mixer, incorporating nonlinear resistance and capacitance, has been used with a new computer program¹ to predict pump waveforms, conversion loss, non-reciprocity, and the effects of higher order harmonics. The optimum performance of the mixer was computed as 4.4 dB SSB conversion loss and 6.6 dB noise figure.

In the IF amplifier program we shall study a GaAs FET amplifier cooled to 77° K, with frequency in the gigahertz range. Areas of interest are FET theory, device measurement and characterization, and design and testing of amplifiers. Industrial cooperation in providing state-of-the-art microwave GaAs FETs is expected.

In the past six months three theses have been submitted to the Department of

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JSEP Electrical Engineering, M. I. T., which are related to this research:

Robert W. Freund, "Microwave Parameters of a Coolable GaAs Schottky Barrier Diode Mixer," S.M. and E.E. Thesis, June 1974.

Wesley G. Brodsky, "Analysis and Design of a Cooled Mixer," S.M. and E.E. Thesis, July 1974.

Wojciech K. Gwarek, "Nonlinear Analysis of Microwave Mixers," S.M. Thesis, September 1974.

References

1. Wojciech Gwarek and Robert L. Kyhl, "Nonlinear Computer-Aided Analysis of a Microwave Mixer," Quarterly Progress Report No. 114, Research Laboratory of Electronics, M. I. T., July 15, 1974, pp. 57-59.

2. Multiple Microwave Solid-State Devices

Joint Services Electronics Program (DAAB07-74-C-0630)

- a. Noise and Power Considerations in BARITT Diodes

Gary K. Montress, Madhu S. Gupta

The BARITT diode offers attractive possibilities for low-noise, low-power microwave amplifier and source applications. Fabrication of single and multiple device BARITT oscillators will be undertaken. Operation at lower X-band is anticipated and an investigation of thermal and noise properties of the multiple-device structure will be carried out. It is hoped that noise and power limitations of individual BARITT diodes will be at least partially overcome with the operation of multiple-device structures.

- b. Multiple-Device Power-Combining Methods

Madhu S. Gupta

We are carrying out a comparative study of various methods of combining the power output of several semiconductor microwave devices. Circuit models of devices and combining networks are being developed in order to determine the performance parameters and to optimize the combining network. The power output, as well as the noise of the multidevice combination, is under study, and the combining networks for both oscillators and amplifiers are being considered.

IMPATT diodes are being used as a vehicle for studying the power-combining methods. A high-frequency limitation to the performance of IMPATT diodes that is due to carrier diffusion has been calculated analytically.¹ A nonlinear active circuit model for IMPATT diodes has been constructed.² It is based directly upon the carrier transport equations, rather than upon the calculated terminal impedance of the device that has been found for an assumed signal and, therefore, should be more generally applicable.

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References

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1. M. S. Gupta, "A Simple Approximate Method of Estimating the Effect of Carrier Diffusion in IMPATT Diodes," Solid-State Electronics, Vol. 19 (to appear in 1975).
2. M. S. Gupta, "A Nonlinear Equivalent Circuit for IMPATT Diodes" (to be submitted for publication).

3. Microwave Measurements and Instrumentation

Joint Services Electronics Program (Contract DAAB07-74-C-0630)
National Science Foundation (Grants GP-40485X and MPS73-05043-A01)

Bernard F. Burke, Alan Parrish, Aubrey D. Haschick, Thomas S. Giuffrida

a. Atmospheric Refraction Studies

The microwave aperture-synthesis interferometer, which is situated at the Haystack Observatory, is a system of three 18-ft antennas that will be used to measure the location and structure of celestial radio sources. The system is phase-stable to approximately 1 electrical degree and, since the minimum angular separation of the fringes is 6 arc seconds at K-band, the inherent accuracy of the system should be of the order of .02 arc-second at K-band. Both atmospheric absorption and refraction will be measured over short (few-second) and long (day-to-day) periods.

b. Aperture Synthesis at Microwave Frequencies

The techniques developed for the aperture-synthesis interferometer will be generalized to other, nonastronomical, examples. We are studying the feasibility of a passive radiometric night-vision apparatus that would have high angular resolution at wavelengths of approximately 1 cm. There are two general questions that must be settled, in order to demonstrate the practicality of such a system. First, relatively small changes in radio brightness of a terrestrial landscape call for a system of good gain stability, and we must establish the necessary parameters. Second, the system would become much less complex if an incomplete synthesis of a field would suffice. The studies of brightness distributions in celestial sources provides a direct test of such effects, and will be used to see whether incomplete Fourier transforms could yield sufficient information.

4. Very Long Baseline Interferometry (VLBI)

Joint Services Electronics Program (Contract DAAB07-74-C-0630)
National Science Foundation (Grants GP-40485X and MPS73-05043-A01)

Bernard F. Burke

In collaboration with the Naval Research Laboratory, the VLBI techniques have been extended to 1.3 cm wavelength and a long-term experiment on the positional stability of 18-cm OH maser sources has been carried out. The data will be analyzed to provide an extensive list of sources for possible navigation and time-keeping purposes. The discovery of SiO maser sources at 7 mm wavelength suggests application of the method at that wavelength, and an attempt will be made to extend VLBI methods to this region.

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