AD-760 545

TRAPATT AMPLIFIER FOR PHASED ARRAYS

Martin I. Grace, et al

Sperry Rand Research Center

Prepared for:

Rome Air Development Center

March 1973

RADC-TR-73-26
Interim Report
March 1973

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Rome Air Development Center
Air Force Systems Command
Griffiss Air Force Base, New York

AIR FORCE 13680 5-24-73/161 copies

41

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Sperry Rand Research Center 100 North Road Sudbury, MA 01776	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP --

3. REPORT TITLE

TRAPATT AMPLIFIER FOR PHASED ARRAYS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Interim Technical Report - 24 Jan 1972 - 24 Sept 1972

5. AUTHOR(S) (First name, middle initial, last name)

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6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
March 1973	40	2

8a. CONTRACT OR GRANT NO. F30602-72-C-0202	9a. ORIGINATOR'S REPORT NUMBER(S) SRRC-CR-72-17
b. PROJECT NO. Job Order No. 55730536 c. d.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) RADC-TR-73-26

10. DISTRIBUTION STATEMENT

Approved for public release. Distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Rome Air Development Center (OCTE) Griffiss Air Force Base, NY 13441

13. ABSTRACT

This report describes the present status in the design of a broadband CW TRAPATT amplifier in microwave circuit form, whose coaxial analog was originally under Contract F30602-70-C-0110. Progress toward the development of CW devices is described with emphasis on surface degradation effects and approaches toward solving this difficulty. An amplifier broadbanding technique and the use of small-area devices to achieve lower input power thresholds for CW operation are also described.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
TRAPATTs TRAPATT amplifiers Solid State Microwave amplifiers						

TRAPATT AMPLIFIER FOR PHASED ARRAYS

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FOREWORD

This technical report was prepared by Sperry Rand Research Center under Contract No. F30602-72-C-0202, Job Order No. 55730536. The Sperry number was SRRC-CR-72-17. Mr. R. Hunter Chilton (OCTE) was the RADC project engineer.

This report was reviewed by the Office of Information, RADC, and was approved for release to the National Technical Information Service (NTIS).

This report has been reviewed and is approved.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (continued)

SECTION 1

INTRODUCTION

The objective of this program is the further development of the wideband TRAPATT amplifier originally evolved at the Sperry Rand Research Center with RADC's sponsorship under Contract No. F-30602-70-C-0110. The general objectives of this program are the investigation and development of the TRAPATT amplifier in microwave integrated circuit form and a study of the compatibility of this type of amplifier with phased-array systems. Specific areas of study include development of a cw amplifier in microstrip, increased bandwidth techniques and measurement of pertinent array parameters such as phase, gain, noise, etc., variations between identical amplifiers.

Section 2 describes progress being made toward the development of cw devices, particularly the surface degradation problems and current approaches to solving this difficulty. An amplifier broadbanding technique and the use of smaller area devices to achieve lower input power threshold amplifiers are presented in Sec. 3. Conclusions of the Interim Report, which are largely in the form of recommendations and plans for further work, are explained in Sec. 4.

SECTION 2

SEMICONDUCTOR DEVICES

Much of the device work has been the study of the effect of surface instability on TRAPATT performance and methods of stabilizing these surfaces. As will be described in detail, there are surface effects which seriously affect TRAPATT devices, especially the large perimeter ring mesa diode used for cw operation.

A. BASIC OBSERVATION OF SURFACE EFFECT

Through the published literature on TRAPATT devices there are no explicit references to the importance of surface effects on the TRAPATT behavior of mesa diodes. Nevertheless, a simple and fundamental relationship has been found between device performance and surface properties which indicates the surface of the diode to be of prime importance. It is a necessary condition for achieving high efficiency and low threshold that the surface of the device does not degrade under the high current state required by the TRAPATT diode.

The effects of surface degradation can be observed experimentally in the arrangement diagrammed in Fig. 1, which permits simultaneous application to the diode of a 120 cycle saw-tooth current from a curve tracer and a periodically applied pulse of much greater current amplitude which is sufficient to excite and sustain TRAPATT operation. It will be initially assumed in this experiment that the 120 cycle current is applied at levels of 50 mA peak or less, even if the device is capable of cw operation. If too large a dc current is applied, the effect to be discussed is prone to change, sometimes rapidly, with time.

The basic observation of the experiment on a nonideal diode is shown in the photograph of the curve tracer oscilloscope presentation shown in Fig. 2. In this experiment, the high current ($\sim$ 400 mA) pulse width was 1 μs at a repetition rate of 1 kHz. The resulting faint trace produced on the oscilloscope by the small duty cycle of the applied pulse was apparent to the naked eye but was not visible in the photograph because of the small dynamic range of the Polaroid film used. It is important to note that the I-V characteristics of the TRAPATT diode are quite "hard" while no high current pulses are applied:

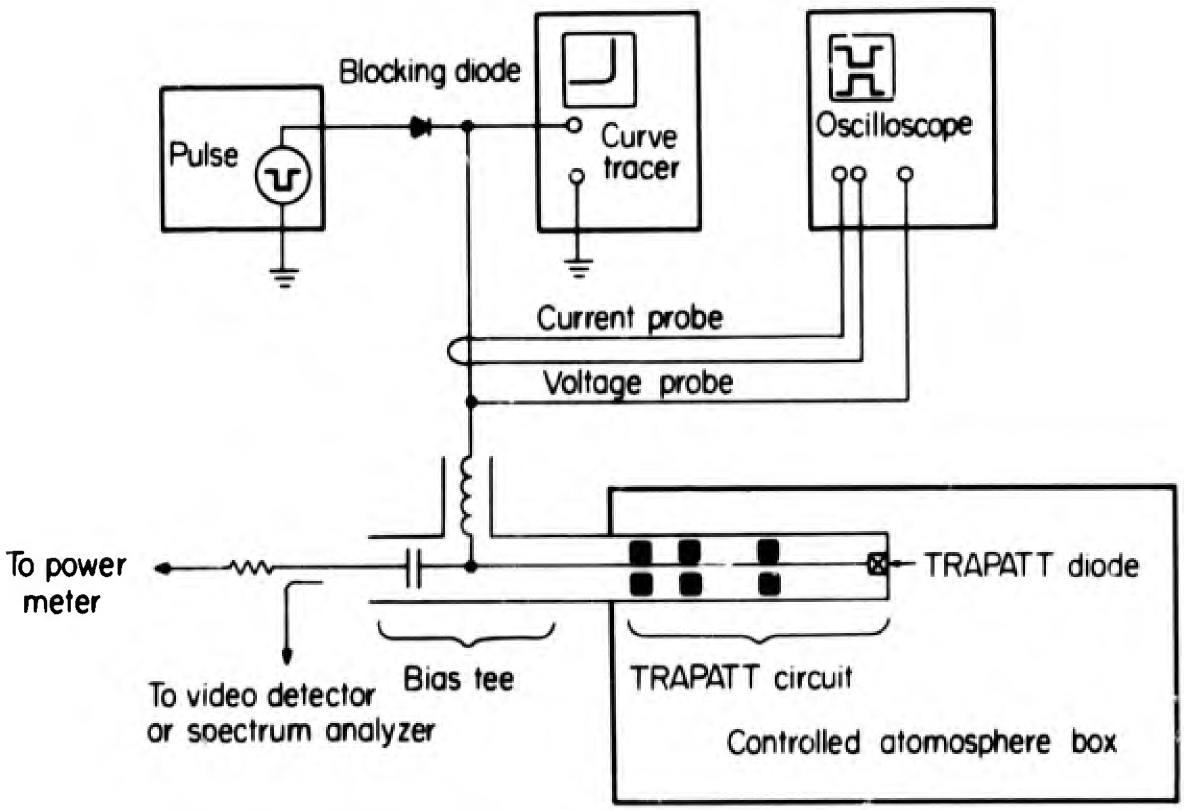


FIG. 1 Diagram of equipment used to study I-V degradation.

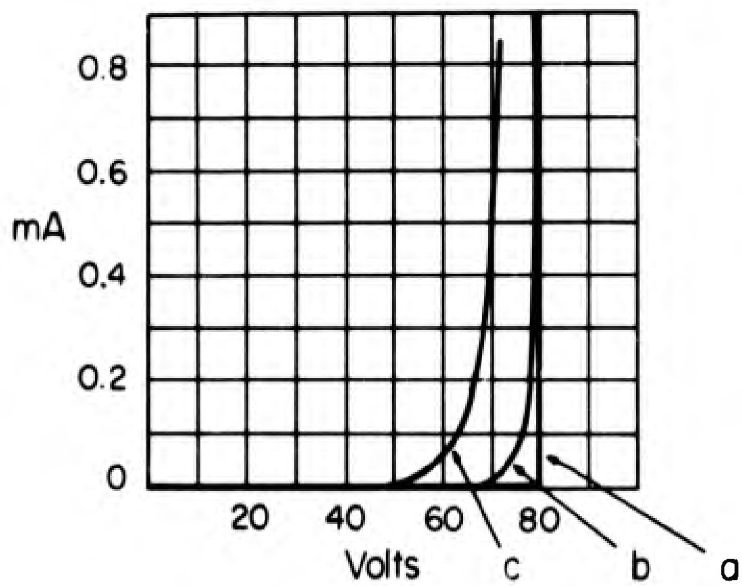


FIG. 2 I-V characteristics showing surface degradation: (a) no pulse; (b) with pulse - not in mode; (c) with pulse - in mode.

leakage currents at avalanche breakdown are often less than 50 nA, even for ring diodes of total perimeter equal to about 0.25 cm. Upon application of current pulses of 400 mA peak amplitude, when the device is not tuned into the TRAPATT mode, the degradation of the I-V characteristic is so significant that "rounding" of the breakdown characteristic occurs. If the pulse current through the device is left unchanged and the microwave circuit in which the device is tuned into the TRAPATT mode, a greater degradation of the I-V characteristic of the diode is produced, as shown in Fig. 2.

