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RF Burnout of *Ku*-Band Mixer Diodes

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***Abstract*—This short paper describes the experiments conducted to determine the burnout capability of various types of *Ku*-band mixer diodes when subjected to narrow RF spikes. This condition results frequently in pulsed microwave systems where the receiver is not adequately protected or where the system's limiting devices degrade or fail.**

The maintenance problems resulting from mixer failures are severe and may become more so with increased usage of Schottky barrier diodes.

INTRODUCTION

Included in this study are four types of diodes all mounted in 1N78 type coaxial packages. These include 1N78C point contact, gold–germanium (AuGe)–gallium arsenide (GaAs) Schottky barrier,[1] palladium (Pd)–GaAs Schottky barrier,[1] and titanium–molybdenum–gold (Ti–Mo–Au)–silicon (Si) Schottky barrier. The criterion for failure was taken as a 1-dB increase in the 30-MHz IF noise figure. Failure at the 1-dB point was not considered valid unless there also occurred a corresponding decrease in diode crystal current. It was found that once the crystal current of a particular test diode decreased in an amount greater than 25 percent of the initial value that the diode could not recover but continued to degrade with increased incident power.

The diodes used for this study had noise figures in the following range. (Ti–Mo–Au)–Si Schottky barrier: 7.5–8.0 dB; (AuGe)–GaAs Schottky barrier: 6.5–7.0 dB; Pd–GaAs: 6.5–7.0 dB; and 1N78C's: 7.5–9.5 dB.

EXPERIMENTAL

To simulate near system environment, a pulse from an Army *Ku*-band PPS-5 radar operating at 16.2 GHz was transmitted through a gas transmit–receive (TR) tube without keep-alive. The radar pulse was about 1.2 kW in amplitude and 0.25 μs wide with a repetition rate of 4000 pulses/s. The resultant spike from the TR was approximately 1.5-ns duration and 30-W peak amplitude.

The maximum spike amplitude was determined by observing the deflection of a sampling oscilloscope through a calibrated attenuator and comparing this with the vertical deflections from known power sources. This scope calibration technique was accomplished with the aid of a variable precision attenuator, a temperature compensated thermistor, and a power bridge [1]. The experimental setup is shown in Fig. 1.

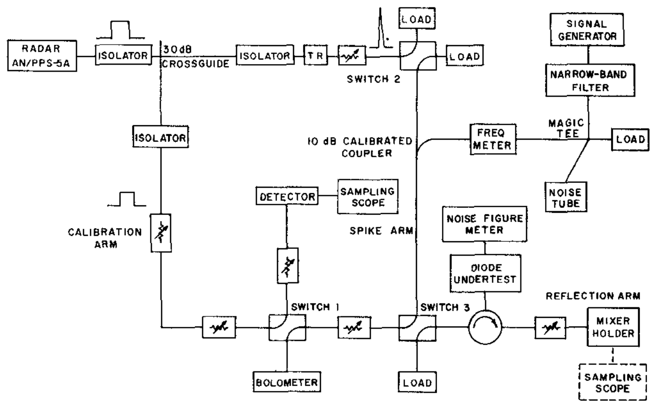

Fig. 1. Diagram of RF burnout test system.

Fig. 1 shows an 0.25-μs pulse emitted from the PPS-5 radar fed into a 30-dB cross-guide coupler. A small amount of this power is coupled into the calibration arm and is routed into the sampling scope by switch 1. The main portion of the 0.25-μs pulse hits the TR tube which emits leakage in the form of a narrow spike. This spike can either be dumped into a load by switch 2 or guided into the spike arm. Switch 3 allows the spike to enter into the calibration arm for determination of peak amplitude or into the arm containing the diode under test. The 10-dB coupler located in the spike arm allows power from the signal generator (LO source) and noise tube to be incident on the diode at the same time as the spike. The calibrated attenuator following the TR tube was used to adjust the incident spike levels for each test.

A complete burnout test for each diode consisted of the following. During this test, the diodes were mounted in a single ended (MA) model 595C Holder, and before each run, calibration of TR leakage was made. The incident power was adjusted to a low level (10–20 mW) and switched into the test diode. The peak reflected power, the noise figure, and the crystal current were monitored during the test period of 1 min (approximately 240 000 spikes). After this time period, the power was directed into a load by switch 2, and the diode's crystal current and noise figure were recorded. This procedure was repeated using the same diode with incremental increases in incident peak power until the diode failed.

