Final Report: UCLA JSEP Activity in Millimeter Wave Electronics

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Accomplishments and pertinent information under the Joint Services Electronics Program (JSEP) for the reporting period September 1992 - September 1995 are summarized. The JSEP program provides the research baseline for all three military services in the expanding electronic sciences requiring interdisciplinary efforts among sub-areas of electronic. The central theme of this research is to resolve issues that have prevented wide spread use of millimeter-wave electronics. Considered are issues that have arisen primarily due to the lack of a coherent approach between solid state (device) research and electromagnetic (circuit and component) research. The device research takes into account the electromagnetic interaction with the circuit and the system environment while the millimeter-wave integrated circuit, as the electromagnetic system, considers the interaction with the solid state devices from the outset of analysis and design. Several research areas are synergistically combined. Research in the exploration of novel material systems and devices structures benefits from device simulation efforts. Novel integrated circuit configurations that exploit the best performance from the devices are studied. The devices and circuits are then implemented into quasi-optical monolithic arrays.

14. SUBJECT TERMS
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(a) OVERVIEW OF ACCOMPLISHMENTS

The central theme of this program is to resolve bottleneck issues that have prevented wide spread use of millimeter-wave electronics. We consider that such bottlenecks have arisen primarily due to the lack of a coherent approach between solid state (device) research and electromagnetic (circuit and component) research. At millimeter-wave frequencies, devices and circuits cannot be analyzed, designed and tested separately due to wave interactions. Under this JSEP program, each unit interacted coherently and strongly. Although there are two units for solid state electronics and another two for electromagnetics, they worked together for several specific subjects such as quantum well devices with different aspects. Unit 1 (K. L. Wang) was concerned with the new integrable devices that were theoretically analyzed and simulated in Unit 2 (D. S. Pan). Unit 3 (T. Itoh) studied the millimeter-wave circuits in which these devices are treated as a part of the circuit in such a way that the optimum of the device capability is extracted. Under Unit 4 (N. C. Luhmann), quasi-optical configurations of the devices and circuits studied under the other units were implemented in complete systems.

Since the inception of the JSEP program at UCLA in September 1992, we have reached significant progress toward the above goal. Some of the significant accomplishments are as follows. (1) Optical control of double barrier Resonant Tunneling Diode (RTD) in which the negative resistance of the device can be externally controlled so that the initiation of the series connected RTDs may be accomplished by temporarily suppressing the negative resistance (Units 1, 2 and 3). (2) Electromagnetic simulation of the distributed gain mechanism was accomplished by incorporating the gain mechanism in the Finite Difference Time Domain (FDTD) algorithm. This technique was developed by Unit 3 with a direct impact on the device work under Units 1 and 2. (3) Stacked quantum barrier varactor frequency multiplier was invented and used in a quasi-optical system by Unit 4. The structure produced 5 W output at W band. (4) Unit 2 has discovered that the series integrated RTD's can be initiated by an injection signal at one half of the intended oscillation frequency (subharmonic oscillation). The injection signal is needed only for a short period of time and can be removed once the oscillation started. This prediction has also been demonstrated by Unit 3, by means of experiments using tunnel diodes that have the negative resistance characteristics similar to those of the RTD. During the experiment, it was found that the injection signal frequency need not be an integer fraction of the oscillation signal. (5) Coupled active antenna has been simulated by the extended FDTD. This is the first time that the microwave circuit was analyzed electromagnetically including the active devices. Unlike the standard network based approach, all the "electrically hidden" phenomena can be displayed visually as well as parametrically. Such understanding heavily relies on the device characterizations that can be provided by the solid state units while the output is useful in the system implementation work for Unit 4.