Any diode which shows significant I-V degradation at currents of $\leq 100\ \mu A$, which are at a level below which true bulk breakdown current begins to flow, will be both inefficient and have a high input power threshold requirement. Conversely, all diodes which have extraordinarily low thresholds or high efficiencies evidence little or no I-V degradation. These statements admit no known exceptions and are based on the analysis of data taken from hundreds of devices fabricated over a three-year period. These diodes operated with fundamental TRAPATT frequencies between 1 and 10 GHz.

B. EVIDENCE FOR IMPORTANCE OF THE MESA SURFACE

The above description of the I-V degradation and its correlation with TRAPATT performance is not necessarily related, by any argument heretofore advanced, to the surface of the device. There are, however, several related observations which substantiate the conclusion that the surface is the critical region of the device directly related to the observed I-V degradation.

1. The final wet chemical treatment of the mesa surface is the most important single means of partially controlling the extent of the I-V degradation. For example, rinsing the device in an H_2SO_4-H_2O_2 solution immediately following mesa etching always reduces the degree of degradation. Also, all mesas etched at one time show almost identical amounts of I-V degradation, while mesas etched from the same wafer (same metallization, diffusion, etc.) at a different date or in different apparatus will often show different though similar I-V degradations.

2. The atmosphere (relative amounts of N_2 and O_2) in which nonpassivated diodes are placed will often change the I-V

degradation and, hence, TRAPATT performance. High relative humidity (> 50%) is almost always effective in increasing the I-V degradation and reducing TRAPATT efficiency.

3. A device may be repeatedly cycled through varying amounts of I-V degradation by repeated etchings followed by alternate strong oxidizing washes (H_2SO_4-H_2O_2) and HF treatments. During these successive etches only a small fraction of a micron of the silicon surface need be removed, as was determined by capacitance bridge measurements.

4. Generally, those processes designed to affect primarily the surfaces of mesa diodes, affect the extent of the I-V degradation. For example, the application of resina commonly used to seal the surfaces of mesa diodes increases the amount of I-V degradation.

In addition, there are other observations which, though they do not prove that the surface of the mesa is directly involved, they are at least consistent with the present hypothesis.

1. Removal of the high pulse voltage generally permits return of the I-V characteristic to "hard" diode conditions. The time constant for the return to hard breakdown is between tens of milliseconds to several minutes. Such time constants are 3 to 7 orders of magnitude greater than the thermal time constant of the devices. Such a long time constant is consistent with a model of trap filling. Although both bulk and surface traps could certainly be conceived as a mechanism for realizing these long-time constants, surface states can certainly be considered to be the prime candidates for such behavior.

2. Almost all devices (≥ 95%) can be improved by "training." Long periods (several hours) of pulsing or relatively short times (~ 5 minutes) of dc TRAPATT operation, can greatly increase efficiency and lower the threshold with a corresponding simultaneous reduction of I-V degradation. Often it is

observed that TRAPATT operation is initially impossible at a given level of dc or pulse current; however, with continued operation (no adjustment of either the circuit or the current level) the device will gradually go into the TRAPATT mode. This phenomenon suggests that a limited amount of surface impurities can be removed by high current operation of the device. Figure 3 illustrates the change in efficiency that resulted from continued operation along with the change in current-voltage characteristics. Improvement in efficiency by as much as a factor of 3 to 5 is not uncommon for ring diodes "trained" under dc conditioning.

3. A given amount of I-V degradation will have a much greater effect in reducing the efficiency of a ring mesa diode than a conventional mesa diode of the same cross sectional area. It may be reasonable supposed that the perimeter of the ring mesa, which is eight times that of the conventional mesa, is the likely reason for this effect. A much larger fraction of the total volume of the device is "near the surface" in the case of the ring diode.

C. METHODS OF REDUCING SURFACE SENSITIVITY

Numerous methods of reducing surface sensitivity have been examined or are currently being investigated. The major experiments are shown in Table 1.

The treatment most likely to be useful is one that can remove ions from the surface rather than just binding them in place. This is because the degradation clearly involves ionic motion since only ionic motion explains the "training" phenomenon. Since we expect that all likely applications of the device will involve local temperatures in excess of $100^{\circ}C$, simple covering of the device with an oxide is not sufficient since ionic conductivity in SiO_2 can become high at such temperatures.

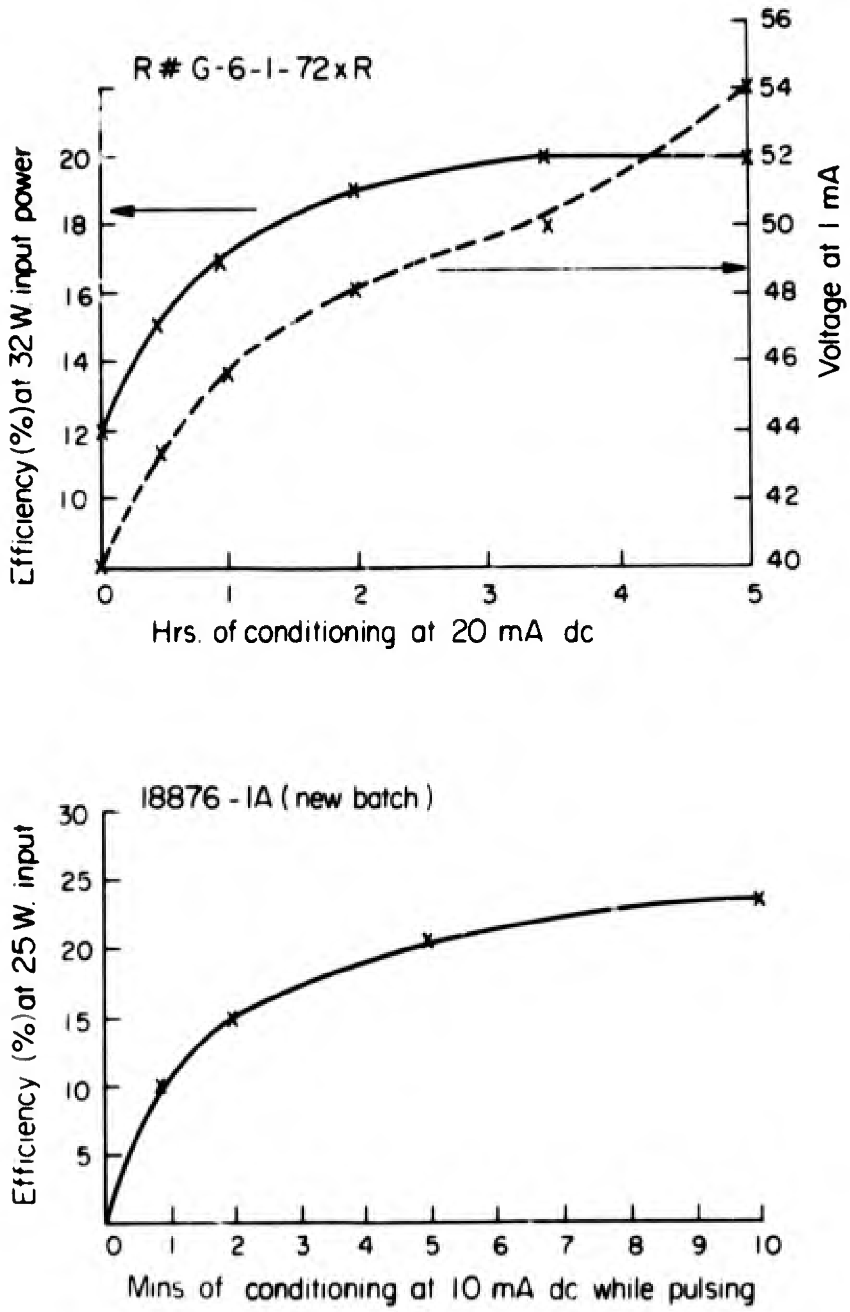


FIG. 3 Effects of dc conditioning on a ring diode.

TABLE 1

SURFACE SENSITIVITY EXPERIMENTS

	TREATMENTS	RESULTS	COMMENTS
1.	Training by dc current	Usually improves performance	Never (or rarely ever) completely successful
2.	Electrolytically etched mesas	No change	Those were attempts to shape mesa to reduce surface fields
3.	Changes in wet chemical treatments		
	a. Prolonged ultra-pure wash after etching	Usually slight improvement	
	b. Use of proprietary sequestering agents	No change	
	c. $H_2O+H_2O_2+NH_4OH$ and $H_2O+H_2O_2+HCl$ rinses etching	slight improvement	These are standard finishing wet treatments used in certain LSI processing
	d. Drying devices after H_2O solution with alcohols	slight improvement	
	e. Wash in hot $H_2O+H_2SO_4+H_2O_2$ solution	Always improves device	Never (or rarely ever) leaves device perfect; best treatment found
	f. Change constituents of etches	No effect	
4.	Use of resins, elastomers and coatings commonly used to seal mesa surface	Usually degradation increases	
5.	Partial test of phosphorus doped glasses to getter devices	No effect	Supposed to getter metallic ions at 400°C; have only been tested to 350°C until metallization scheme is changed.
6.	Gettering of impurities from surface with HCl gas during growth of oxide on side of mesas	No test yet	This method of gettering standard for many MOS devices. Process described in detail in next section.

