RF BURNOUT OF MIXER DIODES AS INDUCED UNDER CONTROLLED LABORATORY CONDITIONS AND CORRELATION TO SIMULATED SYSTEM PERFORMANCE

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ABSTRACT

The mixer diode failure in microwave systems using a TR tube protector depends upon (a) rise time of magnetron, (b) harmonics generated by the magnetron and TR tubes, and (c) spike leakage by the TR tubes. This paper describes the study conducted to establish correlation between mixer diode failure in microwave systems using a TR tube and simulated laboratory set up. Diode failure under microsecond RF pulses and static conditions will also be presented.

INTRODUCTION

In duplex type microwave systems mixer diodes must be protected with a power limiting device, e.g., gaseous discharge TR tubes, "TRL" (Gas discharge TR followed by semiconductor diode limiter), ferrite limiters or PIN diode limiters, to prevent mixer degradation or destruction. Even under the most ideal conditions receiver protection is often inadequate and power, termed leakage, does reach the sensitive mixer diode. This problem is most prevalent in systems using TR tube duplexers or protectors. Peak power passes through the TR tube for a very short but finite period before the gas fill is sufficiently ionized to substantially attenuate the incident power. This power is termed "spike" leakage. The RF spike leakage of TR tubes generally lasts for 0.5 - 10 ns. For narrow pulses, i.e., spikes, diode burnout depends on both the peak amplitude and the pulse width[1]. Flat leakage is the power following the spike and continues for the length of the magnetron pulse. Experiments have proven that for pulses 1 μs and longer, mixer burnout is essentially that for CW conditions and is strictly dependent on amplitude.

In addition, harmonics as well as random bursts of RF power occur in some systems and have caused mixer failure.[2,3]

HARMONIC AND SPURIOUS OSCILLATION

Several sources of spurious power are available from a magnetron. Since the magnetron is a free running oscillator, it exhibits nonlinear characteristics. Power is present at some finite level at the various harmonic frequencies of the fundamental.[4] The first harmonic removed from the fundamental can be of the order of a few percent of the sum power, depending on the tube design. Also, all magnetrons are capable of putting out noise power near the point at which the tube breaks into oscillation. Generally, the noise output will be fairly close to the main resonant frequency. TR tubes also generate spurious and harmonic oscillations[2] which may under certain conditions cause mixer failure.

Since TR's and TRL's act as bandpass filters at low power levels and band stop filters at high power levels, these devices under certain conditions pass harmonic and spurious oscillations generated by the magnetron and TR tubes.

The problem has been to accurately describe the susceptibility of mixer diodes to RF burnout under laboratory conditions and then correlate this behavior to system applications. Laboratory evaluation has been confined to the Torrey line[5] and most recently the peak nanosecond RF burnout test using a PIN pulse shaping network to simulate TR spike leakage. Although RF nanosecond pulse testing is the most realistic criteria to date for burnout evaluation, one still finds discrepancies between failure rates when these devices are deployed in microwave systems. These differences might result from:

(1) Harmonic and spurious oscillation from magnetrons and TR tubes.

(2) High peak power spikes, undetectable due to their narrow widths by ordinary test equipment.

(3) Occasional and random high peak power pulses not observed during laboratory testing.

EXPERIMENT

Experiments have been conducted to compare the RF induced burnout properties of (Silicon) - (Ti-Mo-Au), X-Band, Schottky barrier mixer diodes using a PIN pulse shaping network with that obtained from TR tube leakage.

Control of device properties have been obtained by using a multi-junction array incorporating 100's of Schottky junctions on a single chip. Chips are mounted in special "windowed" IN23 packages so that the location of the whisker contact can be determined before testing and so that the whisker can be physically moved to a new location after destructive testing. In effect, the "same" device is brought to failure under a variety of electrical conditions. This has given the most accurate correlation data obtained to date.

