[6] H. E. Green, "The numerical solution of some important transmission-line problems," *IEEE Trans. Microwave Theory Tech.* (*Special Issue on Microwave Filters*), vol. MTT-13, pp. 676–692, Sept. 1965.
[7] H. N. Dawirs, "Equivalent circuit of a series gap in the center conductor of a coaxial transmission line," *IEEE Trans. Microwave Theory Tech.* (Corresp.), vol. MTT-17, pp. 127–129, Feb. 1969.
[8] W. J. Getsinger, "The packaged and mounted diode as a microwave circuit," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-14, pp. 58–69, Feb. 1966.
[9] R. L. Eisenhart and P. J. Khan, "Theoretical and experimental analysis of a waveguide mounting structure," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-19, pp. 706–719, Aug. 1971.

Wide-Bandwidth Millimeter-Wave Gunn Amplifier in Reduced-Height Waveguide

DAVID RUBIN, MEMBER, IEEE

***Abstract*—A *Ka*-band millimeter-wave Gunn-amplifier structure with 15-GHz gain$^{1/2}$-bandwidth product has been fabricated in reduced-height waveguide. Measurements were taken of the terminal admittance of the diode and its mount and used in the computer optimization of impedance matching transformer sections.**

SUMMARY

A reduced-height waveguide structure housing a Gunn diode has produced *Ka*-band gain$^{1/2}$-bandwidth products of approximately 15 GHz. Previously, large-bandwidth millimeter-wave Gunn amplifiers have been constructed using coaxially mounted diodes iris coupled to waveguide [1], although amplification at *X* band with moderate bandwidths has been reported [2] using reduced-height guide. It is expected that millimeter-wave InP diodes will shortly become more available and it is hoped that low-noise-figure amplifiers (such as the often quoted 7.5 dB [3]) can be constructed with useful gain over large bandwidths.

The purpose of this work was initially to use available supercritically doped GaAs diodes[1] to do the following.

1) Find a waveguide structure which would be both stable and capable of large bandwidth operation with reasonable gain.

2) Develop a method which can be used for experimentally determining the circuit effects of the diode and its mount (including parasitics). The latter, which is called "terminal" admittance in this short paper, is of particular importance in circuit design.

3) Computer optimize a matching structure given the terminal admittance found above.

In the experiments to be described, the Gunn diodes were center mounted in reduced-height double-cosine tapered cavities. A compressible gold-plated bellows allowed vertical movement of the diode as shown in Fig. 1. The 0.118-in-diam heat sink was allowed to penetrate into the 0.010-in reduced-height cavity in order to create a waveguide discontinuity found essential for large-bandwidth operation. With no penetration of the heat sink, useful gain could be found (moving an adjustable short) for only one or two hundred MHz. Maximum bandwidth (7.5 GHz) was obtained for the heat sink inserted about halfway into the cavity.

In the original structure a second double-cosine taper behind the diode was terminated by a spring short formed by doubling over a thin strip of 0.280-in brass. Two extremes of gain and bandwidth found by adjusting the diode height and short position are shown in Fig. 2.

Manuscript received July 16, 1974; revised May 5, 1975.
The author is with the Microwave Technology Division, Naval Electronics Center, San Diego, Calif. 92152.
[1] Varian VSA 9210.

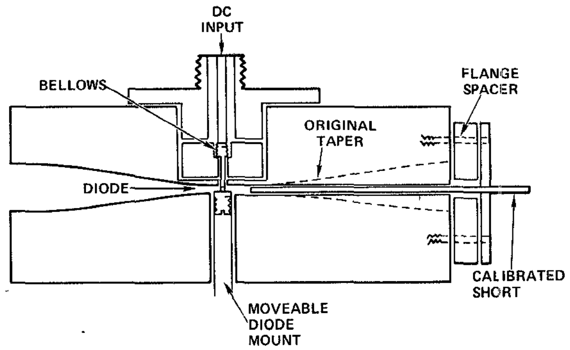

Fig. 1. Original Gunn-diode amplifier mount. Modification allowed measurements of diode terminal admittance.