D. HCl GETTERING AND OXIDE GROWTH ON THE MESA SIDES

One method used in MOS technology to produce stable gates with zero offset voltages is to grow the gate insulator in an HCl atmosphere. This procedure is effective through either binding metallic ions in stable compounds or by removal of the unwanted impurity by formation of volatile compounds, while forming an SiO_2 passivating layer.

Such a procedure seems to be a very attractive solution to the surface sensitivity problem of TRAPATT devices if it can be carried out. One possible configuration for such a finished device with the SiO_2 layer covering the sides of the mesa is shown in Fig. 4.

The method of producing such a mesa structure is shown in Fig. 5. Since the mesa must be first etched before the oxide can be grown, one must have some means to protect the top of the mesa from oxidization during the HCl-oxide growth on the mesa sides. No photoresist process will be useful in removing an oxide grown on the mesa top, since the mesa shape is not perfectly circular from device to device. Thus, one would either leave some oxide on the top or remove some from the side. Either situation is disastrous: the former because of the low thermal conductivity of SiO_2 (10^{-6} cm of SiO_2 would have the same thermal impedance as 10^{-2} cm of Si), and the latter because the SiO_2 layer might be removed at the junction where it is most needed.

Experimentally it has been established that the protective layer which masks against oxide growth cannot be any combination of metals. However, the use of a Si_3N_4 layer has been found to be acceptable. The Si_3N_4 can be preferentially etched by phosphoric acid which will not significantly attack the SiO_2. The first few steps in the process shown in Fig. 5 have been successfully tested (application of Si_3N_4, metal masking, mesa etching, oxide growth and Si_3N_4 removal) and a complete fabrication is in process. The final removal of the metal from the mesa sides is performed after bonding of the device. Silver is chosen for the final metal layer because it can be removed more completely than gold without risking an attack of the surrounding gold metallization on the diamond and the device contacts.

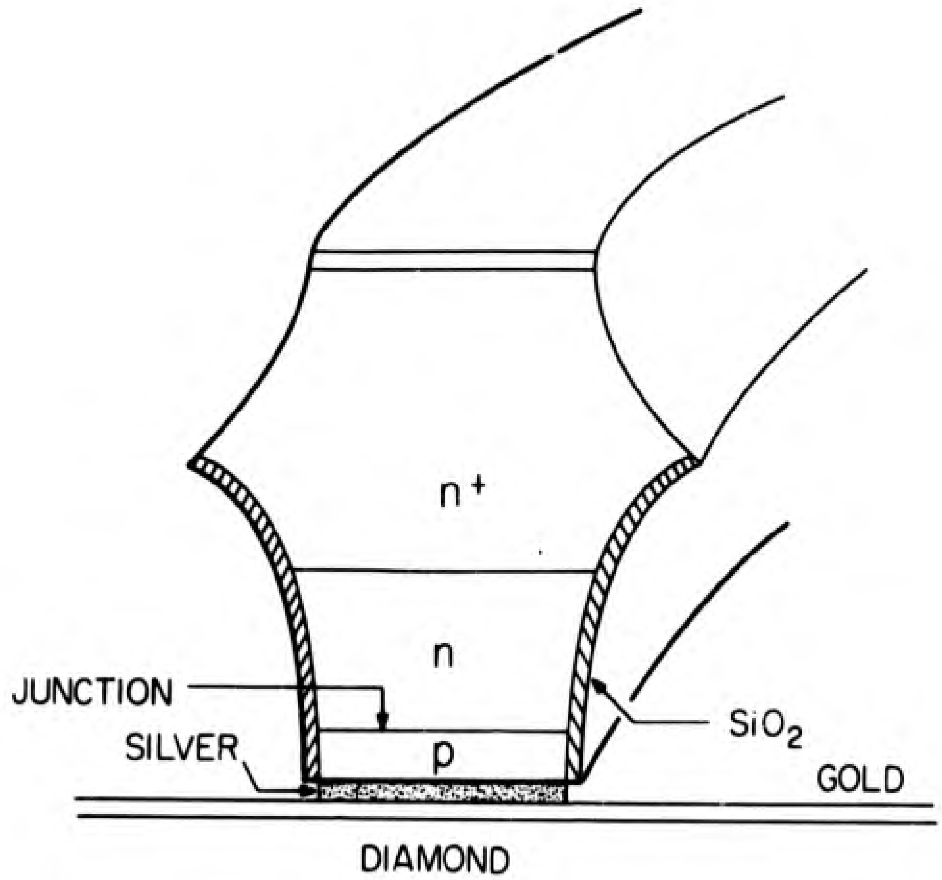


FIG. 4 Cross section of SiO_2 passivated ring diode.

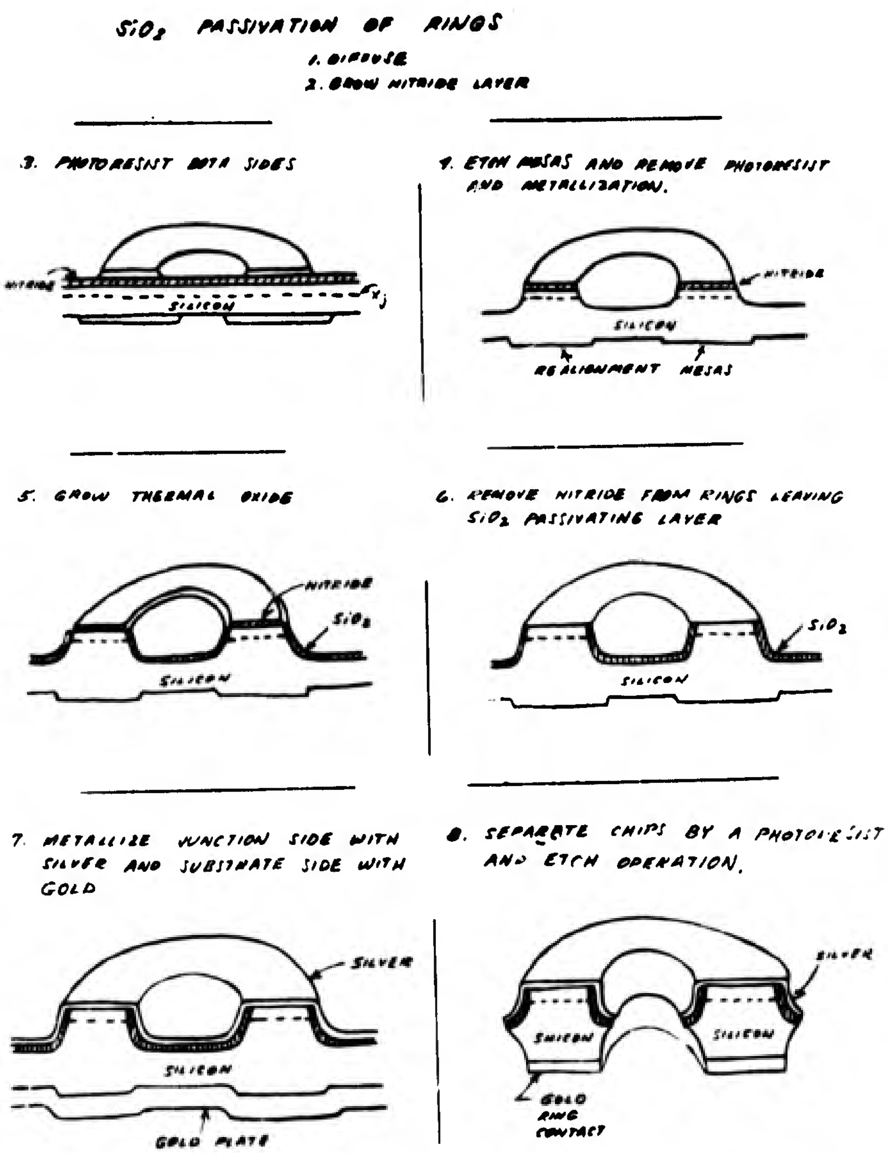


FIG. 5 Processing steps for fabricating SiO_2 passivated ring diode.

SECTION 3

MICROWAVE CIRCUIT INVESTIGATIONS

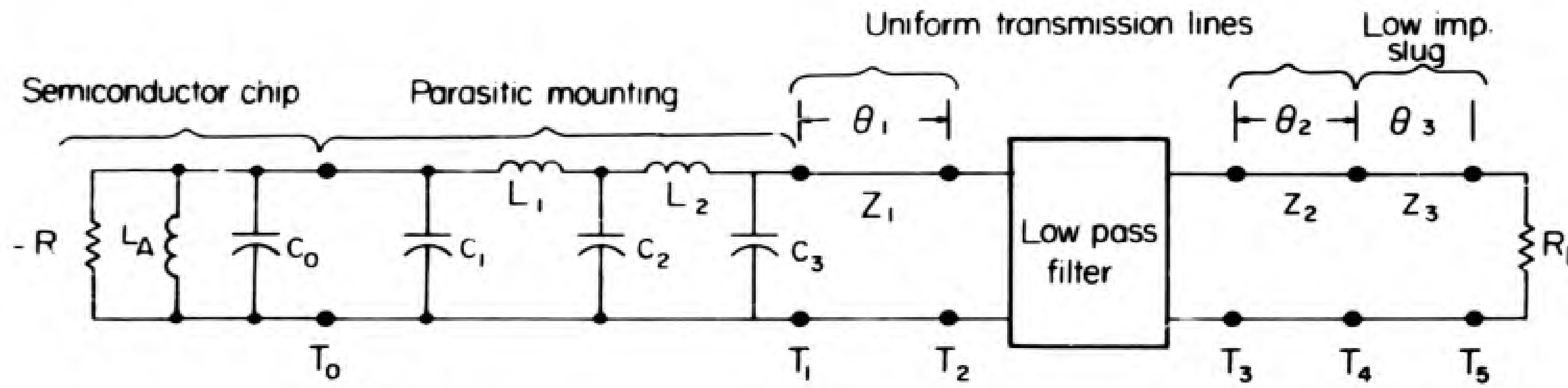
The major effort in circuit investigations has been in broadbanding techniques and the design of amplifiers using diodes of smaller area than those used previously. The section dealing with broadbanding describes the progress being made on a microstrip amplifier configuration using a three-resonator impedance matching bandpass filter located as close to the diode as is practical. The reason for examining the use of smaller area diodes for amplifiers is basically one of lower threshold and, hence, a better opportunity for cw amplifier operation. Some results achieved on a pulsed basis on diodes as small as 0.35 pF at voltage breakdown are described.