Several items on Technology Transfer have been reported in the three Annual Reports. They are: (1) Three-dimensional active integrated array antenna for which the design and structure have been provided to Hughes Aircraft. (2) Complete information on the electronically and optically activated beam control array in a quasi-optical manner has been provided to Hughes, Martin-Marietta, Northrop, Raytheon, Rockwell and TRW. (3) Electromagnetic simulation of the active integrated antenna has been transferred to Los Alamos National Laboratory with related information provided to CRAY, Research. In addition, the items (2) and (3) are now included in the proposal by Martin-Marietta for the ARPA program on MAFET (Microwave and Analog Front End Technology) under the Quasi-Optical Alliance. An extension of (3) to MMIC amplifiers is now being developed for a future CAD tool with Hughes Aircraft Company.
The Quasi-Optical structures being developed have recently found new applications as low cost alternative for wireless communications, at typically lower microwave frequencies such as C, S, X and Ku bands. One of these applications, the non-contact ID transponder card, was presented and demonstrated at the 1994 IEEE International Microwave Symposium. Subsequently, several industrial companies have inquired about potential productization. One of the latest was Select University Technologies, Inc. At the same time, we received an invitation from Microwave Journal to write an article "Quasi-optical Microwave Circuits for Wireless Applications in a feature section. The article will also appear in Telecommunications. Together, the total circulation is 130,000 worldwide. As soon as this article appeared, we received an inquiry from Vehicular Security Electronics, Inc. for assistance in their product of a wireless motion sensor.

In closing, this three year period has been a very rewarding experience for all of the personnel involved in this JSEP program. Significant advances have been witnessed in the basic research for understanding of many bottleneck issues and some solutions for them. Even though the emphasis of the program is of the high risk and high payoff type, emphasizing the basic research, we have found many technology transitions to industry and other organizations for further development and productization.

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(b) LISTING OF INVESTIGATORS

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(c) DEGREES AWARDED

Master of Science (Supervisor)

J. Y.-Y. Liao (Luhmann) 1993
S. Y. Shu (Luhmann) 1993
R. Hsia (Luhmann) 1993
E. Chung (Luhmann) 1993
W. Geck (Luhmann) 1993
T. Liu (Luhmann) 1993
S. Cheng (Luhmann) 1993

Doctor of Philosophy (Supervisor)

L. Sjogren (Luhmann) 1993
H.-X. Liu (Luhmann) 1993
S. Khorram (Wang) 1994
B. Toland (Itoh) 1994
J. Lin (Itoh) 1994
H. S. Li (Wang) 1994
O. Boric-Lubecke (Itoh) 1995
X. Qin (Luhmann) 1995
(d) LIST OF JSEP PUBLICATIONS
Unit 1, "Investigation of Novel Devices and Concepts" (Prof. K. L. Wang)

I. LIST OF JOURNAL PUBLICATIONS


LIST OF CONFERENCE PROCEEDINGS


Unit 2, "Modeling and Theoretical Exploration of Millimeter Wave Solid State Devices" (Prof. D. S. Pan)

I. LIST OF PUBLICATIONS (*JSEP supported in whole or in part)


II. LIST OF CONFERENCE PROCEEDINGS (*JSEP Supported in whole or in part)


7. O. Boric-Lubecke, R. Sun, D. S. Pan and T. Itoh "Excitation of an Oscillator with Several Resonant tunneling Devices Integrated in Series Using RF source" Fifth International Symposium on Space Terahertz Technology, May 10-12, 1994, the University of Michigan, Ann Arbor, Michigan.


I. LIST OF PUBLICATIONS (* JSEP Supported in whole or in part)


II. LIST OF CONFERENCE PROCEEDINGS (*JSEP Supported in whole or in part)


25. M. C. Wu, and T. Itoh, "Ultrafast Photonic-to-Microwave Transformer (PMT)," Proceedings of LEOS Summer Topical Meeting on Optical Microwave Interactions, Santa Barbara, California: July 19-21, 1993, pp. 63-64.


Unit 4. "Millimeter Wave Array and System Development (Prof. N. Luhmann)

I. LIST OF JSEP PUBLICATIONS (*JSEP Supported in Whole or in Part)


II. LIST OF JSEP CONFERENCE PROCEEDINGS (*JSEP Supported in Whole or in Part)


