fundamental with an equal amplitude second harmonic present. The improvement is greatest at frequencies below the optimum transit-time frequency and it is possible to obtain power output comparable to and even slightly greater than that attained at the optimum single-frequency point. The second-harmonic tuning curve extends below the avalanche frequency, indicating that it is possible to obtain power from the diode at frequencies below the single-frequency operating range. However, for frequencies above the optimum 11 GHz the power improvement is small, and for frequencies from 12 to 20 GHz better performance is obtained using first-subharmonic tuning.

The first-subharmonic tuning curve shows that there is little improvement below 11 GHz, but that in the frequency range from 11 to 20 GHz some improvement can be obtained. In particular, at 20 GHz the improvement attainable is nearly 100 percent although the power is not as large as at the optimum single-frequency point.

In summary, the improvement attainable with harmonic or subharmonic tuning depends upon the relationship of the frequency at which power is desired to the optimum operating frequency of the diode. If the desired frequency is equal to the optimum, then the improvement attainable with harmonic tuning is in the range of 10 to 20 percent. If the desired frequency is below the optimum then second-harmonic tuning can provide substantial improvement. However, the power output attainable and the efficiency are still comparable to that attainable at the optimum point. For frequencies above the optimum, first-subharmonic tuning is preferable to second-harmonic tuning and significant improvement can be obtained. It should be emphasized that in this two-frequency mode attainable efficiency does not greatly exceed that attainable for the single-frequency IMPATT mode.

Acknowledgment

The authors gratefully acknowledge discussions with P. T. Greiling concerning this work.

W. E. Schroeder
G. I. Haddad
Electron Physics Lab.
Dept. of Elec. Engrg.
University of Michigan
Ann Arbor, Mich.

Contributors

Robert B. Green, (S'56–M'61) was born in Des Moines, Iowa, on July 15, 1936. He received the B.S. degree in electrical engineering from Iowa State University, Ames, in 1958, and the M.S. and Ph.D. degrees in electrical engineering from Ohio State University, Columbus, in 1959 and 1963, respectively.

From 1958 to 1962, he was associated with the Antenna Laboratory (now Electro Sciences Lab) of the Electrical Engineering Department of Ohio State University, where he was engaged in work pertaining to radar scattering problems, and from 1962 to 1964, he was an instructor in the department. He is currently an Assistant Professor of Electrical Engineering at the University of California, Davis.

Dr. Green is a member of Pi Mu Epsilon, Eta Kappa Nu, Tau Beta Pi, Phi Kappa Phi, and Sigma Xi.

John David Rhodes (M'67) was born in Doncaster, Yorkshire, England, on October 9, 1943. He received the B.Sc. and Ph.D. degrees in electrical engineering from the University of Leeds, England, in 1964 and 1966, respectively.

From 1964 to 1966 he was a Research Assistant in the Department of Electrical and Electronic Engineering, University of Leeds, where he worked in the areas of microelectronic and microwave network theory. In the academic year 1966–1967, he was a Research Fellow in the same department. In the Fall of 1967 he joined Microwave Development Laboratories, Inc., Natick, Mass., as a Senior Research Engineer, where he was engaged in a program to design new classes of microwave filters with particular reference to linear phase filters. He is currently with the Electrical Engineering Department, Leeds University, England.

Cheng P. Wen (S'54–M'63) was born in Canton, China, in 1933. He received the B.S., M.S., and Ph.D. degrees in electrical engineering from the University of Michigan, Ann Arbor, in 1956, 1957, and 1963, respectively.

From 1956 to 1963, he was employed by the Electron Physics Laboratory of the University of Michigan. In March, 1963, he joined the RCA Laboratories, Princeton, N. J., where he has worked on ultra-low-noise microwave tubes, gas lasers, and microwave acoustics including delay lines, ferromagnetic semiconductors, and microwave integrated circuits.

Dr. Wen is a member of Eta Kappa Nu, Tau Beta Pi, and Sigma Xi.