A. WIDEBAND AMPLIFIER DESIGN

The bandwidth of the prototype amplifier can be improved by replacing the lowpass filter with an impedance matching bandpass filter located as close to the diode as is practical. The filter is designed to give a prescribed midband gain and bandpass ripple. The design procedure for the improved bandwidth amplifier is developed in the following section.

The design procedure assumes the TRAPATT amplifier can be represented by an equivalent circuit comprised of a negative resistance and a lossless reactive interconnecting network. The circuit elements which represent the active semiconductor elements are the negative resistance, the depletion layer capacitance and an electronic reactance. The design of multiple device mountings can be included within this design procedure by introducing the interconnection parasitics between adjacent devices.

The large-signal equivalent circuit for the prototype TRAPATT amplifier, as determined from impedance measurements on the experimental amplifier, is shown in Fig. 6. The negative resistance R, the electronic inductance L_a and the capacitance C_0 are the large-signal equivalent parameters of the active semiconductor chip. The capacitance C_0 represents the equivalent depletion layer capacitance of the chip and the inductance L_a represents the electronic reactance due to the impact ionization process. The magnitude of the negative



$-R = 8\ \Omega$
$L_A = 0.5$ nHy
$C_j = .4$ pF
$C_1 = .09$ pF
$L_1 = 2.5$ nHy
$C_2 = .55$ pF
$C_3 = .045$ pF
$\theta_1 = 1.0'$
$Z_1 = 61.1\Omega$
$Z_2 = 61.1\Omega$
$Z_3 = 17\ \Omega$
$\theta_3 = 0.6''$
$R_2 = 50\ \Omega$

Gain = 5 dB

at terminal T_5 $\quad Q_5 = -37.4$
Bandwidth 3 dB = 275 MHz
1 dB = 102 MHz

at terminal T_2 $\quad Q_2 = -22.5$
Bandwidth 3 dB = 424 MHz
1 dB = 170 MHz

FIG. 6 Large-signal equivalent circuit for prototype wide-band TRAPATT amplifier.

resistor -R is calculated from measurements of amplifier gain and load impedance at the terminals of the semiconductor chip. The circuit elements C_1, C_2, C_3, L_1 and L_2 represent the parasitic reactances introduced in mounting the diode. These parasitic elements form the major portion of the TRAPATT amplifier circuit. The short section of the uniform transmission line and the lowpass filter provide a small amount of time delay triggering (TDT) enhancement necessary for TRAPATT amplification. The slug Z_3 of length θ_3 is positioned a length θ_2 from the lowpass filter so as to resonate the diode at the fundamental output frequency ω_0.

The gain and bandwidth of the experimental amplifier are determined by the Q of the network and the value of the load resistance. For the prototype broadband amplifier, the circuit Q at the output terminal T_5 was calculated to be -37.50. The 3 dB bandwidth was 275 MHz and the 1 dB bandwidth was 102 MHz. If it is possible to realize a TRAPATT amplifier having T_2 as the accessible terminals, the negative Q would be reduced to 22.5 and the corresponding 3 dB and 1 dB bandwidths would increase to 424 and 170 MHz, respectively. The computer calculated pass-band response of the amplifier is shown in Fig. 7.

The 1 dB bandwidth of the amplifier can be further increased by the use of broadbanding techniques developed by Getsinger for reflection-type negative resistance amplifiers. This technique involves the use of prototype impedance matching filters to shape the bandpass characteristics of the amplifier.

A bandpass impedance matching filter is chosen rather than a lowpass filter. The terminal T_2 is chosen as a reference point rather than the terminal T_5 in order to obtain the lowest possible negative Q. The equivalent circuit of the amplifier, including matching transformer, is shown in Fig. 8. The negative resistor R_d and the reactance X_d are the equivalent circuit resistance and reactance measured at terminals T_2. An external series reactance X_s is added to resonate the amplifier at the required operating frequency. Figure 9 shows the absolute value of both the real and imaginary components of the impedance seen to the left of terminal T_2 of Fig. 6. For this particular S-band prototype amplifier, the external series reactance X_s was an inductor of 0.48 nH. The real part of the impedance is relatively constant over the band of interest and lumped element equivalent circuit techniques can be used.

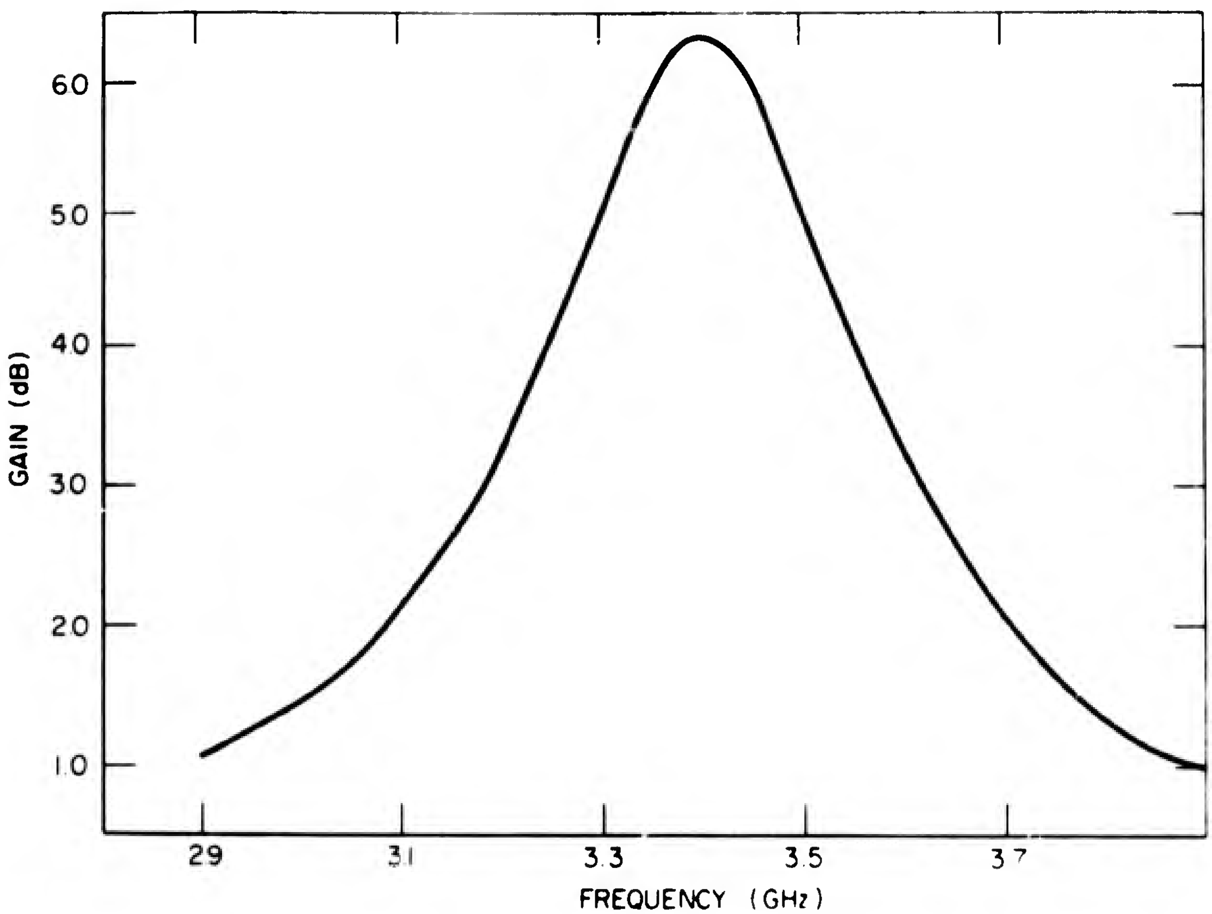
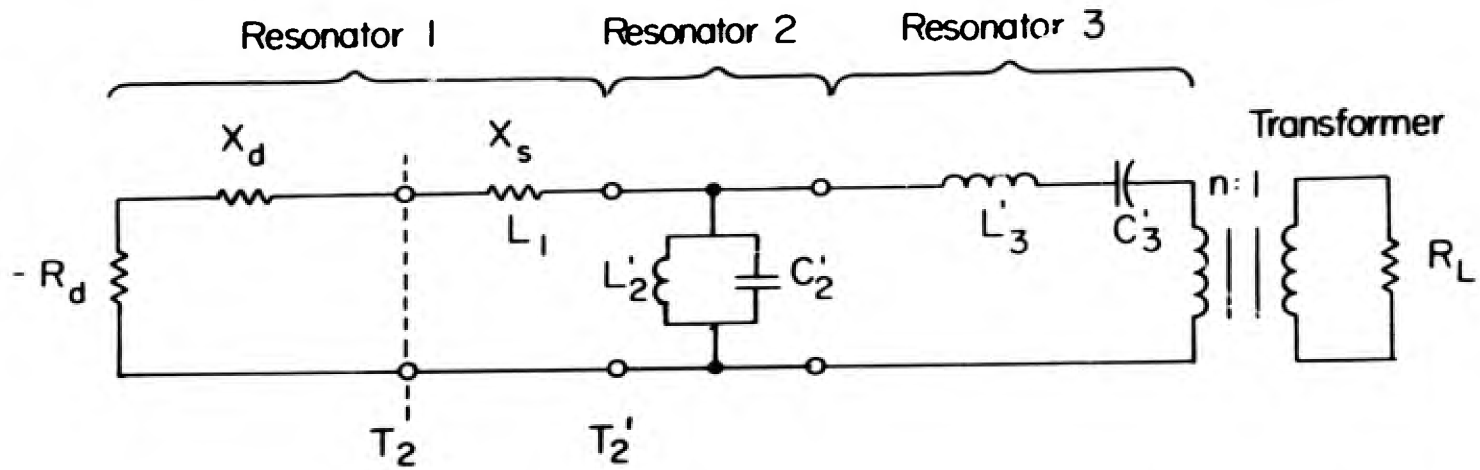