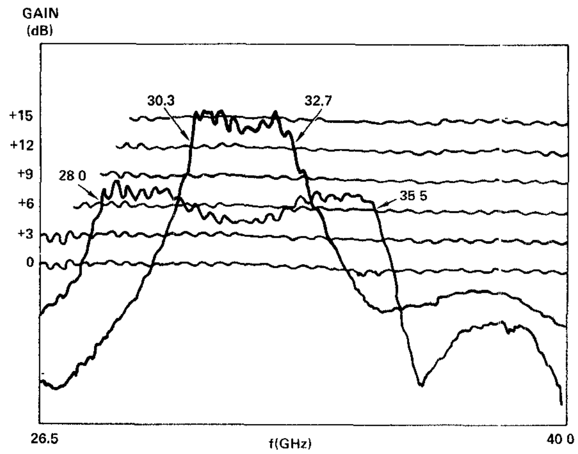

Fig. 2. Measured gain with two different diode and short positions.

In order to make meaningful measurements on reflection coefficients it was necessary to change the original structure as shown in Fig. 1 so that one side of the cavity was merely reduced-height (0.010 in) guide. A metal strip can be positioned accurately within the reduced-height guide by using waveguide flanges of various widths as spacers.

Two-port *S* parameters are found for the double-cosine cavity (between the input flange and the position of the diode) by removing the diode and filling the holes in the waveguide walls with machined slugs. For each frequency of interest, reflection coefficient data are taken for a minimum of three known positions of the sliding short behind the terminal (diode) position. After all the data are taken for the cavity *S*-parameter determination, additional reflection coefficient data are taken with the biased diode in place and the short set at some position where the circuit is stable. From the new data, using the previously calculated cavity parameters, the terminal admittance can be calculated.

Once the diode terminal admittance and matching circuit *S* parameters are found, a check on the accuracy of the calculated values can easily be made. With the diode vertical position unchanged, the calibrated short is set to other positions that also give stable gain and measured reflected gain is compared to calculated gain.

Results are shown in Fig. 3 for the diode terminal admittance data taken with the short 0.142 in from the diode center. Using the *S* parameter and terminal admittance data, amplifier gain was calculated for the short 0.411 in from center and compared to measured reflectometer gain at the latter position (Fig. 4). Other comparisons between calculated and measured results, not so closely matched, can be shown to be due, in part, to the effect of higher order TE_{LO} modes which are created at the diode post discontinuity and reflected back from the short.

The diode terminal admittance data of Fig. 3 were used in a computer optimization program which determines a matching *N*-section transformer. For example, (Fig. 5), a two-section transformer (six

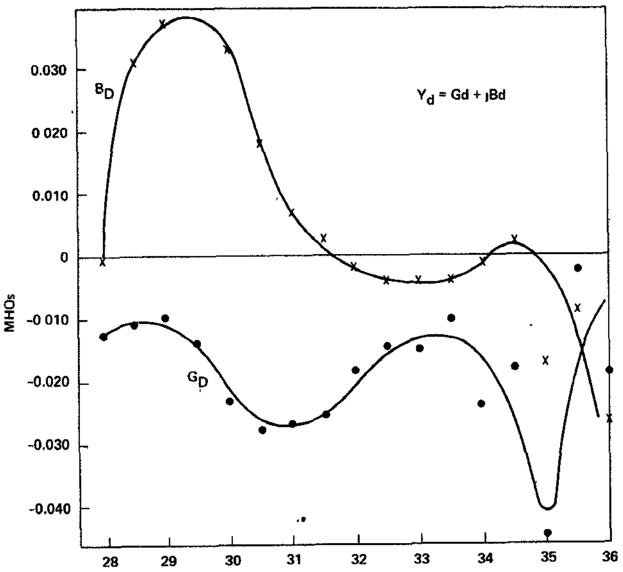

Fig. 3. Terminal diode admittance parameters for one vertical diode position.

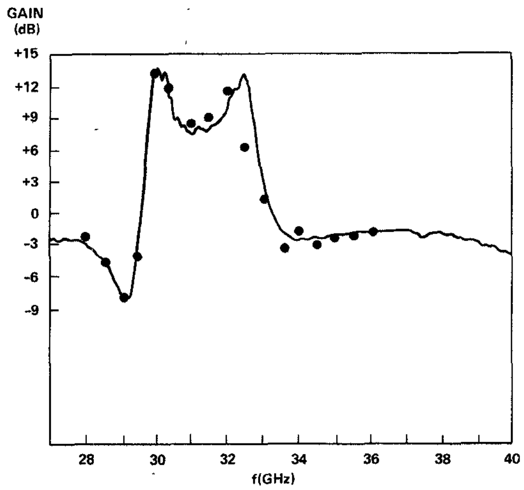

Fig. 4. Calculated versus measured gain with short 0.411 in from diode center. Terminal admittance data used in the calculations were derived from measurements taken with the short 0.142 in from center.