Because the same diode was used for each power level test, the possibility of cumulative effects causing premature burnout was of concern to us. To check this possibility, a set of 1N78C point contact diodes were selected and divided into two groups. Diodes in group 1 were burned out using the procedure previously described. Once the typical burnout level was established, the second group was subjected to a one shot burnout test at this level. It was found that the diodes in group 2 had approximately the same number of failures as those diodes in group 1. It therefore seemed logical to assume that any cumulative effects resulting from narrow pulse energies were minor.

The spike amplitude emitted from a gas TR is not constant with time, and as a result, every transmitted pulse will not reach the maximum level [2]. For this reason, extreme care was taken during calibration to ensure that no spike exceeded a chosen deflection level with a constant attenuation setting. This was done by using the manual scan option on the sampling scope and photographing the spike for 2–3 min through an open shutter. The peak power data presented in Figs. 2 and 3 are the maximum amplitude spike referenced to the calibration amplitude observed before and after each diode run.

RESULTS

The burnout characteristics of the four types of diodes are presented in Figs. 2 and 3. Here, lots of 20 1N78C point contact and 24 (Ti–Mo–Au)–Si Schottky barrier diodes (Fig. 2) and 7 (Au–Ge)–GaAs Schottky barrier and 6 Pd–GaAs Schottky barrier diodes

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[1] Microwave Associates (MA) nomenclature designation MA 40538 (AuGe)–GaAs and MA 40539 Pd–GaAs diodes were received under Production Engineering Measure, U. S. Army Electronics Command, Fort Monmouth, N. J., under Contract DAAB05-69-C-0019, "Schottky-Barrier Gallium Arsenide Diodes," with MA.

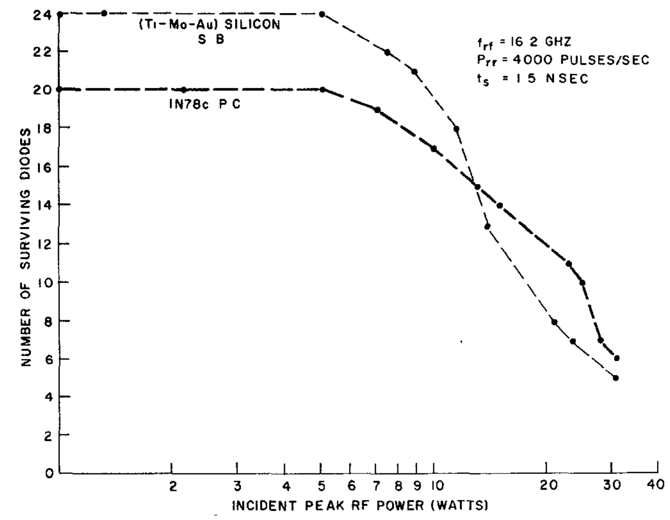

Fig. 2. Number of surviving silicon type diodes as a function of incident RF peak power.

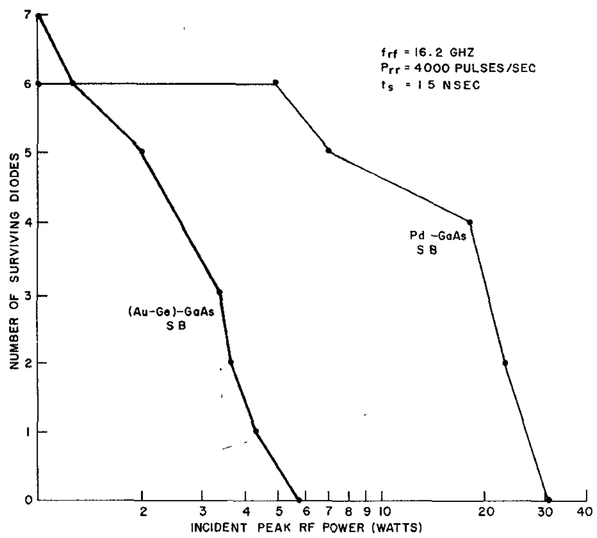

Fig. 3. Number of surviving gallium arsenide type diodes as a function of RF peak power.