FIG. 7 Computer calculated passband response of TRAPATT amplifier referenced at terminal T_2.



$L_1 = 0.48$ nHy

$L'_2 = 0.179$ nHy

$L'_3 = 3.379$ nHy

$C'_2 = 12.234$ pF

$C'_3 = 0.647$ pF

$R_L = 50\ \Omega$

$n \cong 2$

Gain 5 dB ripple 0.5 dB

FIG. 8 Equivalent circuit for wideband TRAPATT amplifier referenced at terminal T_2.

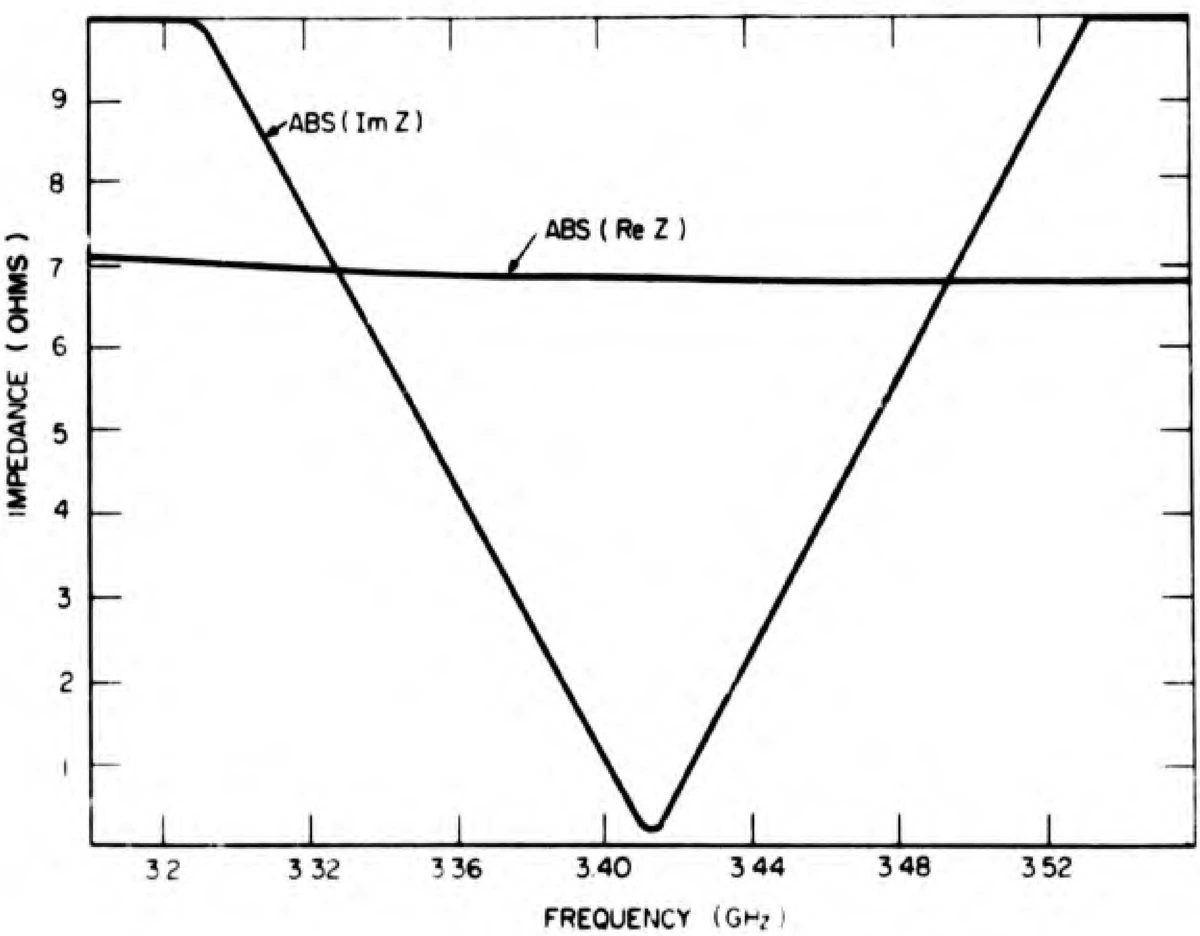


FIG. 9 Absolute value of the diode resistance and reactance referenced to terminal T_2 including the added inductance L_1.

The lowpass filter of the prototype amplifier is replaced by a two- or three-resonator bandpass filter whose values are chosen to give a specific bandpass amplifier response. The circuit elements of the bandpass filter are shown schematically as lumped element inductors and capacitors. However, these elements may not be realizable in this form. If so, impedance and admittance inverters[2] may be used. The transformer T is used to present the proper load resistance for the required gain. The improvement in amplifier performance is illustrated by the computer-generated pass-band response shown in Fig. 10. For this case, a 5 dB gain, 0.5 dB ripple, three-resonator circuit design was used. The 1 dB bandwidth is in excess of 500 MHz. The slight response asymmetry is due to differences in the values of the negative resistance presented to the matching filter at the band edges. It is difficult to realize the circuit elements required for a given bandpass amplifier response. These elements must be frequency invariant up to and including at least the third harmonic in order that the triggering waveforms will be maintained. For the wideband amplifier design shown in Fig. 10, resonator 2 is a 0.179 nH inductor in shunt with a 12.234 pF capacitor. This requires the use of a short length of wire in parallel with a lumped element capacitor. Because of the small values of inductance and, hence, short section of small-diameter wire, MOS capacitors have to be used. A schematic of a microstrip version of amplifier is shown in Fig. 11. The ring diode is mounted upon a diamond heat sink. A short wire whose length and diameter is chosen to yield the required inductance L_1 and distributed capacitance C_1 is connected from the diode to the lumped capacitor C_3. A second short section of wire whose size is chosen to correspond to L_3 and C_3 is connected between the capacitor and the short section of microstrip transmission line (Z_1, θ_1). The shunt resonator (2) is comprised of an MOS capacitor and a wire ribbon inductor. The second series resonator (3) is also formed by using MOS capacitors and a short section of wire. The quarter-wave transformer T transforms the load resistor to the proper value for the required gain. The use of the bandpass filter will not affect the triggering waveform because at the harmonic frequencies the resonator (2) of the bandpass filter presents a very low impedance to the diode in a manner similar to that of the lowpass filter (above its cutoff frequency) used in the prototype amplifier. This is illustrated in Fig. 12 which shows the computer-generater