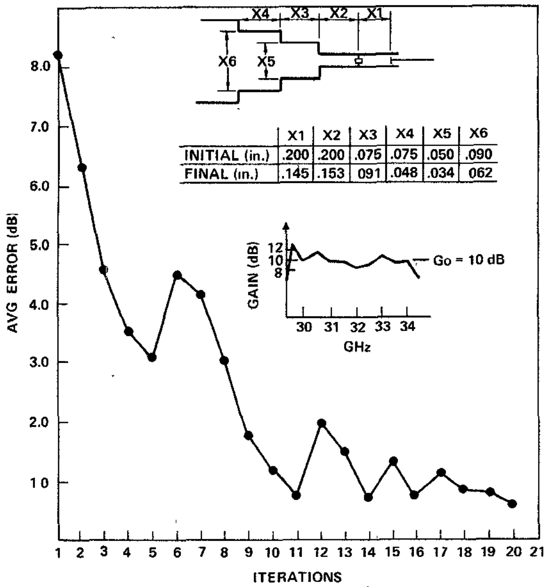

Fig. 5. Computer optimization of two-step matching transformer for 10-dB gain amplifier (30–34 GHz).

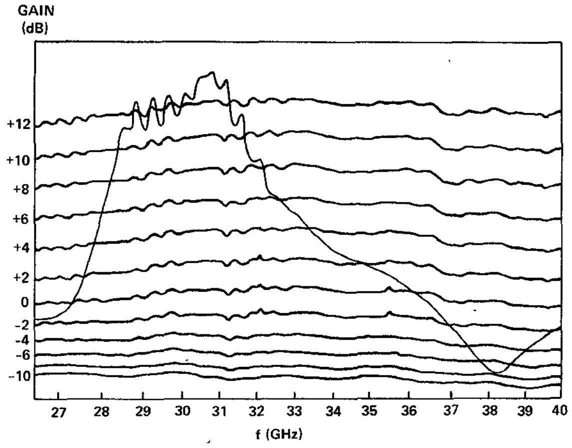

Fig. 6. Measured gain of computer optimized amplifier.

variables) was designed to optimize an amplifier for 10-dB gain over the 30–34-GHz range. Step discontinuities were accounted for in the program. Almost arbitrary initial conditions shown in Fig. 5 led to the final values and computed gain shown. The structure was fabricated and produced over 10-dB gain over a 3.5-GHz band centered 5 percent lower than calculated (Fig. 6). Other positions of the diode and short have produced gain$^{1/2}$-bandwidth products even higher than 15 GHz, indicating the potential usefulness of this type of fabrication.

REFERENCES

[1] J. G. deKoning and R. E. Goldwasser, "A wide band, two-stage *Ka*-band Gunn effect amplifier," in *1974 Millimeter Wave Techniques Conf.*, Naval Electronics Lab. Cen., vol. 1, pp. A3-1–A3-13.
J. G. deKoning *et al.*, "A four stage, 30 dB gain, 100 mW Gunn effect amplifier in *Ka*-band," in *1974 IEEE Microwave Theory and Techniques Int. Symp. Dig.*, pp. 318–319.

[2] A. Sêne and F. J. Rosenbaum "A wide-band Gunn-effect CW waveguide amplifier," *IEEE Trans. Microwave Theory Tech.*, vol. MTT-20, pp. 645–650, Oct. 1972.

[3] S. Baskaran and P. N. Robson, "Noise performance of InP reflection amplifiers in *Q* band," *Electron. Lett.*, vol. 8, pp. 137–138, 1972.

Optimization of Microwave Networks

CHRISTAKIS CHARALAMBOUS, MEMBER, IEEE, AND ANDREW R. CONN

***Abstract*—The application of a new algorithm for minimax optimization is investigated. Unlike most of the previously published algorithms the new algorithm uses to its advantage certain obvious properties of the minimax function, namely, that the discontinuities in the first derivatives can be characterized by projections. An *N*-section transmission-line transformer is used as a test problem.**

I. INTRODUCTION

The problem under consideration is to minimize $M_f(x)$ where

$$M_f(x) = \max_{1 \leq i \leq m} f_i(x)$$

$$x = [x_1 x_2 \cdots x_n]^T$$

$$[M] = \{1,2,\cdots,m\}.$$

Manuscript received February 6, 1975, revised May 5, 1975. This work was supported in part by the National Research Council of Canada under Grant A8639.

The authors are with the Department of Mathematics and Combinatorics, University of Waterloo, Waterloo, Ont., Canada.