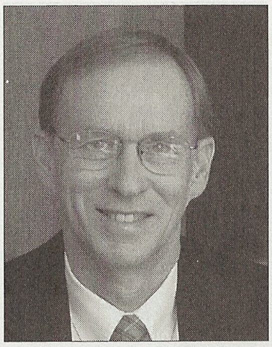
2002 Microwave Pioneer Award

John R. Tucker



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The Microwave Pioneer Award recognizes an individual or a team not exceeding three persons having made outstanding pioneering technical contributions that advance microwave theory and techniques and described in an archival paper published at least 20 years prior to the year of the award. This year's recipient is John R. Tucker, whose citation reads: **"For Generalizing Microwave Mixer Theory to Include Photon-Assisted Tunneling and Discovering new Effects leading to Quantum-Noise-Limited Millimeter Wave Receivers".**

John R. Tucker has been with the Department of Electrical and Computer Engineering, University of Illinois, since 1981. Born in Seattle, he received a B.S. degree from the California Institute of Technology in 1966 and Ph.D. in physics from Harvard University in 1972.

Tucker began his work on microwave photon-assisted tunneling at the Aerospace Corporation in 1974. 'Super-Schottky' diodes were being used to set new records for detector sensitivity at T~1K, based upon a very strong nonlinearity below the energy gap of a superconductor metal contact. Dr. Michael Millea questioned whether this device could be improved indefinitely at lower temperature, and Tucker soon demonstrated that the current responsivity would approach a fundamental limit, e/hn (one electron per absorbed photon), as the I-V nonlinearity becomes sharp on the scale of the quantum energy. A complete quantum mixer theory was subsequently developed, and new phenomena were predicted that violate well-known theorems of classical mixer analysis. The most important of these, noiseless amplification in heterodyne down-conversion, was confirmed in experiments on superconductor-insulator-superconductor (SIS) tunnel junctions by Professor P. L. Richards at U. C. Berkeley. Early SIS mixer results by T. G. Phillips at Bell Labs/Caltech, T. Claeson at Goteborg, A. R. Kerr and M. J. Feldman at NASA Goddard, and H. J. Hartfuss, K. H. Gundlach, R. Blundell at Garching also demonstrated important aspects of this technique.

Tucker assisted Dr. A. R. Kerr at the NASA Goddard Institute for Space Studies in 1980, adapting quantum mixer theory to the design of ultra-low-noise astronomical receivers. Instruments operating on these principles are now mounted on most of the world's millimeter and submillimeter telescopes with receiver noise temperatures approaching the quantum limit, $T_R \sim h\nu/k_B$, at frequencies $\nu \approx 100\text{-}1000$GHz. Based on the success of these instruments, Europe, North America, and Japan have recently begun construction on a giant 64-element array of transportable 12-meter telescopes on a 16,000-ft. plain in Chile, each equipped with ~8-10 SIS receivers for probing initial stages of planetary and star formation and evolution of the early universe. Scheduled for completion in 2010, this Altacama Large Millimeter Array (ALMA) will be one of the first truly global projects in the history of fundamental science.

Tucker was recruited to Illinois in 1981 by John Bardeen, and has remained there since that time. Since 1989, Tucker has collaborated with Dr. T.-C. Shen on ultra-high vacuum scanning tunneling microscope (STM) research. This work centers on developing a fabrication process for atom-scale electronic devices in silicon, using the STM's low-energy electron beam to expose bare dangling bonds on a hydrogen-terminated silicon surface. PH3 molecules are selectively adsorbed onto these STM-exposed patterns and grown into the crystal as phosphorous donors to realize conducting pathways based on overlap of individual electron wavefunctions. This process has recently become the focus of efforts toward building a silicon quantum computer. A new metal silicide source/drain MOS transistor proposed by Tucker operates by field-induced tunneling, and currently holds the world record for smallest CMOS at ~20nmx25nm. Future research is aimed at integrating these devices with atom-scale donor patterns for silicon nanoelectronics and quantum logic.