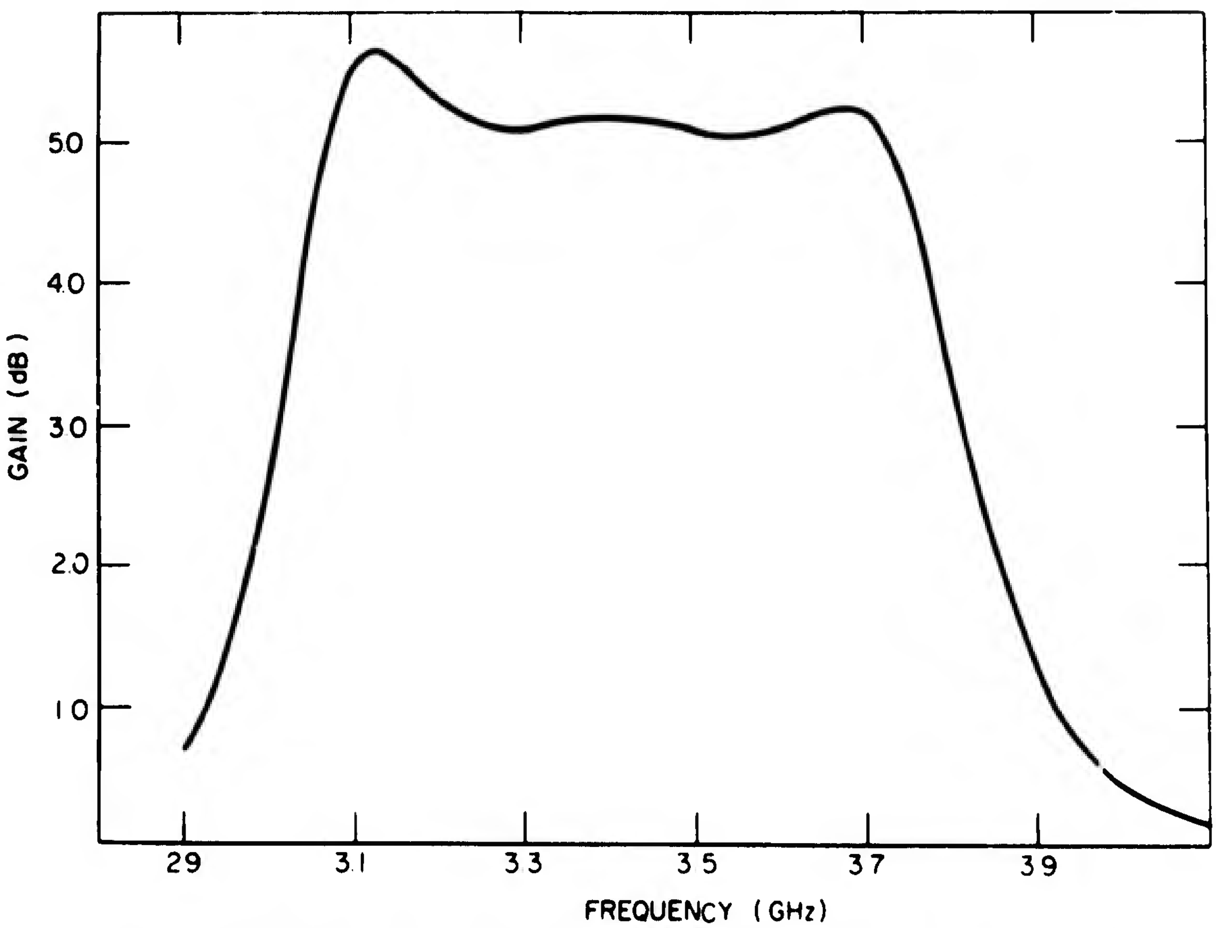
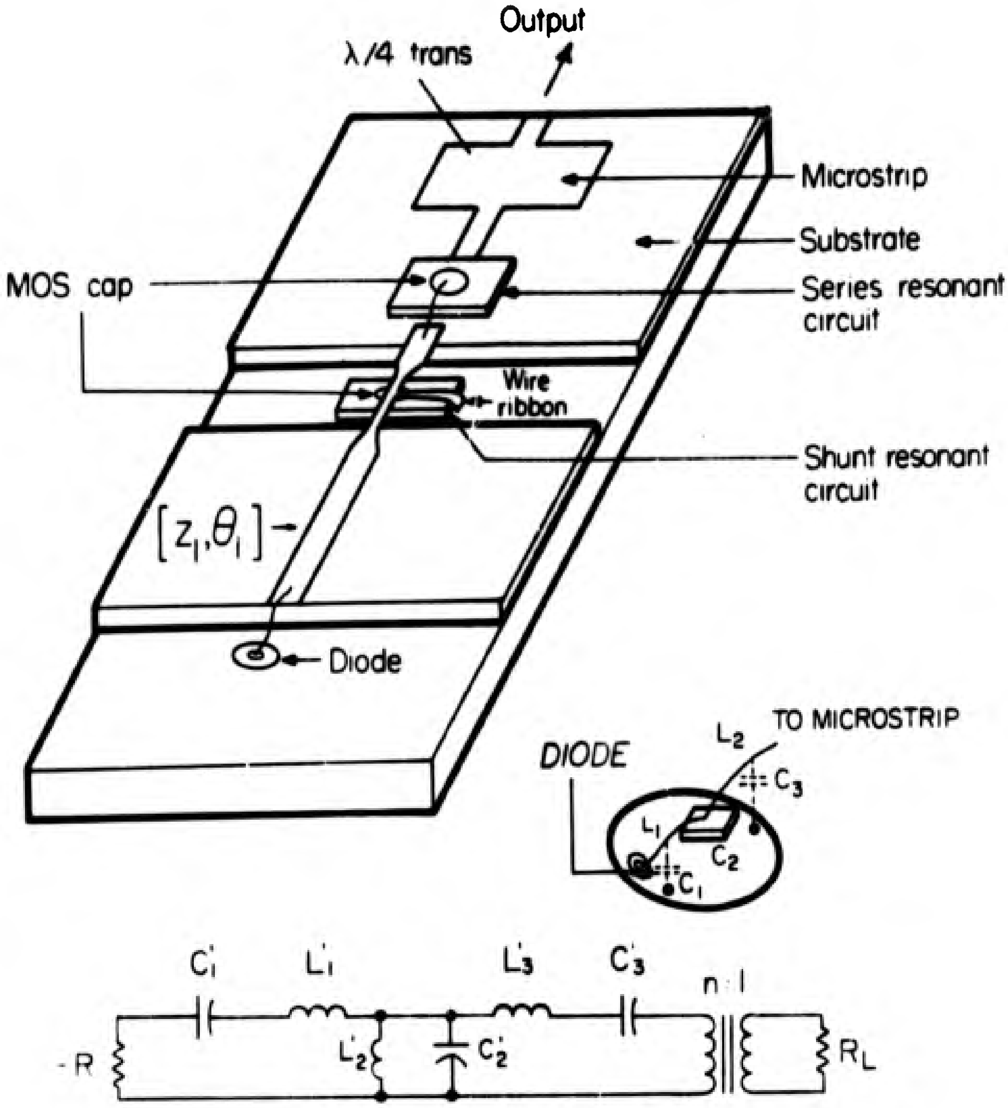


FIG. 10 Computer calculated bandpass response of wideband TRAPATT using 3 resonator impedance matching filter designed for 5 dB midband gain and 0.5 dB ripple.



$-R \sim 6\ \Omega$	$n:2$	$R_2 = 50\ \Omega$
$C_1' = 0.332$ pF	$L_1' = 6.576$ nHy	Gain ~ 5 dB
$C_2' = 12.234$ pF	$L_2' = 0.179$ nHy	1 dB bandwidth 620 MHz
$C_3' = 0.647$ pF	$L_3' = 3.379$ nHy	

FIG. 11 Schematic of improved bandwidth microstrip amplifier circuit.

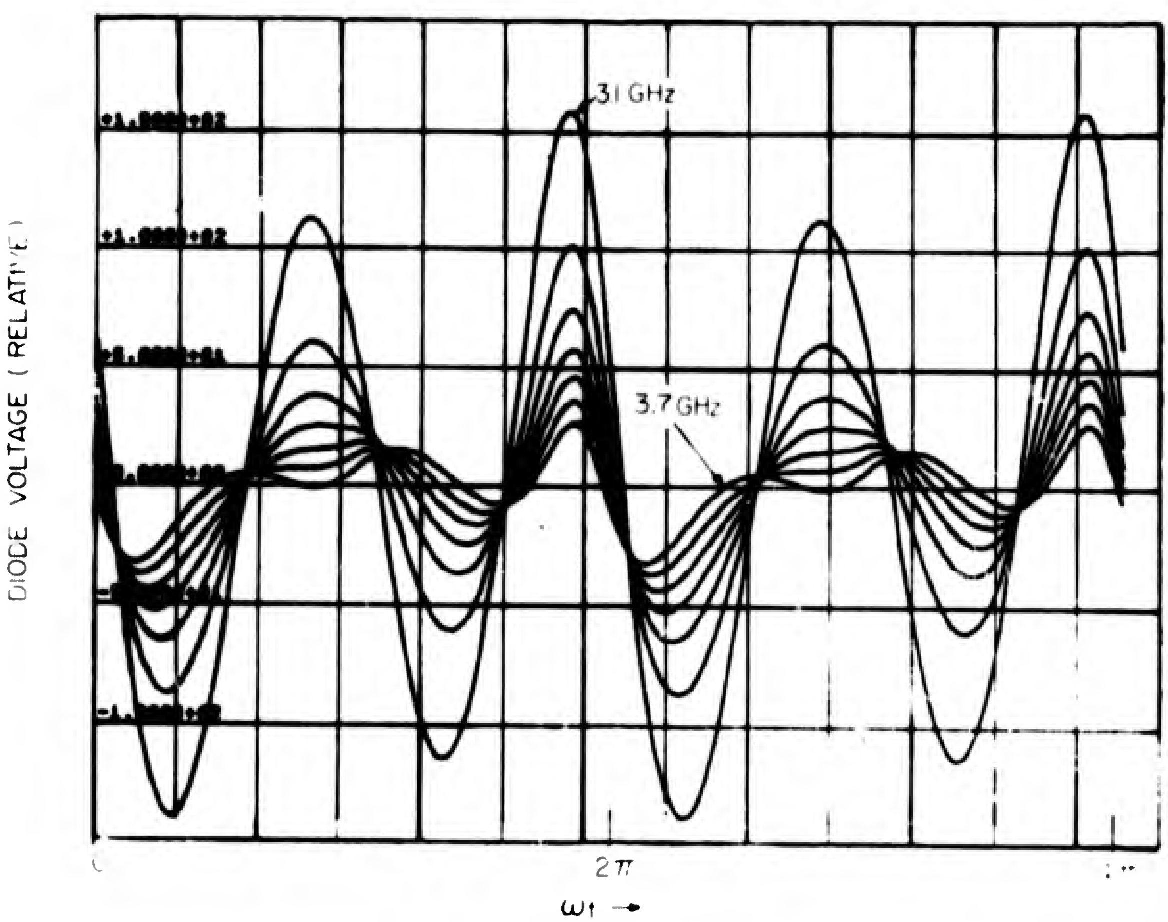


FIG. 12 Computer generated triggering waveform for improved bandwidth amplifier.

triggering waveform as a function of frequency. This does not include any effect due to an externally applied signal. The waveforms are similar to those obtained using the lowpass filter.