Data will be presented on mixer burnout levels for nanosecond and microsecond RF pulses, as well as static discharge. These stress conditions are those which are typically seen by mixer diodes during system use. Nanosecond pulses were generated by two different methods as shown in Figure 1. The first uses a PIN pulse shaping network with the pulse width adjusted to approximate the spike leakage from a TR tube (2-3 ns). The second method uses a TR tube to simulate an actual microwave system employing the same means of protection. Variation in this system was the addition of harmonic filters between the magnetron and the TR tube of band pass filters between the TR tube and mixer diode and control of the rise time of the magnetron pulse. Calibration in both methods was made by closely observing the maximum peak amplitude of the RF spike on a sampling scope.

SEM photographs of typical diode failures caused by a PIN pulse shaping network, TR tube, static discharge, and microsecond magnetron pulses are shown in Figures 2-5 respectively. Nanosecond and static discharge exhibits similar failure mechanism which is due to localized high field conditions at the diodes periphery and microsecond pulse burnout is attributed to thermal dissipation. The metalization has been removed by chemical etching to expose these failures. The burnout levels of Schottky barrier mixer diodes exposed to nanosecond spikes generated by TR tubes were found to be half as much as the burnout levels of the same diodes exposed to nanosecond spikes generated by the pulse shaping network. It appears evident that other causes of burnout in addition to the fundamental leakage i.e., spike and flat attend the use of the gaseous discharge TR devices. Experimental evidence gleaned to date points to high power spurious pulses and high power harmonics emanating from both the magnetron and TR device. For reliable operation of duplex type systems these must be considered and eliminated.

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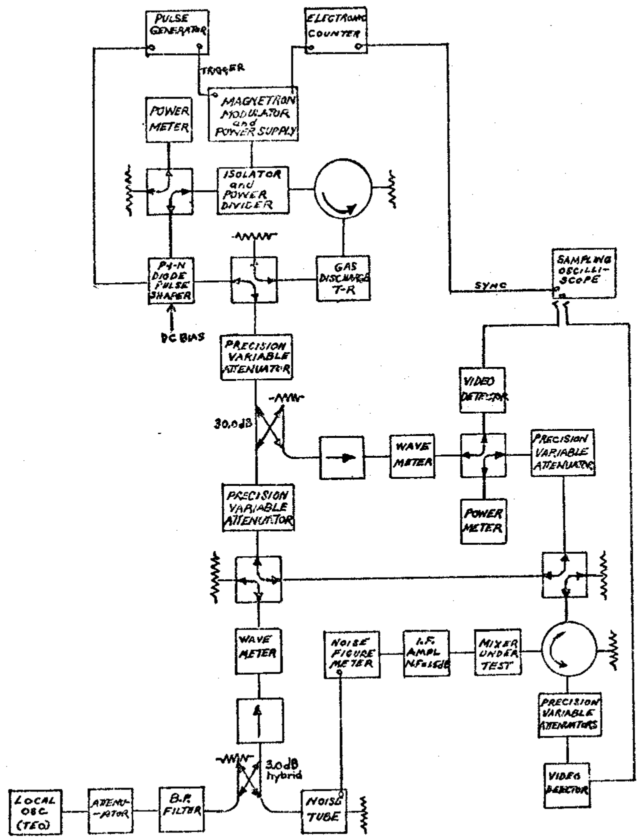

Fig. 1 Microsecond and Nanosecond Burnout System

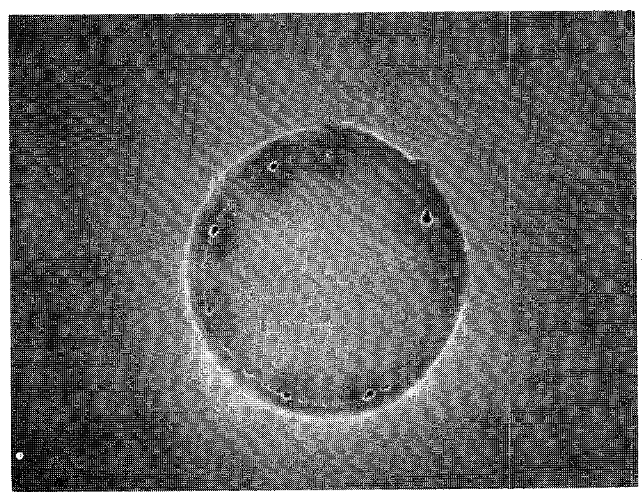

Fig. 2 SEM Photograph, 8000 X, of Diode Failure Caused By PIN Pulse Shaping Network.