(Fig. 3) are plotted on curves showing the number of surviving diodes versus incident peak RF power.

Of the 20 point contact diodes shown in Fig. 2, 6 survived the full 30-W spike for 1-min duration with less than 1-dB degradation in noise figure. About 50 percent have failed at a 25-W level. These diodes were not selected or screened for optimum burnout characteristics but were selected randomly from typical Army supplies. Similarly, of the 24 (Ti–Mo–Au)–Si Schottky barrier diodes selected for this test, 5 were found to withstand the full 30-W peak power. However, of these diodes almost half have failed at 15-W peak power.

The lot samples of the (Au–Ge)–GaAs and Pd–GaAs diodes were small, because of their limited supply; but a trend under the described test conditions can be seen. The results are shown in Fig. 3. By far, the type of diode most susceptible to burnout was found to be the Au–Ge diode. All seven diodes tested were found to fail for a power of less than 6 W. The curve rolls off very fast with an average failure at about 3 W. The Pd barrier diodes were more burnout resistant than the Au–Ge type with an average burnout power of 20 W. Again, all diodes of this type have failed before the maximum test power of 30 W was reached.

Fig. 4 gives the absorption characteristics of a typical mixer diode for each class. These curves were formed by measuring the peak

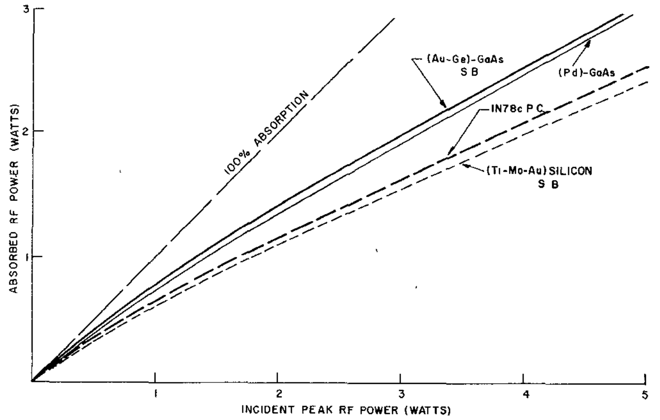

Fig. 4. Absorbed peak RF power versus incident peak RF power for typical diode of each type tested.

reflected power for each incident level, placing all such points on the curve, and graphically taking their average. The trend is for the GaAs type diode to be more absorptive than the Si type and for the Si point contact and the Si Schottky barrier diode to follow the same absorption pattern. It is important to note that these types of curves vary greatly from one diode to another and that it was possible to select some Si diodes, both Schottky barrier and point contact, to absorb more incident peak power than a GaAs diode for the same given power level.

CONCLUSIONS

The point contact 1N78C diodes were found to be the most burnout resistant of all types tested. This was found to be true, in spite of the fact that they were not screened for burnout performance. The remaining diode types would rank from highest to lowest: (Ti–Mo–Au)–Si Schottky barrier, Pd–GaAs Schottky barrier, and (Au–Ge)–GaAs Schottky barrier. Each of these types was specifically manufactured and selected for improved burnout operation.

We did not find a definite correlation between the initial diode noise figure or the VSWR and RF burnout. And, a consistent pattern did not evolve where the most reflective diodes at high incident power were the most burnout resistant.

The observed behavior of the Schottky barrier type diodes, as they progressed to failure, was found to be much different from that of the point contact diodes. For example, the noise figure for some of the point contact diodes was observed to increase past the 1-dB failure point at a particular incident power level, and when the same diode was subjected to a still higher power, the diode noise figure might decrease to an acceptable level. Many diodes would oscillate through this failure point before showing catastrophic changes in overall noise figure and crystal current. At this point, the typical 1N78C would increase in noise figure by about 5 dB, and the crystal current would drop a few tenths of a milliamp. It appears that the point contact diode has an inherent quality for pulse damage recovery. The Schottkys, in contrast, showed a gradual and continuous degradation in both noise figure and crystal current until catastrophic failure occurred. At this point, the noise figure increased to immeasurable values, and the crystal current would drop to near zero.

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