The gain value chosen for the proposed amplifier was 5 dB, to maximize the bandwidth; however, higher gain designs have been generated using the computer-aided broadband design techniques.

A computer calculation of the gain and phase response for the proposed improved bandwidth amplifier is shown in Figs. 13 and 14. The gain response is for an 8 dB midband gain amplifier having a 0.05 dB passband ripple. The gain variation over the required frequency band is due to the frequency sensitivity of the negative resistance, as referenced to the input terminals of the impedance matching bandpass filter. The total gain variation is $\pm$ 0.5 dB and can be reduced by changing the resonant frequency of the shunt-tuned resonator.

The computed phase response for the amplifier is shown in Fig. 14. The phase deviation from linear is due to use of the three-resonator impedance matching network. An improved phase response having a much smaller deviation from linear can be obtained by using a greater number of resonators.

The broadbanding technique described here has been used successfully with many types of negative resistance amplifiers, and, provided the triggering waveforms are unchanged over the frequency band of interest, it will be successful with TRAPATT amplifiers. It should be stressed that the improvement in the 1 dB bandwidth is accomplished by multiple tuning at the fundamental frequency. This technique does not affect the harmonic impedances which control the triggering waveform. Further improvement can only be accomplished by broadbanding the harmonic impedances.

Figure 15 is a photograph of a microstrip amplifier based on the use of an impedance-matching bandpass filter. Preliminary measurements have been made on individual parts of the circuit; that is, the diode mount, the series resonant circuit and the shunt resonant circuit. The major problem to date appears to be the shunt resonant circuit. This circuit appears to be lossy and is being studied further. As soon as the testing of the individual parts is successful the complete amplifier will be assembled and tested.

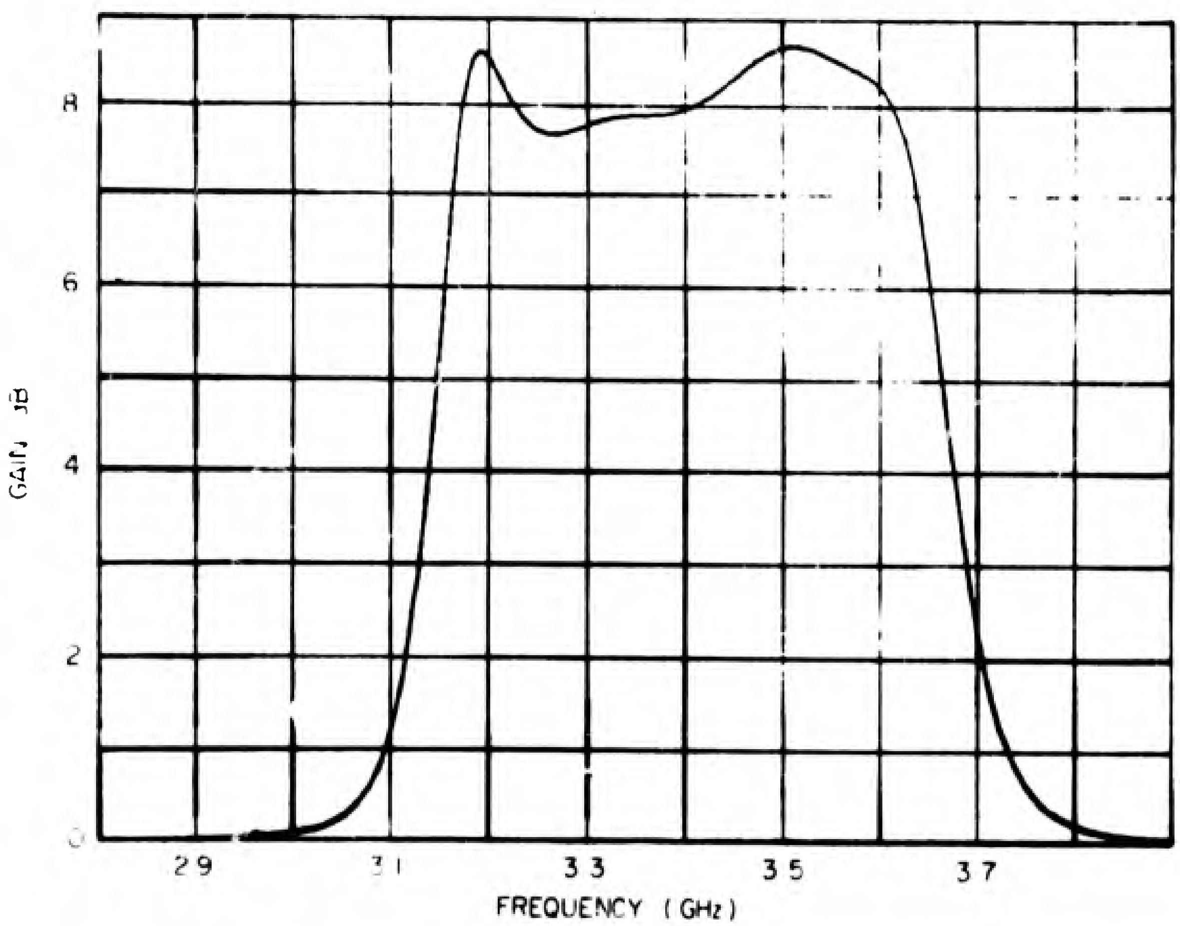


FIG. 13 Computer calculation of the passband of an 8 dB gain, 0.05 dB ripple amplifier stage.

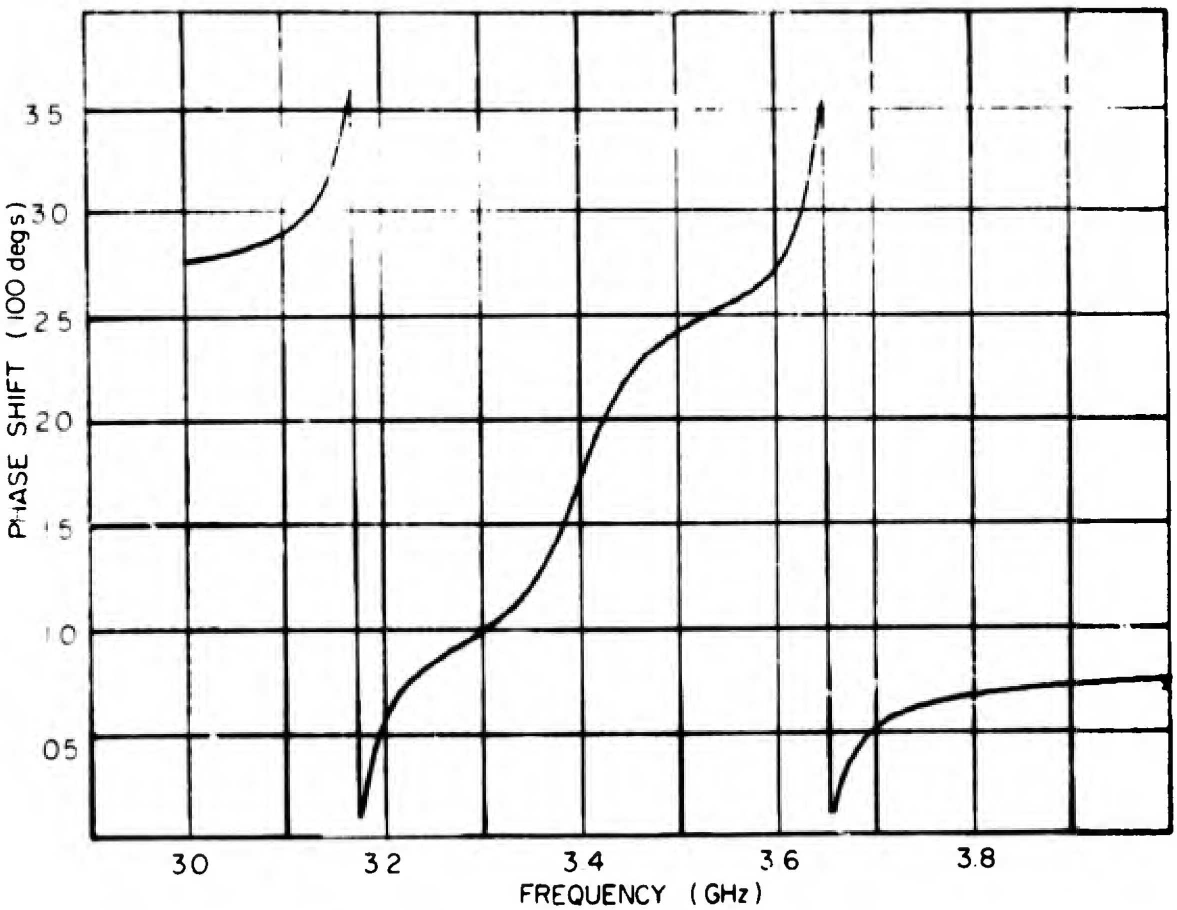


FIG. 14 Computer calculated passband phase response for a three-resonator impedance matching filter.