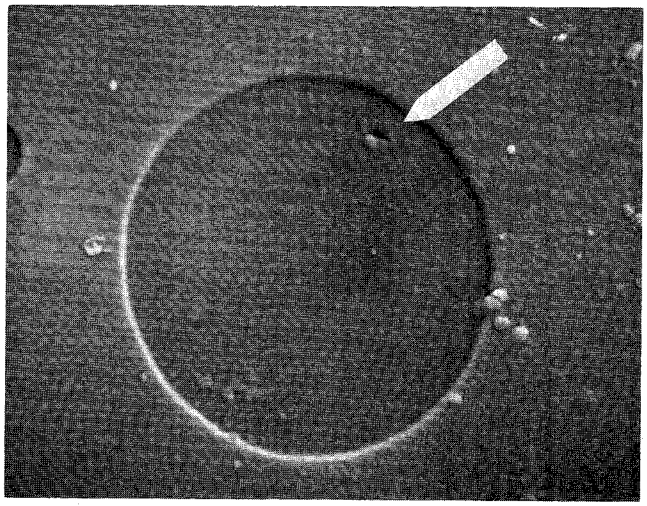

Fig. 3 SEM Photograph, 9000 X, of Diode Failure Caused By TR Gas Tube. Arrow Points to Main Failure Point.

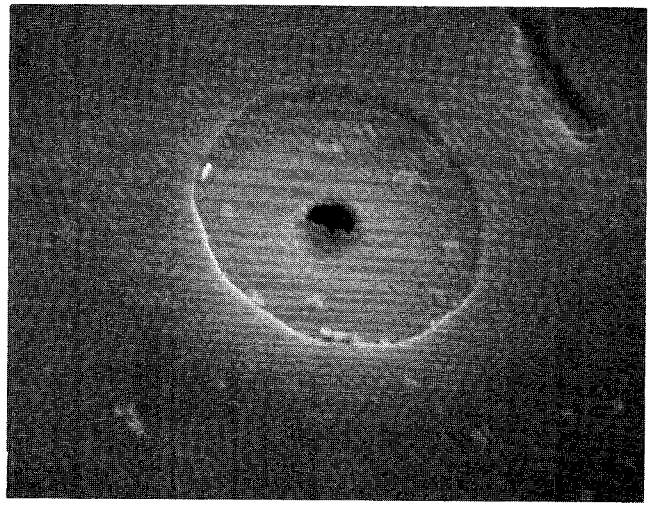

Fig. 5 SEM Photograph, 6000 X, of Diode Failure Caused By Microsecond Magnetron Pulse.

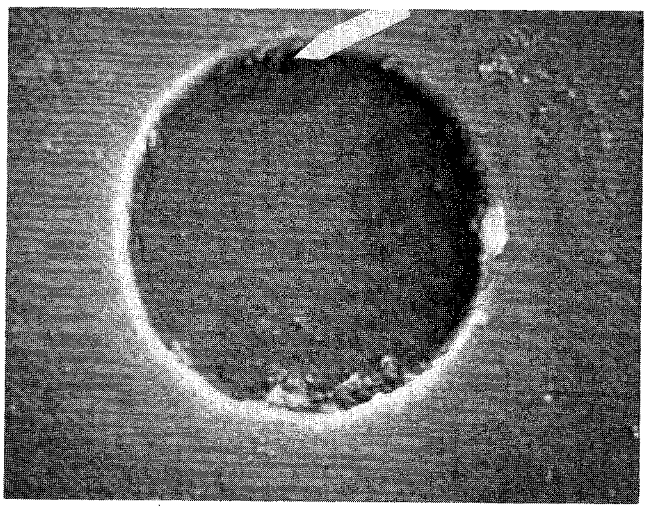

Fig. 4 SEM Photograph, 10000 X, of Diode Failure Caused By Static Discharge.