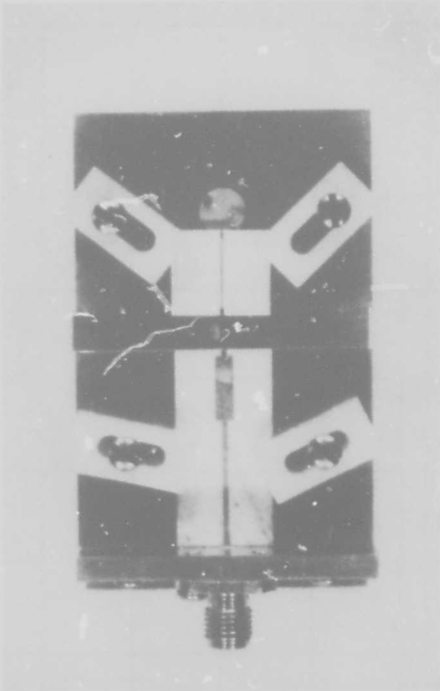


FIG. 15 Photograph of improved bandwidth.

B. SMALL-AREA DIODE AMPLIFIERS

In the prototype (14 mm coax) amplifier, the diodes used have a nominal depletion layer capacitance at voltage breakdown of 0.5 pF. Recent experiments on oscillators and narrowband (TDT) amplifiers have given results showing lower input power thresholds for smaller area devices. This feature is important in achieving cw broadband amplification in that the high-efficiency mode can be initiated at a lower diode thermal dissipation level. From the viewpoint of practicality of fabrication, the smallest diodes that can be made using our 3.5 GHz amplifier material have a $C_j \sim 0.35$ pF at voltage breakdown. These diodes, operated as oscillators in the 2 GHz region exhibited reduced threshold levels; hence, an amplifier design was started using a diode with a $C_j = 0.35$ pF and the package parasitics normally used with a $C_{j(VBD)} = 0.5$ pF diode. Using our computer program which calculates the triggering waveforms and the network characteristics, it was found that this combination would result in a triggered oscillator at approximately 3.2 GHz. This result was verified experimentally. In constructing coaxial amplifiers, we had been concerned about the possibility of higher order moding in the 14 mm circuit, particularly at the second and third harmonics. It was therefore decided to perform all future work in this area in precision 7 mm coax. This choice also has the additional advantage of yielding more accurate network analyzer measurements.

A series of computer experiments were then performed, attempting to optimize the diode parasitics and circuit parameters. Since the most critical constraint on wideband amplification appears to be the existence of an open circuit at the second harmonic, it was decided that the parallel resonance of the parasitic circuit (Fig. 16) should be the same for the 0.35 pF junction as for the 0.5 pF junction. In addition, as a starting point, the parasitic series resonance near $3f_0$ was also chosen to be the same for both area diodes. The corner inductance (L_C) is fixed by the geometry of the line. An attempt was then made using the computer to optimize the remaining parasitics, the lead inductance (L_C) and the package capacitance (C_p). The results of this analysis are:

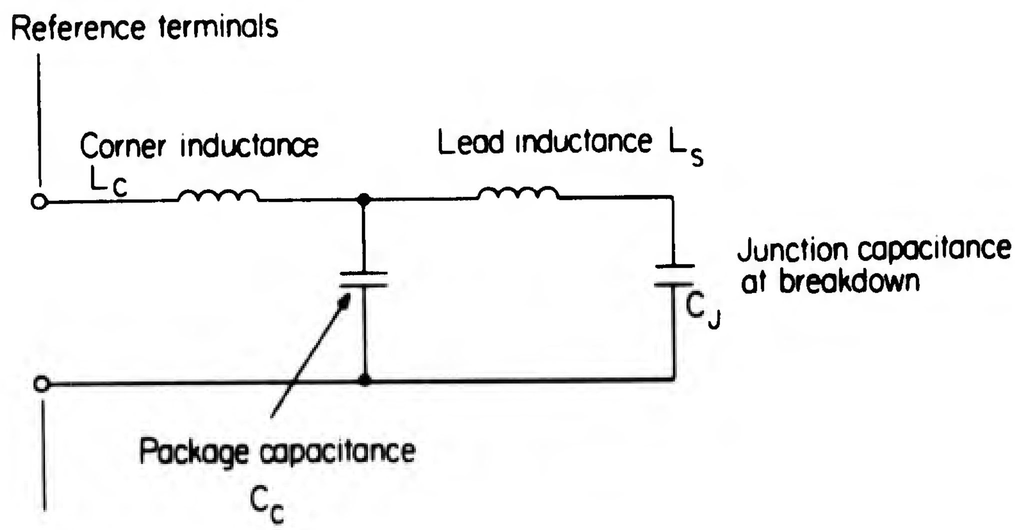


FIG. 16 Diode parasitic circuit model.

	C_J(pF)	C_P(pF)	L_R(nH)	L_S(nH)
Large-area junction	0.5	0.59	0.53^+	1.9
Small-area junction	0.35	0.7	0.42*	2.2

+ - 14 mm coaxial line

* - 7 mm coaxial line

A second series of computer runs were then performed varying five of the amplifier circuit parameters (Fig. 17): (1) the characteristic impedance (Z_o) of the line between the diode and the lowpass filter; (2) the electrical length (θ) of the same line; (3) the characteristic impedance of the tuning slug (Z_s); (4) the electrical length (θ_s) of the tuning slug; (5) the position of the tuning slug. The criteria for optimization used for the computer analysis were: (1) bandwidth of triggering waveforms; (2) circuit response; (3) flatness of the real part of the impedance seen by the diode; (4) linearity of the phase response of the network; (5) efficiency. In keeping with results achieved on the prototype amplifier, a center-band gain of 6 dB was chosen.

It was found that by increasing the impedance of the line between the diode and the lowpass filter from 62 to 70 Ω and by slightly shortening the line length from 1.040 to 0.960 inches, negligible tuning slug changes were necessary. This resulted, at least analytically, with a small-area diode amplifier having essentially the same gain bandwidth product as the prototype 14 mm coaxial amplifier.

Rather than attempt to use any fixed diode package, the diode was TC bonded to a gold-plated copper puck and the parasitic circuit fabricated with lengths of 1 mil diameter gold wire as inductors, and a thin Al_2O_3 ceramic metallized on opposite broad sides as the "package" capacitor.

When the experimental amplifier was assembled and tested, the results were encouraging but not exactly as anticipated. The gain, efficiency and centerband frequency agreed quite well with the computer predictions. However, the measured bandwidth of the amplifier was only 50 mHz while the calculated bandwidth was in excess of 200 mHz. In addition, the circuit tuning was very critical.

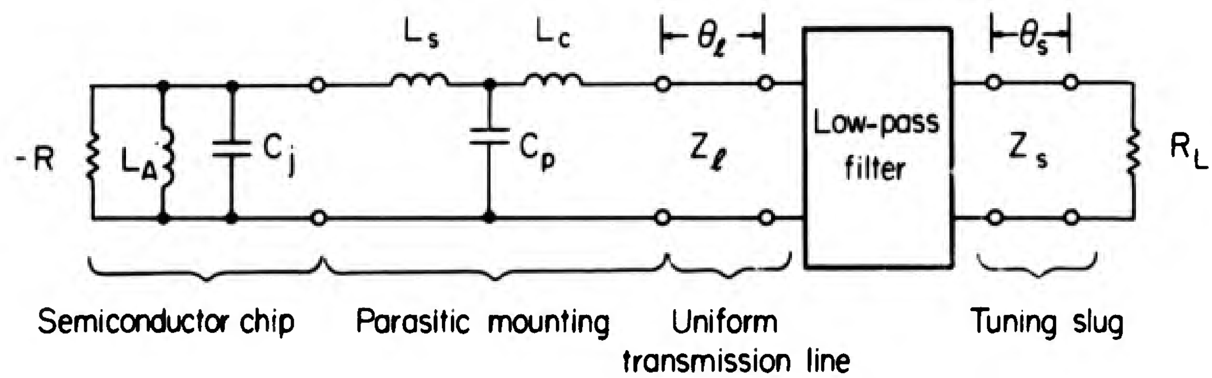


FIG. 17 Large-signal equivalent circuit model for small-area diode wideband TRAPATT amplifier.

A careful examination of the various experimental measurements made on the diode showed discrepancies in the diode small-signal equivalent circuit measurements. This was traced down to reference terminal problems, thus making network analyzer measurements inaccurate. The problem has been corrected and the entire small-area, broadband amplifier design is being reiterated.

REFERENCES

1. W. J. Getsinger, "Prototypes for use in Broadbanding Reflection Amplifiers," IEEE Trans. MTT Vol. 1 (November 1963).
2. G. L. Matthaei, L. Young and E. M. T. Jones, "Microwave Filters, Impedance-Matching Networks and Coupling Structures," (McGraw-Hill Publishing Co., N. Y., 1964).

SECTION 4

WORK PLANNED FOR NEXT REPORTING PERIOD

Major effort in the area of device study will be expended toward developing the $HCl-O_2$ techniques (Sec. 2) for reducing surface degradation and passivating the ring mesa. Assuming this technique to be successful, large numbers of the passivated ring mesas on diamond heat sinks will be fabricated and mated with both microstrip and coaxial amplifier circuits.

Development and testing of the broadband microstrip amplifiers shown in Sec. 3A will continue, as will be the case for the small-area junction amplifier (Sec. 3B).

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